Student Learning in Natural Science with Laboratory Courses
Self-Study Report
Submitted by Marianne W. Robertson

I.) BACKGROUND

A.) Examples of Appropriate Courses
Natural Science with a lab: In a natural science with a lab course, students utilize qualitative and quantitative reasoning and the scientific method as tools in decision making and creative problem solving. Examples include, but are not limited to the following: Biology 102, 125, 130, 205; Chemistry 102, 106, 121/151; Physics 110 or 201, 100/105 and 101/106; Psychology 140/141; or any approved Lab-Science course. Students in these courses will utilize qualitative and quantitative reasoning and the scientific method as tools in decision making and creative problem solving.

B.) Learning Goals
Upon completion of a Natural Science with Lab 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.

C.) Support of Millikin University Mission Statement
A student who is able to successfully meet these goals will also be satisfying the core goals expressed in the Millikin University mission statement. Specifically, the first and third goals will help a student achieve *professional success* since 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 innovative experiments is one way scientists interact with the world; therefore, understanding both the issues in science and the process scientists go through are invaluable in understanding the impact of science-related issues on daily life. The second and third goals are particularly focused on *preparing students for a personal life of meaning and value*. 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 students be life-long learners who continue to integrate future developments in science into their understanding of the world.

D.) Snapshot

The departments of Biology, Chemistry, and Physics at Millikin University were staffed in 2007-08 by 16 full-time faculty, 8 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, Organic Chemistry I, and Introductory Astronomy courses. Lab courses are usually capped at a maximum of 24 students.

E.) 2007-08 Natural Science with Lab Courses

Courses taught Fall 2007, Spring 2008, or Summer 2008 that met the MPSL Natural Science with Lab requirement for non-majors:

- BI 102, Biochemistry of Food - Dr. Samuel Galewsky
- BI 102' Biology of Birds: Evolution, Diversity, and Conservation - Dr. David J. Horn
- BI 102, Biology of Spiders - Dr. Marianne W. Robertson (Honors sections only)
- BI 102, Current Issues in Biology - Roslyn J. O' Conner,
- BI 102, Human Biology - Dr. Harold L. Wilkinson,
- BI 102, Human Genetics - Dr. Terry C. Matthews,
- BI 102, Microbes & Humans - Dr. Thomas E. McQuistion,
- BI 220 - Field Ecology - Dr. Judith Parrish (Summer Immersion)
- BI 280 - Ecol Journey: Alaska Ecology - Judith Parrish (Summer Immersion)
- CH 121/151 - General Chemistry - Dr. Paris Barnes and Dr. Clarence M. Josefson
- PY 100 - The Planets - Dr. Casey R. Watson
- PY 111 - College Physics I - Dr. Casey R. Watson
- PY 151 - University Physics I – Dr. Eric C. Martell

F.) Learning Story

There are three main groups of students who take natural science courses at Millikin: 1) Natural Science majors who take many science courses, 2) students majoring in fields like Nursing or Exercise Science, who take a few required science courses, and 3) students who take one science course to fulfill graduation requirements. The first group of students generally has a different set of learning goals specifically designed by faculty in the major. While some of the above courses (for example BI 102, PY 100) have students from the third group as their primary audience, other courses (CH 121, PY 111, for example) service both majors and non-majors. These courses are designed so that majors get a strong introduction to the field and non-majors or satisfy the learning goals for the Natural Science with Lab.

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 his/her first Natural Science with Lab 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 daily to ensure that they comprehend 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 taking The Planets will become an expert at setting up, taking down, and maintaining a telescope, and learn specifics about the night sky. Students in all courses are exposed to innovative teaching methods in lectures and research-based experiences in the laboratory. Lectures and labs are well integrated and emphasize critical thinking, application, and problem solving skills,

II.) ASSESSMENT

A.) Methods

During the Spring 2008 semester, a subset of faculty teaching courses that satisfied the MPSL Natural Science with Lab 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 wide variety of courses. The courses assessed were BI 102 with Roslyn O'Conner, CH 121 with Dr. Paris Barnes, and PY 100 with Dr. Casey Watson. Individual faculty chose artifacts from their course which addressed the learning goals, including syllabi, exams, lab books, semester-long projects, and presentations.

These faculty analyzed their courses using a series of rubrics to measure the overall success of students at achieving each learning goal. These rubrics are general enough to apply to all courses, while still providing a reliable guideline for assessment. The three rubrics used to assess each of the three learning goals are presented below. In addition, PY 100 was assessed with a pre- and post-diagnostic exam. Data were analyzed, and raw data are included as well as analyzed data presented in graph form.

