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INTRODUCTION

Support is requested for development of a course to introduce freshmen and sophomores to research methods in an interdisciplinary science and selected juniors, seniors, and graduate students to teaching environmental science. The new course, “Exploring the Natural Environment: Methods in Environmental Science” (ENS 110), will fit into an established, successful, and growing Environmental Studies Program at Alfred University.

PROBLEMS TO BE ADDRESSED

1. *The vast majority of U.S. citizens, including college graduates, are not scientifically literate.* Steen (1991) illustrates the magnitude of this problem:

- only 6% of U.S. adults are scientifically literate
- only 17% of college graduates are scientifically literate
- only 10% of education graduates are scientifically literate

In an essay on the subject of scientific literacy, E-An Zen, president of the Geological Society of America, points out that today’s students are the future decision makers for our country:

> “We are obliged to cast wide nets to expose as many people as possible to the basics of scientific methods and knowledge, because we don’t know who will need this knowledge. In short, due to its pervasive role in modern society, science is far too important to be left to the scientists and to uninformed decision makers and opinion makers.” (Zen 1989:14).

In an increasingly technological society all citizens -- whether voters, policy-makers, health care providers, corporate officers, home managers -- are confronted with decisions about environmental management; they must possess basic scientific information needed to make these decisions wisely.

2. *College students’ interest in science is declining rapidly.* Interest of freshmen in science majors has dropped by half in the last 23 years; more than half of new college students intending to pursue science change their majors to a non-science discipline; interest in teaching and research careers has dropped even more severely (Green 1989). Dull, tedious hours of lecture and seemingly irrelevant laboratory exercises diminish interest among students interested in pursuing science as a career.

3. *Students need to learn how to do science.* Science is a process. It cannot be learned passively. Students must be active participants -- they must actually **do** science. Too often, science is taught as a series of facts and figures, as a “noun” rather than as a “verb.”

4. *Students need to realize that science is the integration of “practice” and “theory.”* College-level science courses are traditionally taught as segregated lectures and lab/field exercises. This leaves students with the perception that the active part of science is separate from the theoretical aspects when, in fact, the two are intimately associated.

5. *Most undergraduates do not appreciate the relevance of computers and mathematics in science.* Despite the relatively recent development of hand-held calculators which have basic programming and graphing capabilities, no longer are these devices adequate for scientific computations. Environmental science requires the interpretation of many diverse data, often requiring exhaustive syntheses or statistical testing. It is a disservice to produce graduates who are not computer-fluent.

6. *It is not commonly realized by undergraduates that the study of the natural environment requires application of all of the basic scientific disciplines (chemistry, biology, geology, physics).* Environmental science is truly an interdisciplinary science. In order to understand environmental problems, aspects of all of the traditional scientific disciplines must be applied. In fact, contemporary issues are typically approached by teams of professionals, each individual applying her own expertise to a multifaceted problem.

7. ***Specific Problems at AU to be addressed:***

a. ***There is presently no multi/interdisciplinary lab science course at AU.*** Students in the Environmental Studies Program at AU get laboratory experience in required courses in geology, biology, chemistry, and physics, but each lab course is specific to its own discipline. It is left to the student to make the "connections" among these subjects and to see the way that each discipline can be applied to solve environmental problems.

b. ***Most students at AU are not adequately prepared to initiate or complete required undergraduate research projects in the sciences.*** The Environmental Studies Program is the only scientific major at AU that *requires* an independent study by each senior; similar undergraduate research is strongly encouraged in other science majors. Students are usually not prepared to initiate their own research projects even though they have done well in their traditional science courses. For many, the most difficult part of the required project is the definition of an interesting question! Unfortunately, natural inquisitiveness and curiosity are often poorly developed in a typical science curriculum.

c. ***Advanced students in Environmental Studies and graduate students in education do not have a formal opportunity to teach.*** Without teaching responsibilities, our advanced students miss an opportunity to accelerate their own learning by teaching others. More importantly, they have no personal experience by which to evaluate the potential challenges and satisfaction of science education as a career option. Finally, students in our science education program may not have had a course in environmental science even though they will likely encounter some aspect of environmental science in any K-12 teaching assignment.

OBJECTIVES

The current proposal has several specific goals, all of which address the problems described above. These objectives, when realized, will affect *all* students taking the course, whether or not they major in a scientific discipline. There are also specific, additional objectives for science majors, and for students planning on pursuing careers in math/science education.

Objectives for all students taking the course

1. Provide students with an understanding of the nature and uncertainty of science: there are several rules and checks which make science the rigorous and reliable process of inquiry that it is, but it is still subject to human foibles and therefore is fallible.
2. Provide students with an understanding of the interrelationships among scientific disciplines: processes and techniques in one science are commonly applied to solving problems in another.
3. Allow students to experience the "fun" of science and encourage them to pursue scientific careers: why shouldn't students share at least for a short time some of the satisfaction that we professional scientists enjoy in our attempts to explain the world around us?
4. Provide students with an overview of the techniques and instruments used by environmental scientists: environmental science is much more than saving energy and recycling!
5. Provide students with a sound understanding of environmental processes: how do we know all those facts in our introductory textbooks?
6. Assess students in ways that encourage learning beyond simple accumulation of facts and that provide feedback on both student performance and course effectiveness.

Additional objectives for science majors

1. Introduce future scientists to the scientific process and the satisfaction of scientific investigation.

2. Provide a model which might be followed for approaches to research projects in subsequent courses.

3. Prepare ENS majors for their required undergraduate research project.

4. Give advanced students experience in teaching, especially in working with students one-on-one to encourage critical thinking.

Additional objectives for future teachers

1. Provide a meaningful training experience for students planning to become teachers while these students are still in training and can interact with their teacher-educators.

2. Introduce future teachers to exercises, approaches, instruments, and topics that may be useful in their profession.

3. Allow future science educators to work with other teachers who are trained as scientists.

PROCEDURE AND METHODS

Historical Perspective

One of the "bridges to the future" listed by AAAS (1989:11) in describing its Project 2061 is effective teaching of science which must be "consistent with the spirit and character of scientific inquiry...starting with questions about phenomena rather than answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations, ...; providing students with hands-on experience...; placing a premium on students' curiosity and creativity; and frequently using the student team approach to learning." Numerous recent reports list the problems of science education and their potential solution. For instance, Sigma Xi (1987, Harrison 1989, 1990) in several workshops supported by NSF links the public's welfare with its appreciation of science and technology and declares that undergraduate education is potentially "the most effective leverage point in improving the quality of education in science...at all levels." The National Science Foundation (Williams 1990) makes similar recommendations. The National Research Council has expressed special concern about how children learn "higher order skills" used by scientists (Resnick 1987). Steen (1991) vividly describes that even the very best schools are falling short in science education.

