Development and Implementation of Laboratory Modules to Accompany

Introduction to Environmental Chemistry

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Ruth Beeston, Department Chair Date

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Clark Ross, VPAA Date

PROJECT SUMMARY

In this proposal, funds are requested to develop a laboratory course for non-science majors in Environmental Chemistry. The goal of this course will be to introduce students to the scientific method utilized in solving real world problems. To accomplish this goal, an experience will be developed in which students will be exposed to questions in a variety of environmental contexts or modules: *The Atmosphere, The Hydrosphere, The Geosphere, The Biosphere* and *Energy*. In the classroom, students will be introduced to relevant chemical, biological, geological and physical concepts in the context of issues associated with a region of the environment. In the laboratory, a) the students will be presented with an environmental scenario, b) sampling strategies will be discussed and deployed, c) samples and standards will be prepared and analyzed, d) data will be analyzed using appropriate software, e) results will be interpreted in the context of the original hypothesis and regulatory or literature values and f) reports will be written to a targeted audience. For example, in *The Atmosphere*, students might look at carbon dioxide concentrations as they contemplate global warming, particulate concentrations as they evaluate health impacts, and the effect of acidic solutions on materials as they debate the validity of concerns surrounding acid deposition. They will then report their results in the form of an article for the local newspaper.

Regardless of major, every student will graduate and become part of a society where resources are limited and interactions with the environment have ramifications. For the non-science major, this course will provide background and experience in applying scientific principles. The knowledge and skills gained in this course will be important in the future when they are called to interpret, understand and act on the information provided by government agencies, profit and non-profit groups and the media.

PROJECT DESCRIPTION

Goal: The goal of this project is to develop laboratory modules to accompany an introductory environmental chemistry course. These modules will provide students with exposure to the scientific method by presenting them with a question in an applied context, the analytical tools to obtain information useful in addressing the question, and the challenge of drawing a conclusion based on the data obtained.

Objectives:

1. To develop hands-on activities in environmental sampling of air, water and soil.
2. To provide experience with laboratory techniques including gravimetric, titrimetric, spectroscopic, separations and electrochemical methods.
3. To develop students' ability to analyze and interpret data.
4. To provide an opportunity to evaluate results in the context of a larger issue.
5. To encourage presentation of results to a general audience.
6. To develop tools necessary to evaluate progress in the above areas.

Background and Significance:

The concepts encountered in an environmental chemistry course are relevant to all individuals as we make choices in our daily lives that impact our natural surroundings. This fact alone can facilitate student learning. Laboratory exercises, however, are invaluable in solidifying scientific concepts that may seem abstract to the non-science major. A previous course in environmental chemistry at Davidson College has been offered as a lecture course, fulfilling a core requirement in the curriculum as a science without a lab. In addition to the primary text for the course, students have also been required to read supplementary texts which present the science in the greater societal context.[1-3] Although the content of the course

addresses the core areas of the science, and the supplementary texts provide material for lively classroom discussions and debates, there is clearly a disconnect between the concepts covered in the classroom and the problem solving skills obtained only through hands-on learning activities.

Attempts to bridge this gap have included water and soil analysis activities during the lecture period. Although these activities increase students' awareness of the practical aspects of environmental sampling and analysis, the time is insufficient to develop a true understanding of the scientific method in the context of addressing environmental pollution and remediation. The design and implementation of a laboratory course in environmental chemistry will "bring home" to students the challenges faced in obtaining representative samples, the complex nature of environmental matrices and pollutants, the variety of tools available to the chemist in analyzing environmental samples for contaminants and lastly, but perhaps most important, the processing, interpretation and reporting of results obtained.

This laboratory course would not only fulfill a core requirement in the curriculum at Davidson College as a science with a lab, but also provide a set of modules that can be easily adapted to any introductory chemistry course. It is also possible that with minor modification, these modules could be the foundation for case studies in advanced environmental chemistry, quantitative or instrumental analysis laboratories.

Detailed Project Plan

To meet the objectives of this proposal, the laboratory must provide exposure to environmental sampling methods, laboratory analysis techniques, data analysis and preparation of reports. To provide the context necessary to keep students interested in the process, the semester will be divided into modules. The module sequence will correlate with topic presentation in the classroom. In each module, students address issues specific to a region of the

environment while incorporating the sampling and laboratory techniques appropriate to that module. Using class discussion, students will determine the appropriate number and location of representative sampling sites. In each of the first three modules, students will be required to evaluate their results in the context of national regulatory values and average levels found in polluted versus non-polluted systems. Proposed innovative writing assignments at the completion of each module will necessitate that students gain more than a superficial understanding of the manipulations performed in the field and laboratory. Although the approach has been identified in each of the modules presented, methods, lab manuals and supplemental material must be written and/or optimized.

