Student Learning in Natural Science with a Laboratory Experience Courses
Self-Study Report
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I. Executive Summary

The departments of Biology, Chemistry, and Physics have developed the following learning goals for students taking a course that satisfies the MPSL Natural Science with Lab non-sequential requirement:

1) Develop an understanding of how to use logic and the scientific method to analyze the natural world and solve problems.

2) Learn about issues in science that are important both personally and globally.

3) Utilize technology in laboratory and field environments in order to connect theories and descriptions found in lectures and textbooks with real-world phenomena.

A student who is able to reach these goals successfully will also be satisfying the core goals expressed in the mission statement of Millikin University. The first and third goals, in particular, will help a student achieve *professional success*, as being able to utilize the scientific method as a mode of inquiry will be valuable in any career. Meeting all three goals will also contribute to a Millikin graduate being a *democratic citizen in a global environment*. Dealing with problems in a global society requires integration of knowledge and strong problem solving skills. The second and third goals are particularly focused on *preparing students for a personal life of meaning and value*. Issues in science affect everyone daily, and understanding what these issues are will better prepare students to understand how they in particular are affected.

The courses that students take to satisfy these learning goals come from all three departments and are taught by a substantial majority of the faculty in each department. Each year, faculty gather an assortment of artifacts from their courses that measure student learning with respect to the above goals. Using a set of rubrics, faculty then evaluate the artifacts to assess student learning.

Based on the rubrics created for assessing the learning goals, our current status on all three learning goals is "**green light**" (at an acceptable level). The Natural Science faculty will continue to work on ways to ensure that all our students perform at the "green light" level in the future.

II. Goals

In the opinion of the faculty in the Departments of Biology, Chemistry, and Physics, upon completion of a Natural Science with a Laboratory Experience course at Millikin University, a student will be able to:

1) Use logic and the scientific method to analyze the natural world and solve problems.

2) Analyze issues in science which are important both personally and globally.

3) Connect theories and descriptions found in lectures and textbooks with real-world phenomena utilizing appropriate technology in laboratory and field environments.

A student who is able to reach these goals successfully will also be satisfying the core goals expressed in the mission statement of Millikin University. The first and third goals, in particular, will help a student achieve *professional success*, as being able to utilize the scientific method as a mode of inquiry will be valuable in any career. Meeting all three goals will also contribute to a Millikin graduate being a *democratic citizen in a global environment*. Dealing with problems in a global society requires integration of knowledge and strong problem solving skills. Performing informative and interesting experiments is one way scientists interact with the world; therefore, understanding issues in science and the process scientists go through is invaluable in understanding the impact of science-related issues on their lives. The second and third goals are particularly focused on *preparing students for a personal life of meaning and value*. Issues in science affect everyone daily, and understanding what these issues are will better prepare students to understand how they in particular are affected. Also, being able to connect the theory in texts to the practical applications of science in their lives will help the students be life-long learners and continue to integrate future developments in science into their understanding of the world.

III. Snapshot

The departments of Biology, Chemistry, and Physics at Millikin University were staffed in 2009-10 by 17 full-time faculty, 4 adjuncts, and 1.5 academic staff support people (secretaries). One of the biology faculty (Cynthia Handler) has a half-time position in the department; the remaining half of her load is as the pre-professional advisor. Another biology faculty (Roslyn O'Conner) has a full-time position with half of her load directed to teaching and half to support (lab set-ups, chemical inventory, ordering supplies, etc). All three departments are housed in the Leighty-Tabor Science Center (LTSC), which opened in 2002, and provides an excellent teaching and research facility. Full-time faculty generally teach a variety of courses, including service courses aimed at a general audience (non-majors), service courses aimed at a specific audience (for example, courses for Nursing majors), and courses for science majors. Adjuncts typically help with laboratory instruction. The smallest science courses (upper-level courses) may have approximately 8 students while the largest may serve 60 or more students. Some of these larger courses include Anatomy and Physiology I and II, Essentials of Organic and Biochemistry, and Introductory Astronomy courses. Lab courses are usually capped at a maximum of 24 students.

Courses taught Fall 2009 (F), Spring 2010 (S), or Summer 2010 that met the MPSL Natural Science with a Laboratory Experience requirement for non-majors:

BI 102, Biochemistry of Food – Dr. Samuel Galewsky (F)
BI 102, Human Genetics – Dr. Terry C. Matthews (F)
BI 102, Biology of Disease – Dr. Jeffrey A. Hughes (F)
BI 102, Hormones & Society – Dr. Jennifer R. Schultz-Norton (F, S, Summer)
BI 102, Biology of Birds – Dr. David J. Horn (F, S)
BI 102, Human Biology – Dr. Jennifer R. Schultz-Norton (S)
BI 102, Current Issues in Biology – Prof. Roslyn J. O'Conner (S)
BI 102, Microbes & Humans – Dr. Thomas E. McQuistion (S)
BI 105/155, Ecology & Evolution – Dr. Judith Parrish and Dr. Marianne Robertson (F)
BI 125, Local Flora – Dr. Judith Parrish (S)
BI 130, Environmental Biology – Prof. Roslyn J. O'Conner (S)
BI 280, Ecological Journey: Tropical Ecology – Dr. Judith Parrish (S)
BI 280, Ecological Journey: Alaskan Ecology – Dr. Judith Parrish (Summer)