The problem is not due to lack of methods for effective teaching. Teaching of critical thinking has developed from being a philosophical cause to an almost mechanistic if not commonly applied approach to teaching at all levels (e.g. Pinet 1989, 1990; Paul et al.. 1989; Tyser and Cerbin 1991; see excellent review by Kurfiss 1988). This is apparently in response to the realization that little (if any) time in traditional science curricula is actually spent on helping students learn *how to learn;* the emphasis in traditional courses is on content, not process (Johnston and Aldridge 1984).

Recommendations for "learning-by-doing" are becoming more frequent in virtually all scientific disciplines (e.g. Dunkhase and Penick 1990; Miller and Cheetham 1990; Uno 1990; Laws 1991; see review by Bonwell and Eison 1991), yet it has been recognized that "traditional" laboratory exercises in introductory science courses are "more proficient at turning-off and eliminating students than attracting them to the disciplines" (LaSalle 1989). A good laboratory program can arouse curiosity in students; a poor laboratory program serves only to squelch their interest, sometimes permanently (Brown and Lawson 1990). Strategies that give students the opportunity (and responsibility) to actively participate in a scientific process are being shared more widely by teachers and are variously referred to as "problem-solving" (e.g. Gabel 1989 and papers therein), "guided design" (Wales and Stager 1978), and other names.

Group learning is also rapidly gaining both advocates and adherents (Newell 1990; Johnson et al.. 1991). The pedagogic advantages of peer teaching far outweigh the logistic challenges (Whitman 1988). We have seen many times that active learning, greatly preferred by students over a traditional lecture approach, is nicely facilitated by team projects and group assignments. Joubert's observation (Whitman 1988:1) that "to teach is to learn twice" aptly summarizes the benefits to mentors and future teachers who will help us in our new course.

Finally, there has been concern recently that the teaching of science has become "compartmentalized" into seemingly unconnected disciplines. Emiliani (1991) advocates what he calls a "holistic" approach to teaching science, which illustrates the interconnectedness between the scientific disciplines and mathematics. Centering a course around the planet Earth (or some aspect of earth systems) is an ideal way of teaching holistic science, and has been suggested by Emiliani and others (Emiliani 1989; Mayer et al.. 1992; Metzger 1992).

Course Philosophy

"Environmental Studies 110: Exploring the Natural Environment" will introduce freshmen and sophomores (both science majors and non-majors) to a wide variety of techniques used in several disciplines to monitor environmental conditions. Integrated, these methods comprise the activities of the ever-increasing numbers of professional environmental scientists. Students will learn techniques used to detect and assess environmental damage and to assure compliance with environmental regulations. Ultimately, they will gain a better understanding of the natural environment and how the environment is studied by scientists. We do not expect or even intend that students will master the methods taught in this course. Rather, we will emphasize basic steps of scientific research: formulation of hypotheses, experimental design, determination of sampling protocol, collection and analysis of data, and presentation of results. Most importantly, students will learn why environmental scientists must employ techniques from several disciplines and that effective and efficient environmental analysis usually requires an integrated team-effort.

ENS 110 will be a truly interdisciplinary course. Aspects of the atmosphere, lithosphere, hydrosphere, and biosphere will be studied using an approach which integrates lecture, discussion, field and lab work. The class will be taught by two of the principle investigators, a geologist and a biologist. "Active" learning will be emphasized, and lectures will be kept to a minimum. Group projects will be the focus of all class work. We are particularly dedicated to maximizing field experiences throughout the course. Unlike traditional laboratory science courses, there will not be separate time slots for the "lecture" portion and the lab/field portions of the class; instead, explanations/discussions will be fully integrated with the active-learning process. We intend for the course to restore the sheer enjoyment of discovery for our students. By investigating contemporary environmental concerns such as the need for clean water, clean air, and natural resources, students will find the new course personally relevant regardless of their science background or intended major.

Although our new course is an introductory one, it has a prerequisite of Environmental Studies I: Natural Science (ENS 101; see Appendix IV), a class which presents basic ecological principles and interactions of physical, chemical, and biological forces. We see ENS 101 and ENS 110 as a logical freshman-year sequence, providing all students with relevant experience in seeing how science is accomplished and what has been learned by it. Additionally, our majors will get a solid foundation particularly in environmental science. Both courses are designed to build on the basic science background of our students, yet neither course assumes that that background is particularly strong.

We want to bring freshmen and sophomores to the realization that science, mathematics, and computers are interdependent. Our students will collect data and then be faced with the challenge of interpretation. Computers will be used for arithmetic manipulations as well as for displaying information in meaningful ways (maps, graphs, charts, etc.). While we will not be teaching students to write computer programs, we will be providing them with general tools to solve specific problems. Students will become familiar with a variety of software, including that for word processing, graphing, and data manipulation. Rather than develop our own programs, we prefer to show our students commercial software which has applications outside of class and as they pursue careers in environmental science. We anticipate that after becoming proficient with a spreadsheet program, for example, they will apply this tool in other classes or research projects for data manipulation. We intend to give our students a familiarity and confidence with computers in which the machines are perceived neither as either toys nor intimidating obstacles but just as powerful tools to help get a job done.

Role of teaching assistants

Engaging a classroom of 30-40 students in practical laboratory and field-based activities during every class session will require a high teacher:student ratio and a great deal of logistical support. Even though both Hluchy and Godshalk will be present at every class, assistants will be required, particularly during the first years while the curriculum is being developed. Teaching assistants will provide us with that help, but they will also serve another function. While accessibility to faculty has never been a problem at AU because of a high faculty:student ratio, we recognize that students, particularly freshmen, are sometimes hesitant about approaching faculty with what they feel are “silly” questions. The graduate assistants and especially the undergraduate mentors as “near-peers” will undoubtedly be viewed as more approachable to these students, and therefore they will encourage greater student involvement. In this capacity, the mentors will be able to continuously provide us with feedback from students and thus assist us with course development.

We are not concerned only with students who are enrolled in the new course. Another of our main objectives is to teach advanced students how to teach. We will show our junior and senior mentors how to ask questions that encourage thinking and self-reliance, how to encourage and support their students without doing the work for them, how to anticipate all the questions that might be asked of them, and how to handle the questions that are actually asked and for which they have no answers. We will show our graduate assistants how to prepare for classes, labs, and field trips, how to implement and evaluate new class activities, how to structure exercises that stimulate active learning, and how to assess student performance in ways that encourage learning beyond factual knowledge (cf. Kurfiss 1988:51). Thus, we will be teaching environmental science and *how to teach* environmental science at the same time.