B.) 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-	**[1 point]** Student demonstrates a weak understanding at best. Unable to explain basic scientific

		understood.	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 re 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.

C.) Results of Rubric Analysis

For the first goal, "Students will use logic and the scientific method to analyze the natural world and solve problems," the data (rubric 1) from the three faculty conducting the assessment resulted in an overall ranking of **green**, with an average score of 4.0/5. 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 support that statement. It is also important to note that the ranking increased from 3.8 (also green) obtained in the 2006/07 academic year.

For the second goal, "Students will analyze issues in science which are important both personally and globally," the data (rubric 2) from the three faculty conducting the assessment resulted in an overall ranking of **green**, with an average score of 4.1/5. This goal increased from yellow (3.0) in the 2006/07 academic year to green (4.1) this year for a variety of reasons. Based on last year's suggestions, faculty assignments more intentionally addressed particular aspects of the goal, although different issues are emphasized in different classes. Instruction in political, cultural, and social events impacted by science was approached with more direction, as was instruction in how the scientific issues under discussion impacted students personally. It is a positive outcome that out highest score was in this category, as it had the most need for improvement from last year.

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," the data (rubric 3) from the three faculty conducting the assessment resulted in an overall ranking of **green**, with an average score of 3.7/5. Again, the overall ranking increased from yellow (3.0) to green (3.7) this year demonstrating that students are better able to connect what they do in classes to the real world, especially at the introductory level, than they were before more emphasis was placed on this goal. However, this is the lowest average indicating that real world connections and application are areas where students struggle. While real world connections often seem obvious to faculty, they must be made clear and emphasized to students, and instruction is now more deliberately focused on those connections.

Receiving green scores in all categories of the rubric analyses supports that the Natural Sciences faculty stand behind these important goals and are structuring teaching towards hands-on, innovative techniques that emphasize the combined mission of the university and the sciences.

D.) Results of Physics Diagnostic Exam Analysis

Included in the Physics supplementary materials are a copy of the diagnostic exam and the raw data. The spreadsheet shows the pre- and post- test scores. Analyzed data are presented below (Figs. 1 and 2). A common measure of learning success in the context of pre-and post-test assessment is the normalized gain, defines as follows:

Gain = (Post-test – Pre-test)/(Maximum possible score – Pre-test)

The gain students achieved in this class is well above the average national level, as detailed in the spreadsheet. Additionally, the spreadsheet demonstrates that the final course grades and the gain are fairly well-correlated, supporting that the improvement from the pre- to the post-test is as good a measure of learning success as the grades themselves are, which was the objective in creating this simple assessment metric.

Although the average gain on this diagnostic test was quite good relative to the national average, we are still not happy with the large scatter in the gains of the students that received low pre-test scores. Our ultimate goal is to have a fairly uniform gain across the board even for the low pre-test group. Achieving this would indicate to us that the majority of these low pre-test students underwent a major transformation in conceptual understanding and in their approaches to learning as a result of taking the class. That is clearly the ideal outcome, especially since the low pre-test group most often includes students who are not required to have any additional exposure to university-level science beyond my class.

E.) Assessment for Biology 102: Current Issues in Biology, Spring 2008
Submitted by Roslyn O'Conner

Learning Goal 1: develop an understanding of how to use logic and the scientific method to analyze the natural world and solve problems.

I believe my class earned a **3.7** for this learning goal. Throughout the semester the class applied the scientific method during class discussions (see syllabus and exam review sheets), class assignments (see Childbed Fever: A Nineteenth Century Mystery), in the lab (see Hypothesis Lab and Photosynthesis Lab) and on exams (see Midterm and Final Exams). While applying the scientific method, the class also increased their analysis and problem solving skills but I believe that more data analysis and complex problem solving would be necessary to earn a higher score.

Learning Goal 2: analyze issues in science, which are important both personally and globally.

I believe my class earned a **4.3** for this learning goal. Throughout the semester the class discussed scientific issues and applied the issues to themselves and the world at large. In addition to class discussion (see syllabus and exam review sheets), the class completed various assignments (see Selecting the Perfect Baby: The Ethics of Embryo Design, Chapter 12 Assignment: Cloning, Chapter 14 Drug Presentation, Chapter 9 Assignment People Paradox, Chapter 18/19 Environmental Issues Presentation, Chapter 5/6 Assignment: Evolution) and applied the analysis to exam questions (see Midterm and Final Exams). I believe that more in-depth analysis of the global implications of the issues would be necessary to earn a higher score.

