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ABSTRACT

Fifteen innovative college science programs based on survey results about perceptions of excellence in college science teaching are presented. The goals, program origins, special features of the programs, evaluations, and conclusions are described for each. Discussed are the commonalities among this collection of 15 college science programs and some concerns. Programs include zoo biology, microbiology, biology for majors, biology for non-majors, field experience, anatomy and physiology, chemistry for non-scientists, analytical chemistry, physical sciences, applied geology, science mentors, interactive video, health-science, environmental education, and cooperative education. (KR)

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INNOVATIONS
IN
COLLEGE SCIENCE TEACHING

Edited By

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and
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Table of Contents

ERIC

ERIC

ERIC

Editors' Preface

We find reading and writing about science teaching excellence in ideas and action very stimulating. For us, this stimulation was triggered when we first encountered Angela Sauro at a professional meeting in Indianapolis and heard of her innovative science program. With that, we began looking for other, equally innovative college science programs. While we have found them, this monograph effort, aided by Bob Allen, Linda Crow, Bill Frase, and the National Science Teachers Association, is but a beginning, not a culmination.

We hope this is a beginning for you to be equally stimulated to seek out and implement new ideas. At the same time, we hope to hear of other college science teaching efforts worthy of publication. We look forward to hearing from you.

JEP
JAD

University of Iowa
Iowa City, Iowa

March, 1988

Forward

by
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The Society for College Science Teachers includes many who are making impressive innovations in their teaching. With their highly imaginative, creative and effective ideas they are developing laboratories, teaching difficult concepts, and providing interesting learning experiences. Many of us in the Society were impressed with these varied efforts and recognized that an equally large number of our members are involved with relatively unknown projects -- projects worthy of recognition and publicity.

We wanted to publicize these innovative efforts to the greater science teaching community where they could present a highly valuable source of information and ideas for college science teachers wishing to improve their teaching programs. With this purpose in mind, John Penick, then chair of the research committee, suggested that we invite contributions for a special Society publication describing teaching efforts in the area of applications of science and the ultimate effect such applications may have on students and society. John further volunteered to serve as editor of the publication and Linda Crow, also on the research committee, agreed to supervise the review of submitted manuscripts. With the endorsement and support of the SCST Executive Committee, work was begun and the final product is this publication.

These contributions represent only a very few of the many fine innovative courses developed and implemented by college science teachers. We view this as the first of a series of publications on innovative science teaching covering a variety of topic areas and look forward to publicizing more creative efforts. We hope you have or will develop one of them.

Introduction

The Search For Innovation

by

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In September, 1986 the Society for College Science Teachers Research Committee began to survey society members about their perceptions of excellence in college science teaching.

From a list compiled from a literature search and survey of award-winning college science teachers respondents identified which characteristics from a given list most closely matched their view of excellence in college science teaching. Three hundred members received this first part of the survey and sixty-one percent returned the completed forms. After the results were compiled using a simple tally procedure, five characteristics clearly stood out from the rest.

THE INSTRUCTOR:

•**Possesses** content expertise.
•**Demonstrates** energy.
•**Requires** students to apply knowledge.
•**Encourages** questioning.
•**Develops** critical thinking and scientific literacy

These five characteristics became the core of the second part of the survey in which 300 different SCST members were asked to give them priority, with the most important item ranked 1 and the least important ranked 5. Again, sixty percent of these forms were returned. The results inn Table 1 take into account both ranking choice and frequency, since a low ranking value indicates that the item was often chosen as most important. Although these results only represent a compilation of opinions on this important issue, it seems significant that college teachers could so clearly agree on such a controversial topic.

Table 1

Characteristic	Ranking Value
Develops critical thinking and scientific literacy	280
Instructor possesses content expertise	285
Instructor requires students to apply knowledge	423
Instructor encourages questioning	440
Energetic instructor	564

As John Penick and I, as chair and a member of the research committee, respectively, reviewed these results we were struck by the recurring theme of scientific application in the comments made by respondents. We presented to Robert Allen, then President of SCST, a plan to identify courses or programs that incorporated applications of science or used unusual motivating techniques. He approved that idea and a simple questionnaire was sent to all 765 members of SCST. Sixty-five returned questionnaires indicating their specific use of applications of science.

