Millikin University
Student Learning in the Chemistry Major

By Ed Acheson, Paris Barnes, George Bennett,
Tim Guasco, and Anne Rammelsberg
July 1, 2014

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. 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 learning goal #2 as "green light" (at an acceptable level) and on learning goals #1 and #3 as “yellow light” (declining slightly). We will continue to work on ways to ensure that all our students perform at the "green light" level in the future.

Report

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 ***do*** 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. Eight chemistry majors graduated this May. Two of these students presented their research at the 2014 national convention of Sigma Zeta National Science and Mathematics Honor Society, and one of these students won a 2013-2014 Sigma Zeta research grant for her work. One student presented his research at the annual meeting of the Illinois State Academy of Science. Two of the eight students presented their research at the 247th national meeting of the American Chemical Society. Six of the eight students presented their research at the 2014 Millikin University Undergraduate Research Poster Symposium, and four of those six received awards for their posters. In addition, a senior biology major, more than 50% of whose research was in chemistry, presented at both the Sigma Zeta national convention and the Millikin poster symposium and won the award for best presentation at both venues.

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 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. Approximately 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. Beginning with the 2012-2013 academic year, we added a new course to the curriculum, CH131--Accelerated General Chemistry. CH131, a first semester course in general chemistry, is designed for science majors with a strong high school chemistry background. These students previously received proficiency credit for CH121 and started their college chemistry program with CH224, the second semester course. As we evaluated student learning, we realized that these students, despite their strong backgrounds, would benefit from additional study in general chemistry; hence, the development and addition of CH131 to our curriculum.

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.

In terms of staff, the department added a Laboratory Support Specialist beginning with the Fall 2011 semester. This person teaches half-time and works

half-time setting up teaching labs, maintaining the chemical inventory and storeroom, and assisting with the development of curricular materials. Even with the addition of this position, the department hires nearly 3 FTE adjunct instructors. Therefore, a short-term goal of the department is to add one tenure-track position. The Laboratory Support Specialist and additional full-time faculty are long overdue staffing requirements for the department, and these additions will necessitate more space for the department in Leighty-Tabor Science Center. Finally, the department is experiencing a "changing of the guard" in terms of faculty. Dr. Ed Acheson retired in May 2014 after 35 years of dedicated service to Millikin. While as of this writing the department has not yet filled Dr. Acheson's position, we remain optimistic we will conduct a successful search in fall 2014.

Students can only thrive when they are mentored by an active and engaged faculty. Fortunately, that is the case in the Department of Chemistry. Collectively over the past three years, faculty and students gave nearly 40 poster presentations and over a dozen oral paper presentations in a variety of venues. Faculty collectively submitted three research grant proposals, and two student-faculty papers were published in peer-reviewed journals. One member of the department received the Millikin University Research and Artistic Achievement Award, the Millikin University Teaching Excellence award, the Campus Leadership and Teaching Excellence award, and the Alpha Lambda Delta Outstanding Teacher award, continuing a tradition of excellence in teaching and research that is a hallmark of the Department of Chemistry.

Also of note, the department has established a 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 are participating 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 **comprehensive success rate of 100%** for chemistry graduates from 2003-2013.

<u>The Learning Story</u>

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 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 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	12.5
Adequate	62.5
Total of above (used for rating)	75
Nominal	25
Number of students evaluated	8
Average numeric score	8.75

Rating for goal 1: "Yellow 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	9
Adequate	91
Total of above (used for rating)	100
Nominal	0
Number of students evaluated	11
Average numeric score	11.4

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	37.5
Adequate	25
Total of above (used for rating)	62.5
Nominal	37.5
Number of students evaluated	8
Average numeric score	10.4

Rating for goal 3: "Yellow light".

Table 4.

Year-by-Year Comparisons.

Year →		**2011**	**2012**	**2013**	**2014**
Goal ↓					
1	Rating percentage	89	100	100	75
	"Color" rating	Green	Green	Green	Yellow
2	Rating percentage	100	84	100	100
	"Color" rating	Green	Green	Green	Green
3	Rating percentage	80	83	100	62.5
	"Color" rating	Green	Green	Green	Yellow

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

Analysis of Assessment Results

For the 2013-2014 academic year, student learning for one 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) and for two of our learning goals at the "yellow light" level (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). This is the eighth consecutive year in which student learning for goal #2 has been at the "green light" level.

On a less than positive note, this is the first time in eight years in which student learning for goals #1 and #3 has fallen below "green light" level. Although we are disappointed in the decline, we do not view it as a cause for panic. In the case of learning goal #1, three-fourths of the students evaluated were at an adequate level or higher, and the average numerical score was in the adequate range. In order to improve the quality of the final written presentations, we plan to adopt some of the tactics used in writing-intensive courses, such as requiring that rough drafts be submitted for review and feedback. We are confident that such modifications will return us to "green light" status in short order. In the case of learning goal #3, more deliberation is necessary, but our preliminary analysis shows that the chief factor that separated the five excellent/adequate performers from the three nominal performers was the amount of time spent working on the research project. A mechanism to foster more consistent effort over time from each research student should effectively address this issue. 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.