<u>Learning Goal 3: connect theories and descriptions found in lectures and textbooks with real-world phenomena utilizing technology in laboratory and field environments.</u>

I believe my class earned a **3.2** for this learning goal. Throughout the semester the class completed laboratory activities (see Chapter 10 Nutrition Computer Lab, Chapter 17 Lab: How does an Infectious Disease Spread, Chapter 5/6 Natural Selection Lab, Photosynthesis Lab) that used various technology. We then discussed the results of these labs to try to illustrate the connection between theory and real-world phenomena. I feel these labs activities and discussion are on the right track to achieving the goal, but I believe that more "data generating" experiments and a greater variety of technology would be necessary to earn a higher score.

<u>Summary and Plans</u>

For this particular class, I feel that student-learning goals 1 and 3 could be improved by increasing the complexity of laboratory experiments. This increase in complexity would allow for more enhanced technology and would generate more sophisticated data for analysis and application to real-world phenomena. In addition, a student generated research project would allow for more complex problem solving. For student learning goal 2, each student could research a scientific issue and write a paper that describes how the issue affects not only them but also the world at large.

F.) Assessment for Block General Chemistry 121/151: Spring 2008 Submitted by Paris Barnes

<u>Introduction</u>

Block General Chemistry with accompanying laboratory (or CH121/151 Block) is a course designed to introduce students to the basic principles of chemistry. This course is primarily taken by students with little to no background in the subject to learn the basics of chemistry. Block Introductory Chemistry was designed to help students that felt squeamish about taking a chemistry class. When taught, class is held almost every day for thirty days, covering part of one of the five broader topics listed below.

- Safety in the laboratory and data handling,
- The basics of matter (atomic structure),
- Pure substances (elements and compounds),
- Mixtures (both homogeneous and heterogeneous),
- Chemical reactions (including synthesis), and
- Chemical equilibrium.

Students are required to purchase a textbook written by the chemistry faculty members teaching this course. The textbook is broken up into twenty-nine days, each day with an *In-Class Discussion* section that elaborates on a specific topic, and a *Laboratory* section that reinforces the topic through experimentation.

A typical two-hour class period in CH121/151 starts off with a quiz over the material covered the previous day (sample quizzes are submitted with this document), a discussion of the day's topic, and a laboratory exercise that reinforces the concepts introduced during the in-class discussion. When laboratories are performed, students must keep a laboratory notebook that contains a purpose for doing the experiment, collected data (observational, numerical, and/or graphical), calculations (if required for the experiment), and a discussion of their results. Student performance in CH121 is assessed by their daily quiz scores (thirty quizzes total). Performance in CH151 is evaluated by the format, content, and completeness of their laboratory notebooks.

This document will be used as a vehicle to assess how well CH121/151 Block fits the learning goals associated with taking a natural science course with a laboratory. The learning outcome goals for students taking a natural science course with a laboratory are that students will 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; and
3. Connect theories and descriptions found in lectures and textbooks with real-world phenomena utilizing appropriate technology in laboratory and field environments.

In addition to assessing the learning goals put forth by the Natural Sciences, this document will show how CH121/151 Block evolved during the 2007 – 2008 academic year and will suggest improvements for the future of this course.

Instructors for this Course for the 2007 – 2008 Academic Year

During the last academic year, this course was taught by two different instructors for the first time. The Fall 2007 section of Block General Chemistry was taught by Clarence Josefson. During the Spring 2008 semester, the two sections of CH121/151 were team-taught by myself and Dr. Josefson. The first block, held between January 15 and March 3, 2008, was primarily conducted by Dr. Josefson while I observed and helped with in-class exercises and laboratories. Both sections of CH121/151 Block instructed by Dr. Josefson used his version of textbook, which is included in this assessment.

The second block, held between March 4 and May 16, 2008, was taught by myself with Dr. Josefson acting as my teaching mentor and assisting professor (much like I did during the first block). My section of this course was taught from a version of the CH121/151 Block textbook that I revised and is also included with this assessment.

Students Background

The diversity of the students' background taking this course is very broad. During the 2007 – 2008 academic year, CH121/151 was taken by students in nineteen different majors. Students from a variety of majors were serviced by this course during the previous academic year (Fig. 3).