CH 121/151, General Chemistry – Dr. Edward Acheson, Dr. Clarence M. Josefson, Dr. Gwendalyn Baumann, Prof. Lynette D. Nehmer, Prof. Patricia A. Higgins (F, S, Summer)

PY 100/104, The Planets – Dr. Casey R. Watson (S)
PY 101/105, Stars and Galaxies – Dr. Casey R. Watson (F)
PY 111/151, College Physics 1 – Dr. Eric C. Martell (F)

IV. Learning Story

There are three main groups of students who take natural science courses at Millikin: 1) Natural Science majors, who take a dozen or more science courses; 2) students majoring in fields like Nursing or Exercise Science, who do not take quite as many science courses but still take a sizable number; and 3) students who take one (or sometimes two) science courses to fulfill graduation requirements. The first group of students generally has a different set of learning goals – specifically, the goals for learning within the major. However, while some of the above courses (BI 102, PY 101) have students from the third group as their primary audience, other courses (CH 121, PY 151, for example) have very diverse audiences. These latter courses must be carefully constructed such that majors get a strong introduction to the field at the same time non-majors or general education students satisfy the learning goals from section I.

Because of the variety of courses students can take to fulfill this requirement, there is no single story which best describes the experiences a student gets in a first Natural Science with a Laboratory Experience course. There are some commonalities which all students will experience, such as a full-time faculty or staff member as an instructor and extensive hands-on laboratory experiences (between 24 and 45 hours in the lab, depending on the course), but the ways in which a student can achieve the stated learning goals are as varied as the different courses they can choose to take. For example, a student in the Block General Chemistry course will have an intense experience in which lab and lecture are integrated, and they are tested every day to ensure that they keep pace with the material. A student in one of the Biology topics courses may study some of the most controversial topics facing our society and may develop projects that require them to interact with the Decatur community and deal with issues such as conservation and recycling. A student in Stars and Galaxies will become an expert at setting up, taking down, and maintaining a telescope, and learn what it is about the night sky that has captivated mankind for millennia. Students in all courses will be exposed to time-honored and trusted teaching methods as well as research-based pedagogical techniques that are on the cutting edge of teaching and learning in the field. Lectures and labs are well integrated and emphasize critical thinking, application, and problem solving skills.

V. Assessment Methods

During the Spring 2010 semester, a subset of faculty teaching courses that satisfied the MPSL Natural Science with a Laboratory Experience requirement collected a group of artifacts for each of the three goals. Three faculty were selected – one from Biology, one from Chemistry, and one from Physics, so as to represent a variety of courses. The courses assessed were BI 102 – Jennifer R. Schultz-Norton, CH 121/151 – Ed Acheson, and PY 100 – Casey R. Watson. Individual faculty chose artifacts from their course which addressed the learning goals, including exams, formal lab write-ups, lab books, semester-long projects, and presentations.

The faculty then applied a series of rubrics to measure the overall success of students at achieving each learning goal. These rubrics must, by nature, be somewhat general, but still provide a useful guideline for this assessment, and are provided below.

Rubrics for each Goal
Goal 1: Logic and the Scientific Method

Item	Criteria		
	Excellent	Adequate	Unsatisfactory
Scientific Method	**[5 points]** Student demonstrates strong understanding of the scientific method. Ability to develop hypotheses, test them, and then draw appropriate conclusions from the results. Clear understanding of the meaning of the word "theory" in a scientific context.	**[3 points]** Student demonstrates a basic understanding of the scientific method. Understands the parts, but unable to synthesize them into a coherent whole.	**[1 point]** Student does not demonstrate any substantial understanding of the scientific method. Cannot differentiate between a theory and a guess.
Analysis	**[5 points]** Student demonstrates ability to analyze data and explain results. Results well-understood and appropriate and justifiable conclusions drawn from data or calculations. Honest comparison with previous results influences discussion of results.	**[3 points]** Student demonstrates a basic ability to analyze data. Some conclusions may be insufficiently well-supported, comparisons with previous results may be incomplete, but basic structure of sound analysis is present.	**[1 point]** Student fails to meet basic standards for appropriate data analysis. Results clearly not well-understood, incomplete analysis, failure to compare with previous results.
Problem Solving	**[5 points]** Student demonstrates a clear grasp of how to use logic and reasoning to solve complex problems. Breaks problem into simpler components that incorporate prior knowledge. Combines information in a useful way. Interprets result appropriately and compares with expectations.	**[3 points]** Student demonstrates a basic ability to solve problems. Logic may be faulty at times, may show difficulties in dealing with more complex problems.	**[1 point]** Student fails to show the ability to solve problems beyond the most basic level.

