# Student Learning in Natural Science with Laboratory courses Self-Study Report

## I. Goals

In the opinion of the faculty in the Departments of Biology, Chemistry, and Physics, 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.

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 everyday, 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.

## II. Snapshot

The departments of Biology, Chemistry, and Physics at Millikin University were staffed in 2006-07 by sixteen full-time faculty, one and a half full time academic staff support people, and a small number of part-time adjuncts (the number is as yet undetermined, but is usually around five). 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. The departments are housed in the Leighty-Tabor Science Center (LTSC), which opened in 2002, and provides an excellent facility for the teaching of science. Full-time faculty generally teach a wide range of courses, including service courses which are primarily aimed at a general audience, service courses aimed at a particular audience (such as courses for Nursing majors), and courses for science majors. Adjuncts primarily serve as laboratory instructors. The smallest science courses will have just a handful of students; these are usually required upper-level courses. The largest will have upwards of 60 students, including Anatomy and

Physiology, Organic Chemistry, and Introductory Astronomy courses. Lab courses are usually capped at no more than 24.

The natural science departments are currently undergoing some exciting changes. In the last 3 years, the physics department has gone from one temporary full-time faculty member to two tenure-track faculty, and has undergone a complete curricular revision. The chemistry department has hired a new faculty member, also starting August 1. The biology department hired two new faculty in 2006, and a search to hire a third failed in 2007 (the search will be repeated in 2007-08).

Courses taught this year that included students satisfying their MPSL Natural Science with Lab requirement were:

BI 102 – Topics courses designed for non-majors, including Biochemistry of Food - Samuel Galewsky, Current Issues - Roslyn J. O'Conner, Physiology of Space - Harold L. Wilkinson, Human Genetics - Terry C. Matthews, Microbes & Humans - Thomas E. McQuistion, Biology of Birds – David J. Horn, and Pay it Forward – David J. Horn

BI 105 – The first course for Biology majors - Ecology & Evolution - Marianne Robertson, Judith Parrish

BI 130 - Environmental Biology - David J. Horn

BI 220 - Field Ecology - Judith Parrish (Immersion)
BI 280 - Ecol Journey: Alaska Ecology - Judith Parrish, Ecological Journey: Galapagos – Judith Parrish (Immersion)

CH 121 - General Chemistry - Edward Acheson, Paris Barnes, Clarence M. Josefson

PY 100 - The Planets – Casey Watson
PY 101 - Stars and Galaxies - Casey Watson
PY 111 - College Physics I - Eric C. Martell
PY 151 - University Physics I - Casey Watson

## III. 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 don't take quite as many science courses but still 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 as 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 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. A student in the block Gen Chem 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.

## IV. Assessment Methods

During the Fall 2006 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. The courses assessed were CH 121 – Ed Acheson, BI 130 – David J. Horn, PY 111 – Eric C. Martell. 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.

### 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 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. |

## V. 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 3.8/5.

For the second goal, "Students will analyze issues in science which are important both personally and globally," there was a mixture of results between yellow and green, resulting in an overall ranking of **yellow**, with an average score of 3.0/5.

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 **yellow**, with an average score of 3.0/5.

## VI. Analysis

Goal 1 – Logic, problem solving, and the scientific method are clearly well-established in these courses (and, I would suspect, in all of our courses – future assessment will tell). This is something that science courses generally do well, and our data supports that argument.

Goal 2 – This goal ended up yellow for a variety of reasons, primarily that assignments did not specifically address particular aspects of the goal (as defined in the rubric used for analysis), although different issues cropped up in each class. Instruction in political, cultural, and social events impacted by science was inconsistent, as was instruction in how the scientific issues under discussion impacted students personally. Suggestions of how to improve will be provided in the next section.

Goal 3 – Students have trouble connecting what they do in classes to the real world, especially at the introductory level, and the data supports this. While real world connections often seem obvious to faculty, they are not to students, and instruction was not always deliberately focused on those connections.

Overall, David puts it very well when he says "While two of the learning goals received yellow lights, the yellow lights were primarily a result of how the assignment was structured, and not a failure on the part of students to comprehend the concepts asked (editor's note - or a failure on the part of the instructors to teach the concepts). In the future, assignments will be given that better allow the students to master the learning goals of natural science with laboratory courses."

## VII. Plans

During the last NSM division meeting of the Spring, 2007 semester, natural science faculty discussed these results and developed the following plans for 2007-2008, written as a set of guidelines for faculty. There was widespread agreement that our failures to meet the student learning goals across the board was a result of faculty not fully integrating them into instruction and assessment, and it is expected that more deliberate efforts in this area will lead to marked improvement.

1. If your course can count towards the Natural Science with Lab requirement, remember to include the learning goals in your syllabi. (Hopefully they should already be among the learning goals you actually have for the course.)

2. Plan assignments that can be used to demonstrate student learning for each of the goals.

3. Consider finding some way of incorporating the rubrics into the grading of said assignments (if needed, we can revise the rubrics) – that way, when it comes time to compile the information, you've already done the work and then don't have to duplicate your efforts.

As an example, after seeing the date regarding goal 2, this semester I included an assignment in PY 112 (which isn't a course that generally counts for the MPSL, but had many of the same students who were in PY 111), where students had to write a paper about a scientific issue of importance to them and then make some effort to spread information about the issue beyond the class – write their representatives in Congress, letters to the editor, reach out to the campus community, etc. Students did very well on this assignment, and if I had used it as part of the assessment, they would have clearly rated as green.

Note: For the 2007-2008 AY, Marianne Robertson will be taking over as the coordinator for assessment for the natural sciences.

## Appendix 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) (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 2006-2007 AY, the departments rate student learning for goal 1 as Green, goal 2 as Yellow, and goal 3 as Yellow.

Respectfully submitted by Eric Martell, on 6/20/07.