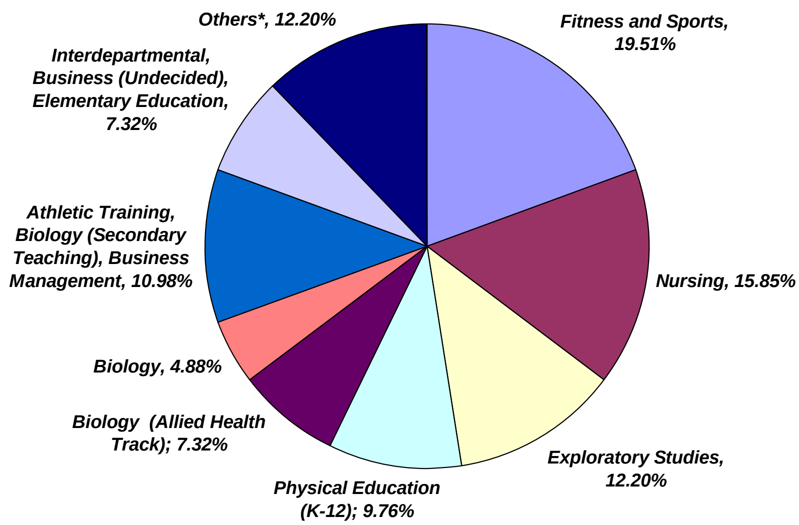

Figure 3. Student enrollment breakdown in Ch121/151 by major. During the 2007-2008 academic year, 82 students enrolled in this course. * - Students included in the "Othersd" major category include chemistry, mathematics (secondary teraching), physics, applied mathematics, music, music business, psychology, and entrepreneurship.

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

Rating: Excellent (4.3)

The ***scientific method*** is a naturally integrated part of CH121/151 Block. Students are regularly asked to examine basic chemistry problems during the in-class discussions and laboratory exercises. One such problem is used to illustrate how the composition of a mixture can affect its physical properties. Early in the course, density is introduced to the students. During our in-class discussion, students are shown two cans of soda, one containing Coca-Cola and the other containing Diet Coke. One unopened can of Coca-Cola is placed in a large container of water. The students observe that the can of soda sinks in water. The experiment is repeated with a can of Diet Coke, and students observe that the soda can floats. The entire class is then asked to ***analyze*** this behavior. A significant number of students point out that the Coca-Cola contains sugar whereas the Diet Coke contains artificial sweetener. To follow up their knowledge, we ask students to tell us to explain why the sugar content of soda affects its buoyancy. At this point, students ***hypothesize*** that the sugar content of Coca-Cola makes it denser than water, so its can must sink. In a subsequent experiment, students are asked to measure the density of Coca-Cola to see if their hypothesis is correct – that the sugar content of soda makes it denser than water.

Another example of this occurs during the third day of class when we cover atoms and elements. During this discussion, we talked about the subatomic particles that make up an atom and how the earliest working periodic table was developed by Dmitri Mendeleev based upon the chemical and physical properties of the elements. The accompanying laboratory asks the students to take a stack of cards with information about hypothetical elements on them and to arrange them in a periodic table several ways until they develop a scientifically consistent periodic table much like Mendeleev did. This exercise reinforced the idea of atomic weight, density (introduced during the data handling discussion during the second day), and physical properties (*e.g.*, electrical resistance, melting point) of the elements. It also introduces students to the idea of chemical properties (*e.g.*, compounds that a particular element forms with oxygen) with elements.

In the textbooks accompanying this assessment, all of the laboratory exercises ask students to take their previously learned knowledge to solve a problem. As the class progresses, the problems they are asked to solve become more involved and the ***numerical and observational analysis*** can be difficult. This rigorous, intensive day-by-day approach to teaching a class is designed to allow students to retain the information and use it to attempt to explain their experimental observations for any experiment they do in the course. Regularly, students think that since topics are covered day-by-day, they do not need to retain the knowledge for future use. We (*i.e.*, the instructors) need to emphasize that students need to remember the basic concepts covered early because they will be used later when ***explaining results obtained by experimentation.*** In the version of the Block Chemistry textbook for the section I taught in Spring 2008, the wording of the *Discussion* section of the laboratory write-ups asked students to explain their results and included related questions to get them thinking about how previously covered topics could be used to explain their observations.