Course Logistics

The class will meet for 4 hours per week in two 2-hour blocks of time. It will be taught every spring semester. We expect enrollments of 30-40 students. We will participate in every class meeting, each leading the activities relating to our own areas of expertise. A graduate assistant and two undergraduate “mentors” will facilitate one-on-one instruction.

Class Projects

We approach this course as a series of projects requiring students to explore humans’ impacts on natural environments (see syllabus in Appendix I). Lecture and discussion will help students reach consensus on research questions of particular interest to them. Then, we will describe field and lab methods by which they might pursue answers to their questions. Three projects will be performed during the semester, one each exploring humans’ interactions with the atmosphere, lithosphere, and hydrosphere. To keep the course fresh for students and mentors (and faculty) we will vary the projects from year to year, especially as local issues develop. We firmly believe that the content of each project, and of all projects together, is not nearly so important as the opportunity for students to design their own work. Hence, it is not a shortcoming that there is insufficient time in any one semester to cover more environments, impacts, or methods.

In each of the projects, the class, either as a whole or in small, independent groups, will receive its assignment in the form of a scenario in which the group is to play a primary research role. The emphasis of each role is on solving a specific problem. Projects will increasingly require students to define questions and devise experimental designs before they can collect data to provide answers. In various combinations of individual and team work, each student will perform all of the following tasks in each project:

1. *Define an appropriate research question*, and, in writing, justify why it is relevant and reasonable to pursue this question as part of the overall project.

2. *State the research question as a testable hypothesis*.

3. *Devise and propose an experiment* (manipulation or monitoring) that will provide data by which to validate or reject the hypothesis; this proposal must describe control and experimental units, how confounding factors will be considered, underlying assumptions, predicted outcomes, and how results will be used to evaluate the hypothesis.

4. *Plan a sampling protocol* that fits within a real or hypothetical budget of time and money.

5. *Implement the experiment* using appropriate field and laboratory techniques. (If the proper experiment calls for sampling over a longer period of time than is available, "synthetic" results will be provided by the instructors to augment those data actually collected by the student; any such data contributed by us will be of exactly the same type (i.e. parameters measured, frequency, reliability, etc.) as would have been collected by the student so she can work with the consequences of her own planning).

6. *Analyze and interpret results* using our computers to perform simple statistical tests and make tables and graphs. (Most of our students will not have had a statistics course yet and it is beyond the scope of our new course to actually teach statistics, but we will continue what we have been able to do in our other courses to help students apply t-tests and correlation analysis meaningfully without extensive preparation.)

7. *Determine the fate of the hypothesis*, justify the reliability of the conclusion, and extrapolate the significance of the results by applying them to some more general environmental issue.

8. *Report results* orally or in writing. Reports will take various forms and may be individually written documents, a series of recommendations to solve a particular problem, or parts integrated by the class into a larger overall report.

We will rely heavily on group efforts so that students have the benefit of each others' ideas. For instance, all experimental designs will be critiqued informally in each student's working group and then formally in a peer-review process. Mentors will be put in the role of skeptical clients who must be convinced their money is being spent efficiently. But, while group work is encouraged and facilitated in all aspects of the course (especially in field and lab), ultimately each member of the class will be responsible for her own accomplishment and understanding of all of the tasks listed above.

Grading

Students will be required to submit a report on each of the projects conducted during the course. Assessment by this means encourages creativity and gives students greater flexibility in demonstrating their accomplishment. Reports may be done individually or by groups depending on our specific assignment; grades will be awarded appropriately (i.e. individually or uniformly for all group members). Reports will earn points based on students' accomplishment in each of five categories: introduction, methods, results, discussion, and overall presentation. Final grades will be determined based on accumulated points in comparison to an absolute scale. This grading scheme will eliminate competition among students and encourage cooperative learning.

Graduate Teaching Assistant

The teaching assistant for this class will be a graduate student in math/science education and will be selected by us and the faculty in Education on the basis of qualifications and interest. The duties of the graduate assistant will include:

1. *Assist with preparation for class:* set up/organize experiments/activities, order supplies, prepare handouts, etc.

2. *Participation in class:* answer questions, lead small working groups in activities/discussion, help with demonstrations/activities, assist with grading reports, critique oral presentations, etc.

3. *Lead the class:* the graduate student will lead the class in one or more of the scheduled activities, or perhaps add a new activity to the curriculum.

4. *Provide extra-curricular tutoring or assistance to students.*

5. *Supervise undergraduate assistants* (see below).

This combination of duties will provide valuable experience to future educators in common aspects of their future profession and will give the graduate student a sense of what types of activities and approaches are successful, both in the classroom and in one-on-one situations.

Undergraduate Student Mentors

Upper-level (junior or senior) undergraduates majoring in science or mathematics will be chosen to participate as peer mentors in the new course. These students will be selected on the basis of background in science and interest in teaching; students who have previously taken the course will be preferred. These students will help set up equipment before class, participate in all activities during class time by answering questions and helping with the exercises, and perform routine maintenance of field equipment. They will also be available at other times, perhaps one or two evenings per week, to help individuals or groups of students in a less formal setting. In addition to the obvious benefits they provide to their students, mentors will gain from this experience by strengthening their own understanding of the scientific concepts covered in the course, acquiring specific teaching skills, and building confidence and satisfaction. We hope they leave this experience wanting to do more teaching.

All teaching assistants involved with this course, as well as those students in education programs who are taking the course, will be encouraged to form peer groups, perhaps as a part of the "fifth hour" (see below) to discuss methods and content. Again, our intent is to expose these "future educators" to many aspects of the teaching profession, even if only briefly. Continuous assessment of students and of the course will be an important task of the peer group.

Course Detail

We will assign three general research topics. In their discussions with us, class members will determine exactly what aspects of these topics will make up their research projects.

Project 1

Title: Measurement of Atmospheric Ozone

Scenario: **"**You have agreed to take part in a nationwide ozone-monitoring network, coordinated by a private research organization, to delineate changes in the amount of ozone in the atmosphere overlying the North American continent."

Systems to be studied: The atmosphere above Alfred, New York, and the continent as a whole.

Some research questions that the class may ask: What is ozone? How is it formed? How is it destroyed? How is it measured and to what sensitivity? Where is the best place to situate the instrument which will measure the ozone? What are "normal" concentrations of ozone? Can we expect to see a change in ozone concentrations on a short time-scale (i.e. one semester)? What constitutes a significant change in concentration? How do we expect the ozone concentration to vary with time and location? How often should we take our measurements?

Probable techniques used and data collected: The total amount of ozone (total column ozone) in the atmosphere will be determined by measuring the intensity of solar radiation at two different wavelengths; ozone absorbs light strongly at one of these wavelengths and weakly at the second nearby wavelength. The amount of ozone is determined from the ratio of absorbances at these wavelengths. Measurements will be taken throughout the semester. Digitized base maps will be made of all monitoring stations with whom we are cooperating (see "General description" below). Data will be contoured and mapped.