Goal 2: Scientific Issues

Item	Criteria		
	Excellent	Adequate	Unsatisfactory
Understanding of issue	**[5 points]** Student demonstrates a clear understanding of a scientific issue. Can explain the scientific principles governing the relevant physics, biology, or chemistry.	**[3 points]** Student demonstrates an incomplete understanding of a scientific issue. Explanation unclear in parts, scientific principles insufficiently well-understood.	**[1 point]** Student demonstrates a weak understanding at best. Unable to explain basic scientific principles.
Understanding of personal relevance	**[5 points]** Student demonstrates a clear understanding of how a scientific issue affects them personally. Can show how they are related to causes and effects. Understands long-term results of effects in their lives.	**[3 points]** Student demonstrates an incomplete understanding of how a scientific issue affects them personally. May not understand how they are related to causes or effects.	**[1 point]** Student unable to draw connections between scientific issue and their own life.
Understanding of global relevance	**[5 points]** Student demonstrates a clear understanding of how a scientific issue affects the world at large. Can draw connections to political, social, or cultural causes and effects. Understands long-term global effects.	**[3 points]** Student demonstrates an incomplete understanding of how a scientific issue affects the global community. May be unable to draw connections to causes and effects.	**[1 point]** Student unable to draw connections between scientific issue and other global issues.

Goal 3: Technology in Lab and Field Environments

Item	Criteria		
	Excellent	Adequate	Unsatisfactory
Use of technology	**[5 points]** Student utilizes appropriate technology to acquire and analyze data in an experimental setting. Uses equipment safely and efficiently.	**[3 points]** Student can utilize technology to acquire or analyze data, but not both. May be inefficient, but uses equipment safely.	**[1 point]** Student unable to use appropriate technology in experimental setting. Cannot take or analyze data. Demonstrates unsafe procedures.
Connection of theory and experiment	**[5 points]** Student connects experimental results with expectations from class or texts. Able to put theory into practice in lab and able to use results to discuss theory.	**[3 points]** Student demonstrates an incomplete ability to connect theoretical expectations with experimental results.	**[1 point]** Student unable to connect the results they obtain experimentally with expected results from class or texts.
Connection to real-world phenomena	**[5 points]** Student is able to generalize from results found in (often) a controlled lab environment to understand real-world phenomena. Can make predictions about what would happen in a less controlled environment.	**[3 points]** Student demonstrates an incomplete ability to connect lab results with more general real-world phenomena. May not be able to understand what happens in a less-controlled environment.	**[1 point]** Student unable to generalize from results in lab to real-world phenomena. Does not demonstrate understanding beyond lab environment.

The grading rubrics used to assess each learning goal have three categories: Excellent, Adequate, and Unsatisfactory. In evaluating student artifacts for each learning goal, rubric scores of 1, 3, or 5 were assigned to each artifact. A weighted average was calculated for all the artifacts assessed for each learning goal. For weighted averages between 3 and 5, a “green light” (an acceptable level or clearly heading in the right direction and not requiring any immediate change in course of action) was assigned for that learning goal, for weighted averages between 2 and 3, a “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) was assigned for that learning goal, and for weighted averages between 1 and 2, a “red light” (our current status or direction of change is unacceptable. Immediate, high priority actions should be taken to address this area) was assigned for that learning goal.

VI. Assessment Data

For the first goal, "Students will use logic and the scientific method to analyze the natural world and solve problems," all three faculty conducting assessment ranked the students at **green**, with an average score of 4.0/5.

For the second goal, "Students will analyze issues in science which are important both personally and globally," all three faculty conducting assessment again ranked the students at **green**, with an average score of 4.16/5.

For the third goal, "Students will connect theories and descriptions found in lectures and textbooks with real-world phenomena utilizing appropriate technology in laboratory and field environments," all three faculty conducting assessment ranked the students as **green**, with an average score of 4.23/5.

VII. Analysis

Goal 1 – Logic, problem solving, and the scientific method are clearly well-established in these courses. This is something that science courses generally do well, and our data supports that argument.

Goal 2 – When first assessed in AY 2006-07, this goal was ranked at yellow (not an acceptable level; either improving but not as quickly as desired or declining slightly). Recognizing this as a weakness in student learning, faculty in the ensuing years have made a conscious effort to include assignments and projects to address this learning goal. The rating of green for this year indicated that faculty have been successful in tailoring assignments toward this learning goal, and more importantly, that students now successfully “analyze issues in science which are important both personally and globally.”

Goal 3 – Like goal 2, this learning goal was assessed in AY 2006-07 as yellow. Again, as was the case with goal 2, faculty have worked to improve student learning under this goal, and students now successfully “connect theories and descriptions found in lectures and textbooks with real-world phenomena.”

Overall, using the results of the first assessment in AY 2006-07, faculty have worked to improve the courses that meet the MPSL Natural Science with a Laboratory Experience requirement so student learning meets the three learning goals for these courses. The “green” rating for all three learning goals, which was first noted in AY 2007-08 and is continued in this year’s assessment, indicates that faculty have indeed been successful in improving these courses. While we are pleased with this rating the Natural Science faculty will continue to work on ways to ensure that all our students perform at the “green light” level in the future.