The Atmosphere. As the Charlotte region continues to grow in popularity, the quality of the air we breathe is a growing issue. Students will first address global warming by evaluating local levels of carbon dioxide using a simple impinger method and gravimetric analysis.[4] In the second experiment students will explore the issue of particulate matter and health effects. They will collect particulate matter on filters, and perform the appropriate calculations to determine atmospheric levels. Sampling of indoor versus differing outdoor sites will provide the opportunity for comparative analysis. Filters can be further extracted to evaluate the compositional fractions (acidic, basic, organic) of atmospheric particles. A final experiment in the atmospheric module will include the investigative analysis of acid deposition. Students will collect and analyze rain samples.[5] They will gain practical experience with the concepts of acidity and evaluate the impact of acid rain by exposing different materials to aqueous solutions of varying pH levels.[6] Upon completion of this module, students will be required to report their findings in the form of a newspaper article.

The Hydrosphere. The popularity of bottled water and increased recreational use of Lake Norman provides an easy hook for non-majors in the assessment of water quality. In the first experiment, students will explore the chemical composition of local water samples using wet chemical methods, such as colorimetric assays and titrimetric analyses. Students will additionally investigate the efficiency of a technological development in water softening using a cation exchange resin.[5] In the second experiment, students will use spectroscopic methods to quantitatively analyze the concentration of iron in natural water samples.[4] Students will have the responsibility of solution preparation and calibration in evaluating the results of this experiment. In the final experiment students will investigate the efficiency of water purification methods, reinforcing physical and chemical separation methods.[5] Upon completion of this module, students will be required to present their findings in the form of a report to the local governing body.

The Geosphere. The chemistry of soil is strongly tied to geology and soil quality is inherently connected to our ability to grow food. In the third module in the series, students will study the physical and chemical characteristics of soil. Students will be introduced to core sampling methods followed by soil sample preparation. Physical characteristics such as grain size and porosity will be evaluated. Following evaluation of physical characteristics, students will use prepared kits to analyze soil health for nitrogen, potassium, phosphorus, and pH as well as chemical analysis for water, calcium carbonate and organic composition.[7] The results of these studies will be submitted in the form of a report to the homeowner with recommendations to improve soil quality for its intended use (*i.e.* grass, garden, flower bed).

The Biosphere. Students are often familiar with the concept of toxic compounds and pollution concerns but not with the approaches involved in testing. In this module, students will be

introduced to measuring of toxicity using brine shrimp bioassays.[8] The growth of healthy brine shrimp colonies will require collaboration with the biology department animal care facility. In this experiment, students will determine LD_{50} values for a variety of household insecticides. They will then determine an appropriate remediation method for a contaminated site, perform the remediation in a laboratory simulation and repeat the assay to evaluate the success of remediation.

Energy. Given the steady increase in fuel costs, discussions of energy in terms of dwindling resources and atmospheric pollution are even timelier. To reinforce energy concepts in the laboratory, a three-part module will be introduced. In the first, students will explore electrochemical reactions and generation of electricity.[6] In the second, they will compare the energy content of fuels, reinforcing the chemical concept of heat capacity.[6] The final component takes advantage of our proximity to McGuire Nuclear Power Station and Marshall Steam Plant. The students will be divided into two groups to tour one facility or the other. The groups will then report to each other in the following class period. Upon completion of this module, students will be required to write an evaluative essay of current energy usage and future needs.

NSF Workshop. To become further acquainted with the teaching of environmental problems in the laboratory context, the applicant proposes attending the NSF Summer Workshop at Governors State University. This workshop entitled "New approaches and techniques for teaching science: addressing environmental problems to stimulate undergraduate learning" will provide information on using environmental problems to stimulate student interest, new theoretical and practical techniques to address environmental issues and assessment of learning outcomes. The workshop is centered around a hands-on environmental problem-solving

experience: Impacts of Biosolid Runoff on Microbial Community Ecology and Water Quality. The interdisciplinary nature of the experience will be most rewarding and likely stimulate new ideas for laboratory activities. The workshop is funded through the NSF, housing and meals are provided (transportation is not).

Prior Activities: The current Introduction to Environmental Chemistry lecture course has incorporated as much water and soil analysis as can be performed in classroom activities. These activities were admittedly very limited. However, the experience has provided much insight into what could be accomplished in a laboratory period, what is appropriate for a student at this level and the strong impact investigative approaches have on learning and retention for a non-science major. The impinger methods have been used in the applicant's research laboratory in independent study projects looking at local air quality. Additionally, the applicant has through past employment, graduate work, and current research projects, expertise in gas and particle phase collection and analysis.