Ancillary benefits: Students will be introduced to large-scale monitoring projects and data sharing via computer networks.

General description: The "scenario" for this exercise is not contrived. During the spring of 1992, AU was invited to join an ozone-monitoring network consisting of 150-200 stations located at colleges, universities, and secondary schools throughout North America (see Appendix II). The invitation came from the Technical Education Research Centers (TERC), a non-profit educational research and development group dedicated to improving mathematics and science education at all levels. One of TERC's strategies to improve science learning is to involve students in collaborative research projects. Students will regularly monitor and report ozone values, sharing the data with other stations via computer networks. Short- and long-term variations in ozone will be observed and interpreted. Since this will be our first project in the course, we will provide extensive guidance both to assure success in students' initial efforts and to assure compatibility of our data with those from other stations in the network. The ozone project will be conducted over the entire semester; students will work in small groups and report their findings individually in writing at the end of the course.

Project 2

Title: Geologic Materials and their Properties

Scenario: "You have been contracted to do a reconnaissance study to determine the feasibility of building a new cluster of residence buildings on Pine Hill, just east of the campus".

Systems to be studied: A plot of land on a steep hillside.

Some research questions that the class may ask: What is the depth to bedrock? What is the nature of this bedrock? What is the nature of the unconsolidated material atop the bedrock? What are the physical characteristics of this material: strength, permeability, porosity, grain size distribution, etc.? What is the slope of the land? How prone is this hillside to erosion with and without vegetative cover? Are buildings likely to slip? Will basements be dry? How much soil moisture is present and what is its composition? What is the depth to groundwater? What is the local groundwater flow system like?

Probable techniques used and data collected: grain size characterization using sieve analyses; in situ and laboratory permeability determination; soil augering and boring; determination of angle of repose of unconsolidated material; construction of detailed topographic contour map; collection and analysis of soil moisture; collection and analysis of groundwater; modeling of groundwater flow.

Ancillary benefits: Several construction projects on campus may give our class the opportunity to observe professional consultants using the same techniques that the students are applying. We will seek to compare results whenever possible.

General description: The class will be told that their "bid" has been accepted for the performance of a geotechnical study of the area in question. Students will be given a fixed sum of money to spend (the amount of their imaginary bid); the actual costs of each test, analysis, procedure, etc. will be provided and they will determine how the funds are to be allocated. Students will be introduced to a variety of techniques used by environmental engineers. Students will work and report in groups of 3-4.

Project 3

Title: Biogeochemistry of Canacadea Creek

Scenario: "The U.S. Army Corps of Engineers has hired your consulting firm to determine the quality of water in Canacadea Creek, the major tributary to Almond Reservoir, and what effects the creek may have on the reservoir."

Systems to be studied: A small stream running though campus that drains an easily eroded basin and is significantly influenced by agriculture and our town's wastewater treatment plant; a flood-control reservoir.

Some research questions that the class may ask: What suspended and dissolved materials does the stream transport? How does concentration vary with discharge? How is loading affected by storm events? What is the annual load? How rapidly are deposited sediments depleting reservoir capacity? What organisms are in the stream? Is the stream heterotrophic or autotrophic? Does the stream export organic matter to the reservoir? How do pastures (or the Alfred wastewater treatment plant) affect the stream (BOD, coliforms, etc.)? What is the trophic status of the reservoir? Does the algal community indicate eutrophication? What is the limiting nutrient of the reservoir?

Probable techniques used and data collected: Measurement of stream cross-section and velocity, computation of discharge; analysis of storm and annual hydrographs; development and application of discharge rating curves; field measurement of dissolved oxygen, conductivity, and pH; lab measurement of suspended solids (gravimetrically) and dissolved nitrogen and phosphorus (colorimetrically); determination of 5-day BOD; enumeration of coliform bacteria; investigation of benthic invertebrates with Hester-Dendy samplers, artificial leaf-packs, in situ sampling, drift nets, etc.; determination of lake trophic index; algal bioassay (simplified EPA "algal assay procedure") to determine limiting nutrients; measurement of stream oxygen flux.

Ancillary benefits: In this project which occurs late in the semester, the scenario is initially left quite vague to give the class greater latitude and challenge in defining the important questions to be addressed. This project also requires that the class members work together to develop an integrated project that initially determines and ultimately integrates their individual efforts.

General description: The class (or independent large groups within the class) will be told that they have been hired to give advice about water quality. Their client is naive, so not only are they expected to come up with the correct answers, they must also determine the appropriate questions! After field and lab work, brief periods of subsequent class meetings will be devoted to preparation of the overall report which will be presented orally, each student describing his own contribution to the group effort.

Faculty Expertise

The two of us (Hluchy and Godshalk) who will actually be teaching ENS 110 have experience team-teaching other interdisciplinary courses. Each of us has taught introductory laboratory courses as well as courses on research methods in our own disciplines. During the spring semester of 1992, we jointly offered a new course entitled "Computing in the Natural Sciences" designed to familiarize science majors with problem-solving techniques using personal computers, and we will present a paper about this course at a conference on Problem Solving Across the Curriculum in June, 1992. Both principal investigators will participate in an NSF-sponsored Undergraduate Faculty Enhancement Program on Water Resources during the summer of 1992 at the U.S. Geological Survey Training Center in Denver. Collectively, we supervise over half of the required independent studies performed by seniors in Environmental Studies, and our students have presented their work at the annual Eastern Colleges Science Conference, an annual meeting of undergraduate researchers in the Northeast.

The teacher-educator among us (Curl) will frequently visit the course to provide the same critique that he provides to students in the education program at AU. He will interact with development of presentations and assessment, and participate in our summer reviews during refinement of the course. He will also lead in our efforts to recruit and select graduate teaching assistants, and provide guidance and critique to that assistant and our undergraduate mentors.

Michele Hluchy

Michele Hluchy is a geologist whose research expertise is in the fields of clay mineralogy and low-temperature geochemistry. She has participated in an interdisciplinary research project to study effects of acid precipitation on lake-watersheds in the Adirondack Mountains, and she has recently been invited to participate in a similar project in Czechoslovakia. Hluchy's teaching duties include courses in hydrogeology, x-ray techniques, sedimentology, geomorphology, and environmental geology, as well as the previously mentioned interdisciplinary courses. Hluchy has had a continuing interest in undergraduate science education stemming from her own undergraduate research experiences. She has attended workshops on teaching critical thinking, has presented papers dealing with the teaching of laboratory techniques to undergraduates, is a member of the National Association of Geology Teachers and the Council on Undergraduate Research, and serves on the Continuing Education Committee of the Clay Minerals Society. Within the college, Hluchy serves on the Curriculum and Teaching Committee and on an ad hoc committee to develop a Math and Science Teaching Institute. Hluchy recently received a grant from the NSF's Instrumentation and Laboratory Improvement (ILI) Program for the purchase of laboratory equipment for use by undergraduates, and she also served on the ILI proposal review panel for 1992.