VIII. Results of Departmental Diagnostic Analyses

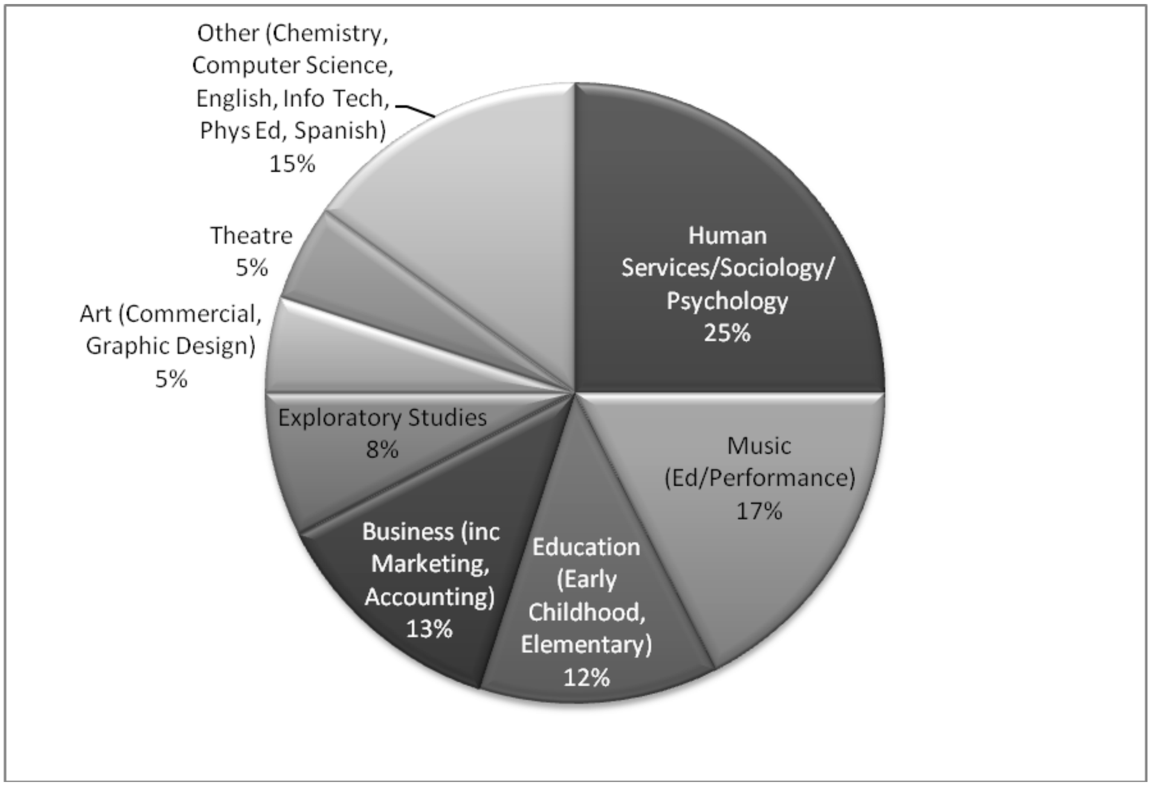
Assessment for Biology 102: Hormones & Society (Fall 2009-Spring 2010); submitted by Dr. Jennifer R. Schultz-Norton

This course covers the basic biology of the human endocrine system, endocrine disorders, and endocrine-related topics from the media. Topics of interest include growth and thyroid hormone disorders, breast cancer, hormone replacement therapy, and diabetes. By the end of the course, students should be able to:

1. Understand the human endocrine system and common disorders that effect how the endocrine system functions *(meets LO Goal 2)*
2. Use their understanding of the endocrine system to discuss in a debate setting the various sides to endocrine system-related issues such as hormone replacement therapy and contraception methods *(meets LO Goal 1)*
3. Be able to use basic laboratory equipment *(meets LO Goal 3)*
4. Use laboratory exercises to understand real-world phenomena such as breast cancer, pregnancy testing, and diabetes *(meets LO Goal 3)*

This course was first developed by Dr. Jennifer R. Schultz-Norton in Fall 2008, has been taught every fall and spring since, and will also be taught in Summer and Fall 2010. Unfortunately, a textbook adequately covering these topics does not exist for a non-majors course. Thus, their reading material consists of copies of the PowerPoint slides used in lecture, as well as supplemental reading handouts that pertain to the topics we are currently covering. This also means that the students must pay attention during lecture and take adequate notes off which to study for exams. Student success was evaluated through 3 exams, a cumulative final, 7 labs, a paper, a group presentation and paper, and class participation. As this course had a lab component, several labs were developed that could be completed in a 2-hour period by non-majors, yet include enough real science to have the labs be valuable, pique the interest of the students, and have them want to understand and interpret what they were learning. These varied greatly in their scientific content. “Light” scientific labs were included where students did taste-tests of caffeinated and non-caffeinated beverages in one lab and sugar substitutes in another, requiring them to draw upon their previous experiences outside of the classroom to draw up a hypothesis. Other labs that required more hands-on science included measurement of the levels of stress hormones when getting a test handed back, and treatment of breast cancer cells with estrogen to look at growth rates. Many of the labs required the students to acquire data and create graphs to show, and interpret, their results.

The background of the students taking this course was greatly varied. In the two semesters this course was taught during the 2009-2010 academic year, 35% of the students were freshmen, 30% sophomores, 20% juniors and 15% seniors. 40 students completed the course; the distribution of majors is depicted below.



For assessment purposes, scores from various assignments were compiled and the averages assigned a rubric score. A score between 80 and 100% was given a rubric score of 5; a score between 60-80% was given a rubric score of 3; and a score below 60% was given a rubric score of 1. Since this course was taught in both Fall 2009 and Spring 2010, data from all students who took and completed the course were included. Scores from those students who did not complete the course (either through a drop, not taking the final exam, or who received an XF due to academic dishonesty on their research paper) were not included in this assessment.