Using a set of criteria, Bob Allen and I reviewed all sixty-five. The major criteria used were:

* How does the course/program relate science to some career setting or relevant real world example?

* To what extent has the flavor of the application been embedded in the course/program?

* How does the course/program include lab or field activities providing students with a first hand knowledge of the application?

* How does the course/program demonstrate the relationship between science, technology and society?

Each entry was ıated and rank ordered. The twenty-five were asked to prepare a full manuscript which included information on:

The college

The students

The course

The role of the instructor

Evidence of success.

The fifteen descriptive chapters of this monograph are the result of this final request.

Chapter 1

Zoo Biology

by

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Mount Mary College, a Catholic liberal arts college for women conducted by the School Sisters of Notre Dame, has traditionally been dedicated to the development of the mind through a program of studies based on the values of the liberal arts. In Mount Mary's curriculum, based on the human search for meaning, students are given a broad base of knowledge from the liberal arts along with professional courses in their chosen career field. Pre-professional and professional programs enable students to prepare for a career of service to others while achieving economic independence and cultural enrichment.

Our thirteen hundred students represent various social backgrounds, ethnic origins, and age groups. The size of the college and friendly openness of its concerned faculty allow for the personal attention necessary to fulfill individual needs and attain personal, academic, and professional goals. With the relatively moderate size of the college community, it is fairly easy to introduce an innovative and creative course. The interests and specialties of faculty members can be woven into their teaching.

OUR BEGINNINGS

As a volunteer worker at the Milwaukee County Zoo, at the request of the General Curator, I participated in a research project on feeding patterns of an infant lowland gorilla (Gorilla g gorilla). The results, later published in Zoo Biology, led to further research focusing on Hoffmann's sloths (Choloepus hoffmanni) and Pallas' cats (Felis manul). Obviously, the zoo had a lot to offer me as a scientist. Wanting the same opportunity and excitement for my students, I introduced the Zoo Biology course to the Biology Department's curriculum. Since the Milwaukee County Zoo is Milwaukee's greatest tourist attraction and Mount Mary students are well aware of its importance to the community, a course centering on the zoo seemed attractive to students from all disciplines, not just biology.

Initially the course was offered in the summer and taken by teachers needing additional post-graduate work. While undergraduates showed interest in the course, their needs for summer employment restricted their enrolling. With good success in the summer, we now offer it as an option during the interim between the fall and spring semesters. Occasionally the course is scheduled during the fall semester on Saturdays.

ERIC

OUR GOALS

Students have many reasons for enrolling in the course with their usual responses being they love animals or have always enjoyed going to the zoo. Besides responding to these interests, the course has several additional objectives. We want students to:

- **Gain** an appreciation of the zoo and its contribution to the community.
- **Obtain** information on animals including: taxonomy, morphology, and ethology.
- **Recognize** the problems of introducing and maintaining an animal in a captive environment.
- **Develop** practical and realistic views and values on wild animals in relation to humans by observing zoo animals.
- **Comprehend** the educational and research potentials of the zoo.
- **Identify** what students, teachers, and citizens can do to fully utilize the zoo.
- **Promote** an awareness of and a commitment to protect endangered species of animals.
- **Recognize** typical problems zoos face today.

OUR CLASSROOM

The Milwaukee County Zoo, situated on 185 wooded acres, has five outdoor continental groupings: Asia, Africa, Australia, South America, and North America. These areas emphasize the predator-prey relationship where a variety of prey animals are separated from the predators by an invisible moat. The zoo also features special indoor exhibits housing particular types of animals such as Pachyderms, Small Mammals, Australia, Reptile and Aquarium, Primate, Aviary and Felines. Scattered between these facilities are specialized exhibits such as the Wolf Woods and Monkey Island.

An obvious addition with our location in Wisconsin, a dairy state, Heritage Farm features domestic animals, a barnyard and milking facility, aviary, petting ring, and raptory theatre. The focal point of the farm is an historic, restored octagonal barn.

To maintain variety in its collection, the zoo exhibits over 500 species and approximately 4000 individual animals. Most of the observation of these animals is done without looking through bars or wire mesh. Instead, an extensive system of moats and glass allow more natural habitats and viewing.