Gordon L. Godshalk

Gordon L. Godshalk is a limnologist concerned primarily with effective science teaching. He directs the growing Environmental Studies Program (see Appendix IV) at Alfred University and teaches general ecology, aquatic ecology, introductory environmental science (ENS 101, with Hluchy), environmental problem solving (ENS 211), environmental issues (ENS 300), environmental studies seminar (ENS 400), preparation for environmental research (ENS 440), several independent studies (ENS 450), and (with Hluchy) a general course on computing in natural sciences which will be taught concurrently with the new course described in this proposal. He serves on ad hoc committees proposing curricular changes in the College of Liberal Arts and Sciences and creating an Institute for Math and Science Education. He has participated in several workshops on teaching critical thinking and national conferences exploring ways to improve undergraduate curricula. He has presented papers on specific techniques used in his classes and is the chair-elect of the Education Section of the Ecological Society of America. His research interests center on aquatic decomposition and the fate of organic matter in lakes, streams, and wetlands. His published articles come from both basic and applied research, and he is writing a textbook.

James F. Curl

James Curl is a teacher-educator and counselor-educator. He is particularly interested in human development and the teaching-learning process (i.e. the person as a learner and the learner as a person). Curl teaches educational psychology and graduate courses in human development and the teaching-learning process. He supervises practice teachers in secondary schools. In addition to being Chair of the Education Division at AU, Curl serves as co-chair of the ad hoc committee that is developing AU's Institute for Math and Science Education. Curl has published on the topic of teacher effectiveness, and he directed an E.E.S.A. Title II funded institute in the teaching of math, science, and foreign languages in the elementary school (A.C.T.I.O.N.).

TIME-TABLE FOR THE PROJECT

Full development of this course will take three years. It will take a couple of semesters's experience teaching the course to fine-tune how much work we can expect from young students who may really be doing science for the first time -- our experience has shown that initially this is a very slow process. We also want to build a positive reputation for the course and demonstrate increasing enrollments to give credibility to our proposals that this approach be considered a model for other science courses. Our plan for course development is as follows:

Year 1

Spring semester: Teach ENS 110 for the first time.

Summer: Spend one month doing self-evaluation of the course, bring in an outside evaluator (see Appendix VII), and revise course material, exercises, etc. as necessary. We will try different procedures, look for better field sites, and so on, as suggested by our initial successes and failures.

Year 2

Fall semester: Propose to the Environmental Studies coordinating committee that ENS 110 be required of all students majoring in the program.

Spring semester: Teach ENS 110 for the second time, incorporating revisions and suggestions from evaluator.

Summer: Plan for incorporation of "fifth hour for future educators" into the course.

Year 3

Fall semester: Propose to the College Curriculum and Teaching Committee that ENS 110 be allowed to satisfy the general education requirement for a "laboratory science course."

Spring semester: Teach ENS 110 with the "fifth hour for future educators" (see below) added.

Summer: Self-evaluation as well as evaluation from outside "expert" on course as a whole. Formulation of ideas for change/ possible expansion of the course.

INTEGRATION INTO THE UNIVERSITY'S ACADEMIC PROGRAMS

Description of Alfred University and programs affected by the new course

Alfred University is a private institution with an enrollment of about 2000 undergraduate students. Founded in 1836, it was the first private university in New York to admit both men and women. The University consists of five colleges and schools: Liberal Arts and Sciences, Business, Professional Studies, Engineering, and Art and Design. Ceramic Engineering and Art and Design are schools of the New York State College of Ceramics, a contracted unit of the State University of New York which AU has managed since 1909. The cornerstone of the university is a commitment to academic excellence. *U.S. News and World Report* recently recognized this commitment by ranking AU *first* among institutions of a similar nature located in New York and second among institutions of a similar nature located in the northern United States. The average combined SAT score for incoming freshmen in 1991 was 1120. AU considers excellence in teaching to be of primary importance, and projects such as the one being proposed are strongly supported by our faculty colleagues and administrators (see Appendix III).

AU has broad "general education requirements" for all students, especially those in the College of Liberal Arts and Sciences which includes the Environmental Studies Program. Two 4-hour science courses are required, one of which must have a laboratory component. Courses that satisfy the science requirement are said to be "F-category" courses, after its place in the listing of all requirements. ENS 101, prerequisite to our new course, is the only extant F-category course offered by Environmental Studies.

The Environmental Studies (ENS) Program at AU has been in existence since 1971, offering a B.A. degree with an emphasis in either natural or social sciences. Common core courses, diverse electives, and an independent research project are required of all ENS majors. This multidisciplinary major takes a broad and comprehensive approach to environmental problems. Enrollment in the Environmental Studies Program has been increasing over the past several years (see Appendix IV). While we have no specific data to verify it, we suspect that this increase reflects overall environmental awareness of incoming freshmen and also the consequence of greater administrative support for the program in terms of faculty assignments, course development, and minor equipment needs. Two-thirds of our majors have an emphasis in natural science, one-third in social science. We strongly encourage our students to get a second major in a "traditional" discipline to add specialty to their education; an increasing proportion of them do this (currently 25 percent), mostly in Geology and Biology. About one-third of our seniors go immediately to graduate school, more within a few years; this proportion is also increasing.

The Geology (GEO) Program at AU is closely related to ENS (and this project) in terms of faculty commitment, student involvement, and subject matter. We expect that many students in the proposed new course, ENS 110, will be either GEO/ENS double majors, or just geology majors. Like the Environmental Studies Program, the geology program at AU has experienced an increase in enrollment over the past few years (see Appendix V). Many of the students taking geology classes have expressed interest in environmental careers. Approximately 60 percent of the current geology majors at AU plan to attend graduate school, and about one-half of the current geology majors plan to pursue elementary or secondary school teaching as a career. In fact, two-thirds of the geology majors in the next two graduating classes will receive a dual major, with the second major being either ENS or Education. Finally, we anticipate that 38 percent of our B.A. degrees in geology at AU in the next two years will be awarded to women, a percentage which is well above the 1991 national average of 28 percent of bachelor's degrees in geology being awarded to women (Suiter 1992).