Assessment of Learning Goal 1: Use Logic and the Scientific Method to Analyze the Natural World and Solve Problems

Rating: "Green light" (3.8/5.0)

Throughout the semester, during discussion, on exams, and in labs, students had to apply the scientific method (see syllabus and attached final exam and laboratory exercise examples). Many times this was accomplished by simply asking them to develop a hypothesis related to the experiment, and they often succeeded in this. However, their ability to interpret the data, even after developing graphs, was often lacking. While this has been rectified in part by going in-depth into how to create graphs and by discussing what the students were observing during the lab periods, I believe that this lower score reflects the diversity of the students' backgrounds and that they unfortunately might not desire to learn from the laboratory exercise. I often had 2-3 students per class who would neglect to complete and turn in the graphs for the labs, which greatly hindered their learning.

Assessment of Learning Goal 2: Analyze Issues in Science Which are Important Both Personally and Globally

Rating: "Green light" (4.4/5.0)

Several of the topics I have selected for discussion are those which may affect the students personally. One of these is the topic of type II diabetes (see Diabetes Lab handout). We discuss the biology behind the disease, and then the students do a self-assessment as to their overall health, family history of diabetes, diet and exercise regime and determine their risk for developing diabetes. This often leads the students to realize that their eating habits and lack of exercise may be increasing their diabetes risk. A second personal topic is that of contraception (see Contraception Debate handout). This topic is one that might be considered controversial, but it is broached with the idea that every couple must make a decision regarding contraceptive methods. The students are divided into groups and must make a non-biased presentation, listing pros and cons of each of five methods (daily hormonal, non-daily hormonal, barrier, male-only, and natural family planning). Following the presentation, an open discussion and debate is held. After the debate, the students must prepare a short paper describing what they learned about each of the methods, and include their personal opinions about which they feel is best for them and why. This topic also has global impact because some of the methods discussed each semester (especially those for male-only contraception) are not available yet in the United States. Another topic of global importance is that of androgenic steroid use and abuse. As with the other topics, I provide a biological background on the topic, and then we watch a series of videos pertaining to steroid use that are made by a proponent of steroid use. This leads to a sometimes heated debate about the use of anabolic steroids in sports and their legality as well as their biological effects. One final topic that becomes personally important to the student is the research paper (see Project Handout). As stated in the handout, I let the students choose to research any topic they find interesting, as long as it pertains to the class, and I often expand this to anything biology-related. A majority of the students choose to write on a disease or disorder that affects a family member, and the students must include a minimum of one paragraph on why they chose the topic and why it is important to them. The quality of these research papers, because they are based on something personally important to the student, often far exceeds my expectations.

Assessment of Learning Goal 3: Connect Theories and Descriptions found in Lectures and Textbooks with Real-World Phenomena Utilizing Appropriate Technology in Laboratory and Field Environments

Rating: "Green light" (4.2/5.0)

I have tried to design the labs for this course to demonstrate or reinforce ideas covered in the lecture material, as well as expose the students to a wide variety of research techniques (see attached Labs). In the osteoporosis lab, students must hypothesize what effects acids and milks will have on bone density. They then spend one week collecting density measurements and making observations about bones placed in these solutions. This involves use of volume displacement methods, scales, and microscopes. In the cortisol stress lab, students analyze the amount of the stress hormone cortisol in their own saliva samples. This exposes them to another technique called an ELISA, which is often used to detect levels of hormones in a hospital or research setting. It also allows them to use micropipettors, which is a technique that biology majors typically learn during sophomore level classes. The breast cancer lab requires the students to hypothesize what effect estrogens have on breast cancer (reiterating what they have been learning that week in lecture) and allows the students hands-on learning with an actual human breast cancer cell line, so they can see how cancer cells look and grow. In the hCG lab, the students must determine whether synthetic urine samples contain the pregnancy hormone hCG using test strips as would be done during home use or at a doctor's office with an early pregnancy test kit. A demonstration of various test kits is included, showing little difference between those obtained from a discount store chain and the more expensive digital versions of the tests. They then must decide what type of kit they would rely upon if they were in a situation where they needed to use one. Each of these above-mentioned labs require data collection and graphical analysis and interpretation.

Assessment for Chemistry 121/151: General Chemistry (Fall 2009); submitted by Dr. Edward Acheson

Introduction

General Chemistry (CH 121) is a one-semester introductory survey course. The course covers the essential concepts of chemistry such as substances, solutions, reactions, structure, stoichiometry, equilibrium, and electrochemistry. Students enrolled in CH 121 co-enroll in Introductory Chemistry Laboratory I (CH 151). The projects students work on in CH 151 are designed to introduce students to laboratory safety, experimental design, careful observation, data handling, problem solving, and scientific writing.

CH 121 is typically taught with three 50-minute lectures per week. CH 151 is typically taught with one 3-hour laboratory period per week. In addition to this “traditional” format, CH 121 and CH 151 are also taught in a “block” format. In the block format, CH 121 and CH 151 are taught together in a 2-hour block that meets 5 days a week for half the semester. In Fall, 2009, two sections of CH 121 and five sections of CH 151 were taught in the traditional format. Three sections of CH 121/151 were taught in the block format.