While we are pleased that the majority of 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 on to successful and distinguished professional careers. Furthermore, the last university self-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. Recently, students have expressed concerns with their understanding of scientific instrumentation. Students felt that they had a reasonable grasp on how to use instrumentation, but did not have sufficient understanding of the underlying principles of the equipment and the appropriate applications. In response to these concerns, the faculty is evaluating the feasibility of implementing an instrumentation review course in the future. Also, students told us that they would have liked more practice at oral presentations and more detailed guidance about the graduate school application process, 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 last year, 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)…"

The Chemistry Department has over $1,000,000 worth of aging equipment that is used throughout our curriculum. What message does the institution send to "entering students and faculty" when our maintenance budget will not cover the cost of even one service call? While we greatly appreciate the Leighty funds that will soon become available for equipment modernization, 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 support from the university must dramatically increase.

During 2013-2014, we searched for an analytical chemist to succeed Dr. Acheson. The search committee identified the top six candidates for phone interviews. Two of these candidates were hired at comprehensive universities equal in size to or smaller than Millikin before we had a chance to interview them on campus. Our fourth-ranked candidate was hired at an institution with an approximate enrollment of 1,500 students and received $50,000 in start-up funding. Our top candidate received $79,000 from an institution with an enrollment equal to 2,400 students. We interviewed the remaining four candidates on campus and extended job offers to three of them. All three turned us down, with salary and/or start-up funding among their primary reasons. After failing to hire a successor for Dr. Acheson, we conducted a survey of selected colleges and universities similar in size and composition to Millikin which have hired chemistry faculty in the last 10 years, and we found the following data:

Institution	**Location**	**Chemistry Faculty***	**Approximate Undergraduate Enrollment****	**Start-Up Funding**
Trinity College	Hartford, CT	10	2,300 (96%)	$100,000 – 150,000
Knox College	Galesburg, IL	6	1,400 (100%)	$80,000 – 100,000
Bradley University	Peoria, IL	10	5,200 (87%)	$70,000
Wabash College	Crawfordsville, IN	6	875 (100%)	$60,000
Hendrix College	Conway, AR	7	1,400 (100%)	$10,000 – 60,000
Christopher Newport University	Newport News, VA	12	5,050 (97%)	$58,000
Macalester College	St. Paul, MN	7	2,000 (100%)	$50,000
Illinois Wesleyan University	Bloomington, IL	6	2,000 (100%)	$50,000
Ithaca College	Ithaca, NY	10	6,000 (93%)	$40,000
St. Catherine's University	St. Paul, MN	8	3,660 (72.2%)	$30,000
Monmouth College	Winona, MN	4	1,400 (24.5%)	>$30,000
University of Indianapolis	Indianapolis, IN	4	1,360 (100%)	$25,000
Luther College	Luther, IA	7	2,500 (100%)	$10,000
Millikin University	Decatur, IL	5	2,000	$10,000

* - Only full time tenured or tenure-track chemistry faculty.
** - The percent in parenthesis represents the percentage of undergraduates making up the student body at the institution.

The chemistry faculty is more than willing to work with the university administration to conceive of ways to offer start-up packages that are competitive

with what other institutions are offering. When a search proceeds as we imagine it, start-up funding is an investment that pays off in multiple decades of service by a dedicated and outstanding faculty member.

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 50th 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. Standardized exams with nationally normed data are our primary tool for the summative assessment of long-term learning. For example, we administer the respective ACS examination at the ends of CH224-General Inorganic Chemistry, CH232-Analytical Chemistry, CH302-Organic Chemistry II, CH303-Physical Chemistry I, CH331-Biochemistry, and CH406-Advanced Inorganic Chemistry. Our CH131-Accelerated General Chemistry initiative is already showing benefits on long-term learning in CH224. In the first two years of offering the course, students who completed CH131 prior to taking CH224 scored on average in the 60th percentile on the ACS standardized exam whereas students who completed CH121 prior to taking CH224 scored on average in the 38th percentile. This improvement is not solely attributable to superior study skills because when incoming students with strong backgrounds started directly in CH224 before 2011, their average ACS exam scores were never above the 50th percentile. CH131 seems to be accomplishing what we wanted it to do.

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. Beginning in 2008, 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 →	**2010**	**2011**	**2012**	**2013**	**2014**
Attempts ↓					
Percent passing on 1st attempt	57	78	67	73	63
Percent passing on 2nd attempt	0	11	17	18	0
Percent passing on 3rd attempt	29	0	0	9	25
Percent not passing	14	11	16	0	13

As can be seen from Table 5, all but one of the students passed the ETS exam this year. Along with student success on the ETS exam, we have also noticed a slight improvement in overall scores on the standardized American Chemical Society exams, most notably in Physical Chemistry with Dr. Guasco and General Inorganic Chemistry with Dr. Barnes. While we do not "teach to the test," we have devoted more energy across the curriculum to better prepare our students for these exams. While we realize we may not achieve 100% passing every year, we will nevertheless continue to work with our students to help ensure a high pass rate.

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. Finally, infrastructure support from the university must increase if we are to continue to deliver a quality education to our students.

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 or CH131/**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.)				