Integration into the Environmental Studies Program

The new course (ENS 110) will be a sequel to our introductory environmental science course (ENS 101) which does not involve field or laboratory experience. Enrollment in ENS 101 now exceeds 70 students each fall semester, making it one of the larger classes on campus. The diverse mixture of students from all majors in ENS 101 assures that we have stimulating interactions and discussions; we want to maintain this diversity in the new course. Nearly half of the students completing ENS 101 go on to take other ENS courses which satisfy no requirements outside of the ENS major, so we believe that we already have an audience for a new course that provides students from all disciplines with a new lab/field opportunity and exposure to *doing* science. We plan to teach the course once before proposing to the ENS coordinating committee that ENS 110 be made a requirement for all ENS majors.

Integration into the College curriculum

After the second year of offering ENS 110, we intend to propose that the course be classified as an "F-category" course which will allow students in all majors to use it to satisfy their general education requirement for a laboratory science course. The college is working to improve its curriculum to enhance critical thinking and participatory learning; our course will help this effort in several ways. At least initially, it will be the only course available to non-science majors that emphasizes science as a process and lets students experience *how* it is done. We expect the course to be successful enough to entice and encourage our colleagues to modify other introductory science courses with similar goals, priorities, and approaches. Long-term development of our new course *may* lead to a one-year sequence offering a broader view of experimental science as taught by a team of biologists, chemists, geologists, and physicists; such a course might become the only way to satisfy a general education requirement in science!

Integration into Institute for Math and Science Education

AU is currently developing an Institute for Math and Science Education. The goal for this center is to integrate the education curriculum with the math and science curricula at both undergraduate and graduate levels. Our new course, ENS 110, will provide an ideal environment for graduate students in math/science education to learn and practice interacting with students by lecturing, leading discussions, tutoring one-on-one, planning and participating in experiments, etc. At the same time our assistant will provide help necessary to make the class one where "learning-by-doing" is a reality. During the third year of the course, we plan to add an optional fifth hour of class time (one extra hour per week) for students planning to go into education, particularly science/math education, but also elementary education. During this weekly "fifth hour for future educators," we plan to discuss ways in which the concepts covered in the course that week can be taught to students at other levels, e.g. experiments and exercises which can be done in elementary or secondary science classes; techniques which can be used by younger, less experienced students; opportunities and challenges when more or less equipment is available; etc. In other words, the extra class hour will be used to teach interested students how to teach to others what they have just learned. Learning how to learn will be enormously valuable to our assistants. We want these students to learn about science and science education *concurrently*. When we demonstrate that this approach is successful, we will suggest that the "fifth hour for future teachers" may be added to other science and mathematics courses at the University as a part of the new Institute for Math and Science Education. (In fact, a similar experiment will be performed by the astronomy program at AU during the fall semester of 1992, when a separate section of Introductory Astronomy Lab will be offered for education majors. This laboratory section will also allow students to learn the science and teaching methods concurrently.)

FACILITIES AVAILABLE FOR THE PROJECT

The Environmental Studies Program is housed in AU's Science Center. This building has adequate space and laboratory facilities for the successful completion of the project. We have specialized laboratories for basic water analyses, sedimentological studies, and basic geochemistry. With the exception of the equipment requested in this proposal, we have the facilities and apparatus to adequately complete this project (Appendix VI).

IMPACT OF THE PROJECT

Innovations

Several aspects of this course are exciting to us because they are not common in traditional college science curricula and are new to AU's science programs. Our experience and consultation with others in science and education convinces us that the following features of the course will substantially improve our students' understanding and appreciation of science:

1. *Lecture and lab/field work (i.e. "theory" and "practice") are integrated.* This will serve to cement the relationship between concepts learned in "lecture" and the application of those concepts in research activities. Students will realize that this is how scientists really work, by integrating (not isolating) theory and experimentation. A practical advantage to this approach, from the students' point of view, is that they will be given full academic credit for time spent in a combined lab/lecture class, rather than the traditional, less satisfactory, formula of one hour of credit for every two hours spent in the laboratory, thus avoiding a common complaint from students and faculty alike (Brown and Lawson 1990).

2. *Activities are relevant, "real world" problems, rather than "canned" experiments.* Students will pursue projects which are most interesting to them. They will learn practical skills that they can use in future research projects or job situations.

3. *Students will use an investigative approach to solve open-ended problems.* Neither students nor faculty will know what the results of each exercise will be until it is actually completed!

4. *Interdisciplinary approach is required.* Rarely do experiential courses incorporate aspects of biology, chemistry, geology, mathematics, physics, and computer science.

5. *Mathematics and computers are routinely applied to scientific problems.* Students will not just be told the importance of math and computers to science; rather they will come to that realization themselves, as they face the problems of data acquisition, manipulation, and interpretation firsthand!

6. *Students will work on activities in groups.* A "team" approach to learning and doing science is realistic.

7. *Presentation of results is as important as their acquisition.* Written and oral communication is stressed.

Impacts on Students

Of course, we plan and expect our major impact to be directly on the students who take our course. We have designed this course with several specific objectives in mind (see earlier section), and discussion of the impact of this project on our students and the community can therefore be best summarized as the achievement of our goals as described below:

Students will:

- learn science as a *process* rather than an accumulation of facts
- work in groups, participating actively in their own education
- learn to think and analyze critically
- rediscover that science is fun
- integrate science, mathematics, and computers, to actually *do* science

Impacts on the Environmental Studies Program at AU

This project will also affect the Environmental Studies Program in a variety of ways, providing students in that program with:

- a stronger introduction to environmental science
- a survey of methods used in scientific approaches to solving environmental problems
- better analytical skills and greater confidence so that they will do better in upper-level science courses
- a stronger background with which to approach their required senior projects

Impacts on the Institute for Math and Science Education at AU

ENS 110 will serve as a "starting point" for courses in math/science education at Alfred. We envision the course as providing the following to that program:

- a model for other courses integrating content and teaching methods in specific scientific disciplines
- increased diversity and extent of contact of future teachers with practicing scientists

Impacts on AU as a whole

In addition to the direct benefits for students who take our course, ENS 110 will have other positive effects on AU's curriculum. We feel strongly that science courses should be taught differently than most are taught now. ENS 110 will serve as an example of what can be done to emphasize scientific process over facts, learning by doing, and taking advantage of student mentors to maintain one-on-one instruction even in large introductory classes. Furthermore, we plan to use ENS 110 as a model in the developing Institute for Math and Science Education where emphasis will be on getting future teachers into classes to gain experience and confidence under direct supervision of experienced teachers in specific scientific disciplines.

Impacts on wider community of scientists and educators

Finally, we believe that there is great potential for this project to serve as a model to our colleagues at other schools of what can be accomplished with interdisciplinary courses which integrate theory and practice, improving the quality of science education as well as increasing students' interest in the subject.

BUDGET JUSTIFICATION

Personnel Time

In order to teach environmental research methods to 30-40 students in the manner described in this proposal, we need the aid of a graduate teaching assistant and two undergraduate "mentors". Salaries/stipends for these assistants are requested for the duration of the project. One month of summer salary is also requested for the principal investigators during the first year at which time we will evaluate and revise the course.