Projected Timetable:

Dates	Activity
May 1 – May 22, 2006	Order and inventory necessary supplies.
May 29 – June 30, 2006	Applicant and student intern collaborate on initial testing of proposed experiments and drafting of laboratory procedures.
August 15 – December 15, 2006	Finalizing of laboratory procedures and reporting requirements by applicant. Course included in 2006-2007 course catalog
January 1 – May 1, 2007	Course offered. Implementation of laboratory modules. Ongoing assessment.
	Final assessment and reporting.

Requested Budget:

Laboratory Supplies				**$4100.00**
Module 1: The Atmosphere				*$1300.00*
Air Sampling Pump			$500.00	
Particulate Sampler			$400.00	
pH probes – also needed for Module 2	8	$50.00	$400.00	
Module 2: The Hydrosphere				*$2000.00*
Wet Chemical Analysis Kits			$300.00	
Ion Exchange Resin			$100.00	
Spectrophotometers or Colorimeters	2	$800.00	$1600.00	
Module 3: The Geosphere				*$300.00*
Soil Analysis Kits			$300.00	
Module 4: The Biosphere				*$200.00*
Brine Shrimp Bioassays Cysts, food, tank and aquarium pump			$100.00	
Insecticide, Remediation Supplies			$100.00	
Module 5: Energy				*$300.00*
Fuel Burners	8	$25.00	$200.00	
Voltmeters	8	$12.50	$100.00	
Personnel				**$6800**
Student Intern Stipend, FICA and Housing allowance Five weeks summer 2006			$2300	
Faculty Stipend - five weeks mentoring plus three weeks finalizing			$4500	
Travel				**$1300**
National Science Foundation Summer Workshop at Governors State University June 2006 Airfare and Ground Transportation			$250	
Student Intern presentation North Carolina Academy of Science Meeting Spring 2007 – East Carolina University			$300	
American Chemical Society National Meeting Fall 2007 – Boston, MA Airfare, Ground Transportation, Lodging, Food and Registration			$750	
Total Amount Requested				**$12,200.00**

Context of Course in the Curriculum and Impact on the Institution: All students are required to take a lab science as part of the core curriculum. Due to a lack of these types of courses across the natural science disciplines, the ceilings in these courses must always be raised. Typical course enrollment is 32. The department of chemistry at Davidson College currently offers two very successful courses with a laboratory for non-science majors (Chemistry in Society and Chemistry of Art and Artifacts). This would be an additional offering in this category. There are a number of student who are not science majors but are interested in environmental studies or environmental education. There is currently no lab course offered in this area in any department, hence this course fills a void not just in the departmental offerings but also in the overall curriculum. Ideally, in the future, the department will be able to offer two laboratory courses for the non-science major in the same semester to accommodate the needs of these students.

Evidence of Institutional Support: The laboratory course has already been approved by the Educational Policy Committee and has been entered into the course catalog for the next academic year.

EVALUATION, DISSEMINATION, and CONTINUED SUPPORT

Evaluation: Success in meeting project objectives will be evaluated using a number of methods. In the classroom, pre and post-assessments of chemical and environmental base knowledge as well as perception of current environmental issues will be administered. In the laboratory, students will be provided with case studies at the beginning and end of the semester for which

they will be asked to provide a critical analysis. The development and analysis of assessments will be performed in consultation with a colleague in the psychology department who specializes in statistical analysis of assessment. The Science and Math Values Inventory (SaM-VI) assessment will also be incorporated to provide standardized data.

Dissemination: The results of this project will be communicated in the following arenas: (1) on campus via a teaching group discussion, (2) poster prepared and presented during the Chemical Education section of the American Chemical Society Meeting in the Fall of 2007, (3) all materials will be made available to other institutions through the course website and (4) student intern presentation of general goals and first two modules of assessment analysis at North Carolina Academy of Science Meeting in the Spring of 2007. Opportunities to present the results of this project at ACS or other workshops will also be utilized.

Continued Support: In recognition of the value of hands-on activities, the department has already invested a significant amount of funds for materials needed to perform the limited in-class exercises done in the lecture course. These supplies include an air sampling pump, impingers, particle collector, and water and soil analysis kits. These materials can be used in the laboratory course. Once the initial materials for the course are purchased and the laboratory modules developed, the cost to maintain the laboratory will not be excessive. As the accompanying letter from Dr. Ruth Beeston attests, the department is committed to offering at least one lab course for non-majors per semester. The funding is already established to support this offering in that context.

LITERATURE CITED

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DISCLOSURE STATEMENT

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Cindy DeForest Hauser, "Heterogeneous Chemistry of Gas-Phase Oxidants and Organic Aerosols" *Petroleum Research Fund* for a Research Grant Type G, 2005-2007, $35,000.

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