<u>Assessment of Learning Goal 2: Analyze Issues in Science Which are Important Both Personally and Globally</u>
Rating: Excellent (4.0)
CH121/151 Block asks students to understand issues which are important both personally and globally. Examples of how a student's world is influenced by chemistry are discussed in the assessment under *Learning Goal 3*. Two major global issues covered in this class are the effects of gaseous pollutants on atmospheric chemistry (*i.e.*, the Greenhouse Effect) and the concerns associated with nuclear chemistry.

Day 19 in the revised edition of the CH121/151 textbook focuses on nuclear chemistry. In the textbook and in-class discussion, we focus on looking at the positive and negative aspects of nuclear chemistry, how they could affect the student personally and how they influence the world as a whole. We also ask students to test their beliefs about nuclear reactions through a ten-question nuclear "phobia" quiz.

Day 29 (in the revised edition) focuses on atmospheric chemistry. On this day, we discuss the composition of the Earth's atmosphere, its different layers (or spheres) and the chemistry that occurs in each of the different layers. We also talk about the different pollutants in our air (nitrogen oxides, carbon dioxide, ozone, carbon monoxide), how they affect people and how they affect our environment. During the in-class discussion, we spend a significant amount of time discussing the importance ozone in the stratosphere (to protect humans from ultraviolet radiation which damages our skin) and why global warming and the Greenhouse Effect is important.

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: Excellent (4.3)

CH121/151 Block is designed to survey and discuss many important and useful topics in general chemistry. Many of these topics are important to chemists, but the way the topics are presented, we try to convey that the concepts covered in this course are important to them personally. Examples of topics that are connected to real world applications are covered on

- Days 10, 11, and 12 – Mixtures (or what are common everyday things like pretzels and mouthwash made of),
- Day 13 – the electrical conductivity of solutions (or why is it a bad idea to drop something electrical into your bath tub while taking a bath),
- Days 17 and 18 – Chemical synthesis (which can lead to the discovery of new substances, like the drugs that we use to treat diseases), and
- Day 21 – Electrochemical cells (or what is chemistry behind how batteries work),
- Days 26, 27, and 28 – Chemical equilibria (or how does industry synthesize ammonia via the Haber process in order to make fertilizers),
- Day 28 – Buffered solutions (or how does the blood maintain its *pH* and why is it important to maintain this *pH* near 7.4),
- Day 29 – Atmospheric chemistry (or why is it important to reduce gaseous emissions from cars, factories, etc.).

In this class, ***we try to include how chemistry plays an important part in the student's understanding of the world around them in all course materials*** (the textbook and quizzes) ***and in-class discussions***. We strive to place chemistry within the context of the other natural sciences, attempting to make connections with biology and physics where appropriate. For example, on Day 28, we discuss buffers. In the introductory material given in the textbook for Day 28, the blood buffer system that maintains the *pH* of human blood is extensively discussed and related to Le Chatelier's Principle. Many of the quizzes that follow Day 28 (included in the quizzes artifact) contain questions about the carbonic acid/hydrogen carbonate buffer that is used (in part) to buffer human blood.

Suggestions for Improvement of CH121/151 Block

Block General Chemistry is a reasonably well assembled course that Dr. Josefson has spent a significant amount of time developing. The day-by-day approach taken to teach this course really works and allows even the most squeamish student to learn many basic concepts in chemistry. However, there is room for improvement in this course. First, the in-class textbook originally used by Dr. Josefson is a patchwork of different topics that was written in a semi-organized fashion. With Dr. Josefson's help, I have decided to revise and rewrite parts of the textbook to improve the content and clarity of the material for use in future sections of CH121/151 Block. We want students to have a factually correct and clear textbook to use for this course. Older versions of this textbook (such as the artifact included with this assessment) have typographical errors, incomplete thoughts and inadequately covered material. The most recent revision of this textbook (also included as an artifact) strives to clarify and elaborate on many of the topics covered. Even though the most recent version is still a work in progress, we have decided to use it as the base for the Fall 2008 textbook for this course.