Release Time for Michele Hluchy

Hluchy participates in the interdisciplinary Environmental Studies Program in a variety of ways, but she is a full-time member of the geology department at AU. Hluchy's involvement in ENS 110 will divert some of her time and energy from a growing geology program and leave the geology curriculum understaffed. Release-time compensation is requested so that the geology department can hire a graduate teaching assistant under her supervision to teach three credit-hours of introductory laboratories that Hluchy would otherwise teach herself. (This will also benefit the math/science education program because the teaching assistant will come from that program and thus provide one of the graduate students in that program with teaching experience in science.)

Permanent Equipment

Computers make up the bulk of the permanent equipment requested. The routine use and importance of computers in this project has been described previously. Computers are needed because the only IBM-compatibles available to our students are networked in a general-use lab where we cannot configure them with peripherals and software to meet our specific needs. Consistently heavy use of the lab has resulted in a formal policy that prevents us from scheduling a course in it. Macintosh computers are even less accessible to students on our campus. It is important to expose students to both Macintosh and DOS-based machines because they will surely encounter opportunities to use both systems later in graduate schools and careers. Both types of computers are compatible with our LCD computer projection panel (Chisholm Looking Glass ™) so that instructors and students can demonstrate their computer work to the entire class.

Related equipment includes color video monitors for the computers when they are used in the classroom. We will purchase a Hewlett-Packard PaintJet XL300 printer (also compatible with both Macintosh and DOS computers) which will provide high-quality, large-sized color output of maps and graphs and. Finally, a CD ROM is requested so that students can access information pertinent to their class projects from the several geographic, hydrologic, and environmental databases available on CD.

Most of the laboratory and field instruments needed for the class are already in hand (see Appendix VI), but we still require field and laboratory permeameters (for permeability measurements on geologic materials). We plan to purchase a Combination Permeameter and Guelph Permeameter (Soiltest Inc.) with requested funds.

Travel

Travel Costs for Class Activities

We are requesting nominal funding for transportation costs for students to and from field areas where some activities will take place.

Travel Costs for PI's

We anticipate that the principal investigators (and therefore the class) will benefit from the opportunity to travel to meetings or short courses at which topics relevant to the project will be discussed. Examples might include short courses on critical thinking and/or problem solving, and workshops or symposia on science education. We anticipate that we will be presenting the results of this project at such forums so that our colleagues at other institutions can gain from our experience. We would also like to allow for the opportunity for us to travel to/from other institutions or laboratories to get ideas for new or improved class activities and to share ideas and help initiate similar courses at those institutions.

Materials and Supplies

Computer Supplies

A portion of the funds allocated to this category will be spent on expendable supplies such as diskettes, printer cartridges, cables, etc. Two printers for lower quality/higher volume output are also requested for the computers.

Software

Because we plan to familiarize students with both DOS-based and Macintosh operating systems, we are requesting software (SOFT AT ™) which will enable students to move data from IBM-compatibles to Macintoshes. We will also buy a hydrologic modeling program entitled OASIS which was developed at the National Center for Ground Water Research and which will be used as a database for chemical and hydrological information as well as for interactive simulations of phenomena such as plumes of chemical contaminants in groundwater. Finally, we are requesting software (DIGITIZE ™ and GRIDZO ™) which will enable students to read and display data in map format.

Ozone Detection Equipment

The simple device required to make reliable measurements of ozone in the upper atmosphere consists mainly of a UV detector and interference filters. We will purchase this instrument from TERC, the organization coordinating the ozone monitoring network, at a cost of about $300.

Miscellaneous Laboratory Supplies

Funds in this category will be used for chemical reagents, sample bottles and bags, and other consumables necessary for the planned activities.

ASSESSMENT AND EVALUATION

The new course will be evaluated by students using both objective and subjective instruments (e.g. McKeachie 1986:299, Cross and Angelo 1988, Olmsted 1991, Chickering and Gamson 1991:71, and Theall and Franklin 1991). Continuous course evaluation will be incorporated into the learning process by means of frequent end-of-class “minute papers” (Angelo 1991, Lewis 1991). Mentors and graduate assistants will be responsible for providing their own critique during the course and at its completion each semester and they will be actively involved in the evaluation and revision process. We will solicit suggestions from our colleagues at other institutions as we share our results with them. Finally, we will rely heavily on the assessment of an outside evaluator (Appendix VII) who will visit our campus to observe the class in action.

SHARING RESULTS

The results of this project will be reported to a variety of audiences, both in oral and written form. We plan to present our results at national meetings held by professional organizations such as the National Association of Geology Teachers, the Geological Society of America, the Council on Undergraduate Research, the National Association of Biology Teachers, the Association for Biological Laboratory Education, and the Ecological Society of America. We will also publish a description of the project and its outcome in one or more periodicals such as the *Journal of College Science Teaching* or the *Journal of Geological Education* .

We have several other opportunities to share our results to a wide audience of educators. Participation in the nationwide ozone monitoring network will be a tremendous asset for communication. We will continue to encourage our students to present their research at regional meetings of professional societies and special conferences for undergraduate researchers. We also hope to share our ideas with other small colleges with similar interests or programs. Godshalk has recently conducted an informal survey for sharing information among Environmental Studies Programs throughout the United States; a "letter report" about our project will be sent to all participants of that survey. There is also an Internet interest group of directors and teachers in environmental science programs with whom we will share our results and suggestions.

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Appendix II: Information on the "Ozone Network"

The following is a letter received over Internet which describes the proposed ozone project:

Date:2/21/92
Dear Ozoners:

Please excuse this impersonal group letter; it is necessary because of the wonderful response to my appeal for support. Many of you have raised questions about our ozone project, so I thought a group answer would help clarify what it is all about. I hope you find this useful.
TERC is a non-profit educational research and development group dedicated to improving mathematics and science education at all levels. One of our strategies for improved science learning has been to engage students in collaborative research projects. This strategy led to the development of the Kids Network, now published by the National Geographic Society, and to several other successful projects. One of these, the Global Lab, is designed to involve students in ecological research projects which have global impact. As part of that on-going project, and with the assistance of several collaborators, we have developed a relatively inexpensive way to accurately measure the total amount of ozone in the atmosphere, the total column ozone.

Our approach relies on measuring the intensity of the light coming from the sun at two different wavelengths in the ultraviolet. At one of these wavelengths, ozone absorbs the light strongly, and the second, although it is nearby, ozone absorbs little. The ratio of the light observed at these two wavelengths is a good measure of the amount of ozone and, because the wavelengths are close, this ratio relatively insensitive to the presence of haze and other gasses that absorb in the ultraviolet. The key parts of our instrument are a new low-cost UV detector and interference filters which pass only the desired wavelengths. We hope we can have the instrument manufactured for $100-$300 depending on quantity.