Data were collected from one section of traditional CH 121 and one section of traditional CH 151 in order to assess student learning. The breakdown by major of the students in CH 121 is as follows:

Athletic Training/Physical Education: 12%
Biology: 35%
Business: 6%
Chemistry: 6%
Exploratory Studies: 6%
Nursing: 31%
Physics: 4%

Artifacts from ten students chosen to represent a cross-section of the majors in CH 121 were used, and the laboratory notebooks from eight students chosen at random from CH 151 were used. The artifacts and notebooks were evaluated using the rubrics given earlier.

Assessment of Learning Goal 1: Use Logic and the Scientific Method to Analyze the Natural World and Solve Problems

Rating: “Green light” (4.2 / 5.0)

The scientific method is a naturally integrated part of both CH121 and 151. Chapter 1 in the textbook used in CH 121, for example, begins with a discussion of both the scientific method and problem-solving. Since students are asked to solve problems throughout the semester in lecture, the final exam was used to evaluate Learning Goal 1. A score between 80 and 100% on the final exam was given a rubric score of 5; a score between 60-80% was given a rubric score of 3; and a score below 60% was given a rubric score of 1.

Students are regularly asked to examine basic chemistry problems in lecture. They practice their problem solving skills in the laboratory. A good example of this is the CH 151 experiment "Mass, Volume, and Density." In this experiment, students have to measure the density of two irregularly shaped pieces of plastic. Multiple trials have to be run, and students analyze their data using several statistical tests. Once students are confident they have a "good" value for the density of their plastics, they then use the density to identify their unknowns. The scientific method and logic both play an important role in this experiment. Student grades on their laboratory reports were used to assess this learning goal in the laboratory using the same scale described above.

Assessment of Learning Goal 2: Analyze Issues in Science Which are Important Both Personally and Globally

Rating: "Green light" (4.1 / 5.0)

Understanding the nature of acids and bases is particularly important for the students enrolled in CH 121. For students in biology and nursing, understanding the effects of acids, bases, and buffers on such things as physiology, metabolism, and drug absorption is knowledge they will use throughout their professional lives. Acid rain and its effects, both environmentally and economically, are important issues that society must still deal with today. Chapter 9 in the textbook discusses acids and bases. There is particular emphasis in this chapter on: 1. the environmental impact of acids and bases; and 2. buffer systems in our blood. Since understanding acids and bases will play an important role in the personal and professional lives of the students in CH 121, and chapter 9 in the textbook emphasizes these very issues, the chapter 9 quiz was used to assess learning goal 2. In CH 151, the final experiment students perform is an acid-base titration. The purpose of this experiment is to reinforce some of the concepts discussed in lecture regarding acids and bases. While not exactly an "issue in science," student scores on this experiment were also used to evaluate their understanding of acids and bases in general. A score between 80 and 100% on the chapter 9 quiz was given a rubric score of 5; a score between 60-80% was given a rubric score of 3; and a score below 60% was given a rubric score of 1. This same scale was used to assign rubric scores to the lab report for the experiment.

Assessment of Learning Goal 3: Connect Theories and Descriptions found in Lectures and Textbooks with Real-World Phenomena Utilizing Appropriate Technology in Laboratory and Field Environments

Rating: "Green light" (4.5 / 5.0)

Students "connect theories and descriptions found in lectures and textbooks with real-world phenomena" in the laboratory. One excellent example of this is the CH 151 experiment "Getting the "Scoop" on Scope." Not only does this experiment involve the analysis of "real-world phenomena", but it also uses appropriate technology to do so. In this experiment, students analyze Scope mouthwash to determine the percentage water and the amount of blue food coloring present in Scope. Students use the analytical balance and a drying oven to determine the percentage water in Scope. In doing so, they follow the identical procedure that is used in the "real world." Students also prepare a series of blue food coloring standards and use the standards to generate a calibration curve. This calibration curve is then used to determine the amount of blue food coloring present in Scope. Preparing a calibration curve and using the curve to determine the amount of an unknown connects the theoretical concepts discussed in lecture with the practical application of these concepts to a real-world sample. As an added benefit, students are often amazed at how much water is present in Scope, and how little of the active ingredients are present, making them more knowledgeable consumers. Since this particular experiment fits the assessment criteria of learning goal 3, lab notebook scores on this experiment were used to assess learning goal 3. As before, a score between 80 and 100% on the laboratory notebook report was given a rubric score of 5; a score between 60-80% was given a rubric score of 3; and a score below 60% was given a rubric score of 1.

Concluding Remarks

As noted earlier, students with a variety of backgrounds and majors enroll in CH 121 and CH 151. We try to prepare these students for success after this course by giving them not only a foundational understanding of some of the basic concepts in chemistry, but also by emphasizing how chemistry plays an important role in the students' understanding of the world around them. The topics covered are often related to the student and the world surrounding them and are reinforced by closely related laboratory experiments. We strive to place chemistry within the context of the other natural sciences, attempting to make connections with nursing, biology, and physics where appropriate. It is these connections between lecture, lab, and the lives of our students that enable us to meet the learning goals set forth for the natural science with laboratory component course.