STRUCTURE OF THE COURSE

The first meeting of the course occurs at the college. At this meeting, I try to set a foundation for the experience at the zoo. Captive wild animals are faced with a number of problems not encountered in their natural state. So, in our discussion we consider the complexities of obtaining an animal and how that animals is acclimated to the zoo environment. Topics that are addressed include captive stressors, zoo nutrition, anthropomorphism, endangered species, and taxonomy.

All remaining sessions are given on the zoo grounds. We cover all exhibits as well as behind-the-scenes portions of these areas. To get a complete picture of zoo operations, we include visits to the zoo hospital and the commisary, where the animals' food is stored and prepared. The zookeepers give the presentations in the off-exhibit locations while the areas open to the general public are covered by the course instructor.

As students visit the zoo, they begin to plan for the two major assignments, an exhibit design and a final project. For the exhibit design, students select an exhibit that they feel can be improved or could be added to the present zoo facilities. While planning the exhibit, they consider the type of animal or animals in the exhibit and their various needs such a shelter, social structure, space requirements, activity requirements, food and health requirements, and an appropriate environment. Also, the student must respond to desires of the zoo-going public and the needs of the keepers in maintaining the exhibit and its occupants. Since the zoo is an educational as well as a recreational facility, each design must include an instructional component such as signage, special graphics, tour guides, or an interactive computer game.

Artistic or architectural talent is not a prerequisite of the course. The finished product does not need to conform to esthetic or structural specifications. The evaluation of the finished product is governed by the ability of the student to create a plan for an exhibit that meets the given requirements and displays an understanding of a proper zoo exhibit and the animals' needs.

To make it easy for the students, they are given a generous (though imaginary) budget, and can suggest elaborate and dream-fulfilling projects. However, the exhibit they plan must conform to the present zoo facilities and the available space in the zoo grounds.

The final project must be an outgrowth of their experience at the zoo. Since course participants come from a variety of disciplines, projects that connect these disciplines with the zoo are encouraged. Depending on the students' majors, some projects have materialized into mini-internships under the direction of appropriate zoo personnel.

SOME EXAMPLES

Two projects illustrate the material benefits acquired by the students and zoo personnel.

A graphic design student worked with the zoo's director of graphics. Under his supervision, the student created several illustrations for the covers of a monthly "What's Going On At The Zoo" pamphlet. The student submitted her designs which were then critiqued by the design director. The final, approved covers were then used on the appropriate pamphlets. (The student could add the completed pamphlets to her portfolio). When determining the grade for the course, the instructor consulted with the design director. His assessment of the student's performance was critical to the final evaluation. To our student, this was no mere academic exercise -- the illustrations were really going to be critiqued and used!

The zoo's education department encourages visiting school groups, ranging from pre-school to high school. While various units have been prepared for each level, they had none for the mentally or physically handicapped. To adapt some of the units for these special visitors, a student from the college's occupational therapy department worked with the education department on this project. Using her background from her major courses, she restructured these units around the limitations of the disabled. The zoo's education department

ERIC

personnel, not having formal training in this area, felt the student's contribution to be quite useful and based on proper therapeutic principles.

It is not mandatory that the final project involve one's major or be a joint venture with zoo staff. Many students concentrate their efforts on a personal interest or an idea kindled by their exposure to the zoo. Oil paintings, animal Christmas ornaments and their marketing, poetry, and campaigns for the funding of endangered species have materialized as a direct response to this course.

No matter what the final product, care must be taken to insure that the information used is correct. Anthropomorphism and animal misconceptions are avoided by careful monitoring, discussion, and presentation.

EVALUATION

Several weeks after completion of the course, students reflect upon the course and respond to a questionnaire. Students respond to questions about the course's application to their major, the value of the course in the future, understanding of the zoo and its role in the community, and if there were any unexpected benefits.

Students feel that their knowledge and appreciation of the zoo was greatly enhanced. They had never realized the extent of care and concern that is focused on zoo animals. They also find that the zoo is a microcosm of professionals not just zookeepers. And, with their college work completed, maybe a student in a major, such as business or graphic design, might find a position at the zoo.