The current global ozone depletion is being detected by a surprisingly small amount of data. The standard way of measuring ozone is the Dobson spectrometer, a huge, clumsy turn-of-the-century optical device. There are only a few (47, I think) labs in the world regularly making ground-based measurements of ozone, most using Dobson spectrometers which are inter-compared regularly and based on a world standard maintained at NCAR, the National Center for Atmospheric Research, in Boulder. Large sections of the third world are have no ground-based measurements at all. The only important alternative source of ozone data is a spectrometer on an aging satellite, the Total Ozone Measurement Spectrometer (TOMS). You may have heard of the 3% increase of mid-latitude ozone last summer; this was due, not to a change in the levels observed, but to a 3% change in the calibration of the TOMS instrument. Because of this paucity of data, there is an urgent need for more observers, but only if the data are reliable. We need to be able to detect changes in the total column ozone to a total precision of at least 3%. To reach this level, we will need serious and dedicated students and a detailed set of measurement, calibration, and cross-check procedures. Some of these might include: Assembling all the instruments in Boulder and getting volunteers to use them all at the same time that the NCAR standard measures the same column. Circulating several standard instruments among sites which are periodically re-calibrated against the NCAR instrument. Having two or more schools in the same area regularly measure the ozone column at the same time independently. The goal would be to create a network of colleges and schools regularly measuring ozone and reporting values which could be easily accepted by the scientific community. At very least, this would supply essential data as the ozone level is predicted to diminish over the next few years. But perhaps we will also discover new effects: urban ozone clouds, patches of ozone-poor air, or short-term variations. Who knows what we might discover if we have greatly expanded monitoring capacity? We have been working with Forrest Mims III on this project. Forrest is editor of Science Probe! magazine and a long-time advocate of amateur science. Forrest has developed a similar instrument and we want to combine the best features of both our designs in order the achieve the highest possible accuracy at a cost schools can afford. We might be able to publish plans and student results in his journal. Forrest has made contact with scientists at NCAR who are highly supportive of the creation of a amateur ozone network. He has also contacted the chief scientist involved in ozone measurement at NASA who should like to use such a network to cross-check the satellite ozone data. For this project to be meaningful in an educational setting, the measurements must be surrounded with good curricula and students need prompt access to the combined data. We will use networks for collecting and redistributing the student data. We would follow the lead of our Global Lab project which uses Econet because it is low cost, has an ecology orientation, and can be reached through Internet and SprintNet. To support teachers, we imagine assembling a collection of readings about the ozone problem and its social implications, suitable for different levels of students. A teachers' guide would accompany the package, suggesting different ways to use the material with different student populations. As new material is generated and current developments change what should be covered, we can distribute updates on the network.

..... We could use the network to collect, annotate and distribute the curriculum material. The chief problem would be the instruments. How much of a problem would the $300 cost of the instrument be? This is not an off-the-shelf item, yet, so we would have to arrange for someone to make them in small numbers.

Sincerely,

Robert F. Tinker

Appendix VI: Major equipment holdings available for use with this project.

Stevens Water Lever Recorder
Teledyne Gurley Pygmy-style current meter
DynaMetric Seismic Timer
8 American Optical Stereoscopic Microscopes
Cenco-Meinzer Sieve Shaker
Derrick Lab Sieve Shaker
3 Drying Ovens
Bausch & Lomb Zoom Transfer Scope
Weathertronics Water Level Recorder
2 Olympus Polarizing Microscopes
Branson Ultrasonic disaggregator
Beckman benchtop centrifuge
Fisher high-speed centrifuge
Fisher constant temperature water bath
Lindberg Muffle Furnace
Eberbach shaker table
Recording rain gage
3 Soiltest Soil Moisture Collectors
Apparatus for determination of Atterberg Limits
Surveying level
Van Dorn water samplers
YSI model 58 dissolved oxygen meter
YSI model 33 salinity-conductivity-temperature meter
Li-Cor model 185B photometer with sensors for air and water
Orion model 720 pH/mv meter with Ross pH electrodes
Mettler model PM4600 top-loading scale (not a balance!)
Vacuum filtration manifold and filter funnels
Bausch & Lomb Spec 20 and Spec 21 spectrophotometers
Turner model 340 spectrophotmeter
Environmental chambers regulating light and temperature; walk-in with artificial stream channel
Various dip nets and seines
Various compund and dissecting microscopes
Chisholm Looking Glass and Lightwriter LCD Projection Panel

Appendix VII: Consultant for Course Evaluation, Dr. Paul R. Pinet

Dr. Paul Pinet, Professor of Geology at Colgate University, has enthusiastically agreed to serve as an external evaluator for this project. Dr. Pinet has been teaching geology at Colgate since 1978, during which time he has authored several publications on the subject of teaching science to undergraduate students. Dr. Pinet has given workshops on critical thinking and has recently finished a five-year term as University Professor of General Education at Colgate. His responsibilities for that position included helping faculty to design multidisciplinary, team-taught courses, and to devise ways to integrate science and the humanities. Dr. Pinet has also served as a consultant on curriculum improvement to universities and colleges in the Midwest and on the west coast of the United States . He has written a laboratory textbook in historical geology and recently completed an introductory textbook in oceanography. Below is a partial list of Dr. Pinet's publications relevant to our project.

Pinet, P. R., 1992, A primer on teaching higher-order thinking in introductory geology courses: Jour. Geol. Ed., 40, 1-9.

Pinet, P. R., 1992, Oceanography: An Introduction to the Planet Oceanus, West Publishing Co., 572 pp.

Pinet, P.R., 1990, Studying the relationship between science and civilization: Jour. College Sci. Teaching, 19, 282-286.

Pinet, P.R., 1989, Understanding the language of argument and the methods of science: Jour. Geol. Education, 37, 197-201.

Pinet, P.R., 1989, Developing models to convey understanding rather than merely knowledge of the methods of science: Jour. Geol. Education, 37, 332-336.

Pinet, P.R., 1989, The language of argument and the art of critical thinking in the sciences: in Innovations in College Teaching, Crow, L. W. (ed.), Soc. for College Science Teaching, Ch. 11, 83-87.

Pinet, P.R., 1990, Ramblings and Notions About Teaching Critical Thinking, 1990 Northeast Geol. Soc. Amer. Short Course, Syracuse, N. Y., 49 pp.

Pinet, P.R., Frey, R. W., Whitney, J. A., 1988, Earth History: An Introduction to the Methods of Historical Geology, 3rd edition, Hunter Publishing Co. North Carolina, 187 pp.