Second, keeping students interested in the subject can be very difficult. Too often, I found that students were having difficulty paying attention due to the dryness of the presentation. Even though I would ask students to participate in class by asking thought-provoking questions, students seemed apprehensive to answer questions, partially because they were not paying attention or they were afraid they would answer the question incorrectly. One of the ideas that I found to work best and the students really retained the information was when I presented them with a challenge. On Day 10, I had the students clear up a scientific disagreement between myself and Dr. Josefson. The following is part of the narrative taken from the Day 10 laboratory, "Dr. J versus Paris – Just How Much Water Is There In $CuSO_4 \cdot 5\ H_2O$?":
During the first Block of this semester, Paris and Dr. J had a disagreement on the percentage of water in $CuSO_4 \cdot 5\ H_2O$. Dr. J said that when he dried a sample of $CuSO_4 \cdot 5\ H_2O$, he found that only four molecules of water evaporated for every copper sulfate pentahydrate. Looking at the chemical formula, Paris questioned Dr. J's conclusion because he believed that five molecules of water should evaporate from every $CuSO_4 \cdot 5\ H_2O$. Today, you are going to help us determine how much water is removed from copper sulfate pentahydrate when it is dried. Is it five molecules of water as Paris believes, or is it four like Dr. J's data shows?

This question had students participating in class offering honest scientific opinions based upon experimental results. I would like to develop more challenging problems such as this one where students are asked to critically evaluate and answer a question through experimentation and self-discovery. In addition, during lecture, I would like to explore fun methods to get students learning the material so we get away from traditional lectures and more toward discussions. For example, when discussing the periodic table and all of the information included in it, one of the teaching assistants for this course during my Block suggested developing a "Jeopardy" style game to help students retain all the information that this tool contains.

One final improvement I would like to make in the course is to have one or two experiments where the students design their own experiment to answer a question. All of the laboratory exercises used during the section of Block General Chemistry I taught were cookbook style with directions explicitly written for students to follow and data tables set up for them to fill in. This needs to change so that the Block General Chemistry students are doing science like scientists do it – creatively, using their previously gained knowledge to answer a real problem.

Concluding Remarks

After assessing Block General Chemistry (CH121/151 Block) against the learning goals for a natural science course with laboratory, I honestly believe we meet and exceed these criteria in this course. The topics covered are often related to the student and the world surrounding them and are reinforced by closely related laboratory exercises. The intense day-by-day approach to this course has students practicing what they learn everyday when preparing for daily quizzes and working through the various experiments. Ultimately, they learn some of the chemistry behind how their bodies work and how chemistry influences the world around them.

G.) Assessment for Physics 100: The Planets, Spring 2008
Submitted by Casey R. Watson

Supporting Materials Addressing Learning Goals 1 - 3:

A. Conceptual Diagnostic Test (given one the first and last days of class)
B. 3 In-Class Exams
C. Lunar Eclipse Lab (especially Learning Goal 3).

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

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 students overall understanding of the learning goals with in 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 that they think much of what they do because society tells them that 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 it 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, or 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, break down complex problems into simpler sub-problems, and 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.

<u>Learning Goal 2: Analyze issues in science, which are important both personally and globally.</u>
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 300 extra-solar planets found so far *might* be able to support Earth-like life and it's 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, a 4 out of 5 is again the appropriate rating.

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

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. The lab instructor, John Werner, and I have worked together on lab design, preparation, and set up, since I first arrived here in the Fall of 2006. The curriculum we have developed enables the students to use the equipment we have to effectively apply the theories they learn in class to real astronomical objects and events. This February, we were fortunate enough to witness a full lunar eclipse. We made the most of the event by recording it, webcasting it, and asking our students to use what they saw to determine a fundamental length in our solar system, the Earth-Moon distance. I have included the lab hand-out that provides an overview of the method and the step-by-step questions that must be answered to arrive at the result in the assessment packet. Note that many conceptual questions related to lunar (and solar) eclipse(s) are also present on the first exam. This is a specific example 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, homeworks, 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 and Plans

Following the first test, on which the class average was a 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 be more used to doing in high school. As the diagnostic pre- and post-test scores, as well as the second and third in-class test averages (80% and 83%, respectively) and the final grades demonstrate, the students' overall mastery of the learning goals, which are integral part of all of these exams, is roughly 80%, hence the consistent 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.

To further enhance the assimilation of learning goals 1 – 3, more hands-on activities 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 tried to talk more about the labs in class in an attempt to benefit the students who are not enrolled in them, but not to the desired end. Ideally, I would like to require the lab for future semesters, if the logistics are not too problematic.

H.) Overall Conclusion

The courses that students take to satisfy these learning goals come from all three departments and are taught by a 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. However, our **excellent** rankings in all categories demonstrates that biology, chemistry, and physics faculty are supportive of the Natural Sciences with lab learning goals and are working very intentionally to ensure that students have these skills after their science experience, and we will strive, as described above, to insure that these goals continue to be met and enhanced.