Assessment for Physics 100: The Planets (Spring 2010); submitted by Dr. Casey R. Watson

Supporting Materials Addressing Learning Goals 1 - 3:

A. Conceptual Diagnostic Test (given on the first and last days of class)
B. 3 In-Class Exams and the Final
C. Goal 3 in particular is met through extensive use of Millikin's inventory of telescopes and accessories. The simulations on the Nebraska Astronomy Applet Project's page (http://astro.unl.edu/naap/) are also used during cold, winter months of the semester to help the students better understand many of the major concepts covered in the class, e.g., celestial coordinates, the effects of Earth's axial tilt and orbit upon the seasons, planetary orbits in the geocentric vs. heliocentric models of the solar system, etc.

Assessment of Learning Goal 1: Use Logic and the Scientific Method to Analyze the Natural World and Solve Problems

Rating: "Green light" (4.0/5.0)

I gave my class a rating of 4.0 out of 5 for their steady improvement on class and test exercises that focused on this learning goal. Every class discussion, homework assignment, quiz, and test contained many questions that pushed the students to achieve this learning goal. As the intent of each exam was to assess the student's overall understanding of the learning goals within the context of a particular set of ideas, I have included them as my primary supportive materials.

Specific topics that emphasized Learning Goal 1:
A major theme of the course is the development of our understanding of the arrangement of the solar system and how the scientific method played a crucial role in unraveling this mystery. We discuss how Galileo pioneered the scientific method, in part to address this problem. In particular, we discuss his counter-arguments to the Aristotelian/Ptolemaic geocentric worldview, and how and upon which experiments and observations those counter-arguments were based. I emphasize how revolutionary it was to propose and test a hypothesis rather than simply believing in the wisdom of some ancient authority, like Aristotle or the Bible. We then go on to discuss how Brahe, Kepler, and Newton followed in Galileo's footsteps to overturn the ideas that we are the center of the solar system, that planetary orbits are circular, and so on. At first, some students are dismissive of these scientific developments because the arrangement of the solar system is second nature to them. However, when I ask them to tell me, for instance, how they know the Earth moves rather than the Sun (since they can't *feel* the Earth move), or generally question some of their basic assumptions, they are forced to say they believe much of what they think because society tells them that is the right answer. In this regard, they are no different than the members of pre-scientific-method cultures. As they come to appreciate this and the luxury of being able to think freely and

critically about major issues - astronomical and otherwise - without feeling any major authority breathing down their necks and telling them what to believe, they begin to see the important, pragmatic benefits of the scientific method and clear, logical reasoning. In addition, as we progress from simple concepts like why we have seasons to more complex ideas, like why the solar system is stratified the way it is – with the densest planets closer to the Sun and the more diffuse, gas giants farther away – most of the formerly dismissive/bored students see that they don't know everything just yet, that there is definite value in creating and testing hypotheses, and that the scientific method is, in fact, the best light we have to guide ourselves through unfamiliar territory.

Another important aspect of problem solving in most science classes, particularly physics, is the use of mathematical analysis to better understand the precise (quantitative) behavior of a physical system. Although a fair fraction of my students have some math phobia issues when they enter the class, they become increasingly more adept with the use of basic trigonometry, algebra, and mathematical logic to solve simple astronomical problems. Examples of these exercises include the use of Kepler's 3rd Law to determine how long it would take an object inside or outside Earth's position to orbit the Sun or how measuring the time necessary for a moon to orbit a planet can reveal that planet's mass. Another example is the use of Newton's Law of Universal Gravitation to understand how their weights would change if they were on a more or less massive and/or larger or smaller planet than the Earth, etc.

Although, as a whole, the students grew considerably in their ability to logically break down arguments, to break down complex problems into simpler sub-problems, and to apply mathematical analysis to achieve quantitative understanding of a variety of physical phenomena, 10 – 20% of the class was still shaky on these issues by the end of the term. Consequently, I can only give them a 4 out of 5 ranking for achieving this learning goal as a group.

Assessment of Learning Goal 2: Analyze Issues in Science Which are Important Both Personally and Globally

Rating: "Green light" (4.0/5.0)

I gave my class a rating of 4.0 out of 5 for their work involving this learning goal. The main issues of personal and global relevance that we discussed were related to the uniqueness of our planet and therefore the importance of maintaining it. These points were addressed in several contexts: understanding greenhouse gases and the greenhouse effect on Earth, how and why a runaway greenhouse effect happened on Venus and turned it into the boiling, lifeless inferno it is today, and finally how only *one* of the over 400 extra-solar planets found so far *might* be able to support Earth-like life and that one is not exactly next door (over 20 light years away). The students' realization that logic and the scientific method not only help science advance but also keep them from becoming intellectual lemmings, as mentioned above, is also relevant here, as it defines the way they consider *any* issue of great personal and/or global significance. These topics were also addressed in class discussions, homework assignments, quizzes, and practice and actual tests, as summarized by the three exams included in the assessment packet.

Although, as above, most of the students gained a great deal of perspective both about the particular issues we covered and the use of critical thinking skills to weigh the aspects of any similarly important topic, there were still 10 – 20% who failed to grasp either the significance of Earth's environment or the skills to thoughtfully address a major issue. Consequently, 4 out of 5 is again the appropriate rating.

Assessment of Learning Goal 3: Connect Theories and Descriptions found in Lectures and Textbooks with Real-World Phenomena Utilizing Appropriate Technology in Laboratory and Field Environments

Rating: "Green light" (4.0/5.0)

Once again, I gave the members of my class who were enrolled in lab a rating of 4.0 for this learning goal. We are able to introduce our students to a truly remarkable set of telescopes and related technologies to drive home the concepts we discuss in lecture. I have worked continuously on lab design, preparation, and set up since I first arrived here in the Fall of 2006. The curriculum I have developed (along with John Werner, who has helped as an adjunct lab instructor during multiple semesters) enables the students to use the equipment we have to effectively apply the theories they learn in class to real astronomical objects and events. We also use the simulations on the Nebraska Astronomy Applet Project's page (http://astro.unl.edu/naap/) to drive home major concepts during the cold, winter months of the semester. This spring, we were fortunate enough to have three planets-Venus, Mars, and Saturn-visible throughout the entire semester. We observed the phases of Venus, the retrograde motion of Mars as we passed the opposition point in our orbits (when Earth and Mars are closest to each other), and the orbital periods of two of Saturn's largest moons: Titan (16 days) and Rhea (4.5 days). These exercises allow the students to follow directly in Galileo's footsteps (albeit with better equipment) to see how the phases of Venus indicate that the geocentric model is incorrect, and how – even before discovering this – Galileo realized that the moons of gas giants, like Jupiter (which he observed) and Saturn (which we observed this semester), are orbiting them rather than Earth, contrary to the tenets of the geocentric model, i.e., that everything revolves around the Earth. The opportunity to study the apparent retrograde motion of Mars in the sky also made it clear to the students why the idea of epicycles (that the planets were literally moving through looped paths in space) had seemed strange yet plausible to astronomers for centuries. These concepts are fundamental to the development of our understanding of the solar system and are tested extensively throughout the class – on the first and final exams, in particular. These are just a few examples of the interplay between lecture and lab concepts and activities that was constantly emphasized throughout the semester. Real-world applications of the principles we covered were also a constant part of in-class discussions, homework, quizzes, and tests. See, for instance, the final bonus essay on the first exam about geosynchronous satellites, which requires an understanding of Kepler's 3rd Law and applies to the whole telecommunications industry.

Summary

Following the first test, on which the class average was 60%, the students became more aware of what I expected of them and that I wanted them to think – particularly along the lines of the above three learning goals – rather than just regurgitate information, as they (unfortunately) seem to be used to doing from high school. As the diagnostic pre- and post-test scores, as well as the second and third in-class test averages (76% and 80%, respectively) and the final grades demonstrate, the students' overall mastery of the learning goals (an integral part of all exams) is roughly 80%, hence consistent with a 4 out of 5 ranking for each learning goal. The pre- to post-test gain (see spreadsheet and figures) and its correlation to the final grades show that it is a simple and accurate, summative diagnostic of the overall learning experience. (The few outlier points on figure 2 of the attached spreadsheet are due to a few intelligent but somewhat lazy students who learned a significant amount – as evidenced by high gains – but fell short of their grade potential by failing to turn in several assignments and/or perform to up to their ability level on exams).

To further enhance the assimilation of learning goals 1 – 3, more hands-on activities and visualization exercises are probably needed. Over the last four semesters, I have seen a clear trend: students who are not enrolled in the lab tend to do more poorly in the class overall. I think there are two reasons for this. One is the simple fact that students who are enrolled in lab are exposed to course concepts one more time per week than those who are not enrolled. The other, more important reason is that the lab forces the students to think about what they are learning in practical and concrete terms. Why could I see the moon at 6 pm last night, but not tonight? Why do the stars look different this month than last? Why have the planets moved around in the sky the way they have during the semester? Asking and answering these types of questions are invaluable to the learning process in any field. I have added more and more of these types of questions to class discussions and exams each semester and have incorporated a steadily growing number of simulations from the Nebraska Astronomy Applet Project's page (http://astro.unl.edu/naap/) and other sites to help the students internalize the course material as effectively as possible.

IX. Conclusion

The departments of Biology, Chemistry, and Physics have developed the following learning goals for students taking a course that satisfies the MPSL Natural Science with Lab non-sequential requirement:

1) (Students will…) Develop an understanding of how to use logic and the scientific method to analyze the natural world and solve problems.

2) Learn about issues in science that are important both personally and globally.

3) Utilize technology in laboratory and field environments in order to connect theories and descriptions found in lectures and textbooks with real-world phenomena.

The courses that students take to satisfy these learning goals come from all three departments and are taught by a substantial majority of the faculty in each department. As a result, the learning experiences of students may vary widely in the process of their study of science.

Each year, faculty gather an assortment of artifacts from their courses that measure student learning with respect to the above goals, along with a rubric that describes how the learning has been assessed. These artifacts will be studied individually, departmentally, and within the science departments as a whole in order to better understand how faculty collectively work to help students achieve learning goals. Faculty will then be given time to reflect on feedback and make changes before they are assessed again.

For the 2009-2010 AY, the departments rate student learning for all three learning goals as Green.

Respectfully submitted by Dr. Ed Acheson and Dr. Jennifer R. Schultz-Norton, on 6/25/10.

Note: For the 2010-2011 AY, Dr. Jennifer R. Schultz-Norton will be taking over as the coordinator for assessment for the natural sciences.