With the increase in the number of endangered and extinct species of animals, zoos are attempting to halt this trend and offer the best chance for survival through captive breeding programs and artificial insemination. Through their exposure to the course, students become aware of this problem and that the responsibility for halting this dangerous trend belongs not only to zoos but also to them. As one student described the situation, "Just as Noah and his sea-faring menagerie saw Mount Ararat as an island of salvation amidst the treacherous floods, so are today's zoos the "high ground" that offers respite and rejuvenation for endangered animals."

The students find their experiences to be exciting and they eagerly share these experiences with family and friends. After the course, return visits to the zoo are frequent. Now, they look at the zoo with a new perspective. After being apprised of the various programs and activities offered by the zoo, they begin to look at the zoo as a site for education, not just recreation. As a senior summed up her evaluation, "I saved the best-this class for last!"

Overall, this course has been extremely successful and well received. By word of mouth, its reputation has spread through the Mount Mary community. However, without the cooperation of the zoo staff, this course could never be taught using this format. The original commitment of their time was fostered by the interrelationships between Mount Mary College and the course instructor. Now, however, the benefits received by the zoo staff from various student projects has made this program truly beneficial to all concerned.

Chapter 2

Reptiles As Patients--Applied Microbiology

by

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Mount Mary, as a small, women's college located in a metropolitan area, also recognizes that it bears a responsibility to the community in which it exists. Mount Mary College also educates the student of today for the future within the framework of Christian principles. In education for the future, the faculty of Mount Mary realizes that true maturity develops along a self-directed path. Thus, the college provides the opportunity for increased choices within the liberal arts curriculum including the option for professional training.

Within this educational framework, the Milwaukee Zoo provides a unique opportunity for students in our upper level clinical microbiology and immunology course to do applied research and community service. With three hours of lecture and three of laboratory, this course enrolls biology majors or minors interested in health related areas or biotechnology which may or may not have direct clinical applications.

OUR GOALS

Our course goals must include an appropriate emphasis for the varied microbiological applications our students may be making in the future. As in most clinical microbiology courses we want our students to:

* **Know** basic microbiological media, protocol, and agents important in diagnostic microbiology.
* **Develop** an understanding of the host-parasite relationship and the molecular level of pathogenesis in significant infectious diseases, microbial, mycological, and viral.
* **Become** proficient in identifying unknown bacteria in the laboratory with traditional and rapid-testing procedures.
* **Understand** problems associated with modern microbial taxonomy, especially in the family Enterobacteriaceae.

While the course was first developed in 1971, it soon became apparent that many of the course's basic goals could be better fulfilled and enhanced if students could apply what they were learning. At the same time, we felt the varied needs of our students could be better met. Our students:

* **Collect** data from live materials in an original research project.
* **Obtain** microbiological skills through data collection.
* **Use** a computer data-base program to sort data appropriate to selected problems.
* **Assemble** data in clear comprehensive data charts, graphs, and visuals.
* **Discuss** data in view of previous studies cited in the literature.

* **Draw** conclusions on the selected problem based on data analysis.

As a result, students accumulate original data to add to the sparse information available on the microbiology of reptiles. Not only is this useful to the zoo, but the educational and scientific community benefit from dissemination of this data at conventions and in science journals.

OUR BEGINNINGS

The Mount Mary College Biology Department strongly felt it educationally important to incorporate primary research experiences into our curriculum. We perceived this need for several reasons. First was the growing body of literature that addressed the importance of teaching the process of science as well as its content. Primary research approaches science as a process, it aids the students in learning how to observe, measure and draw inferences in an effective manner. Secondly and more practically, our department realized we needed to do more to prepare our biology students for graduate and professional schools. We also believed they needed the opportunity for job-related experiences. And, since community service is an integral part of the college's institutional goals, through the zoo research project we could fulfill these needs and also be of service to the Milwaukee Zoo.

The ongoing nature of the microbio' v research made it useful in fulfilling goals in both the clinical microbiology ourse and microbiology research and allows students to have a more continuous involvement in one project during the course.

OUR PROGRAM

In January of 1981, a group of microbiology students was interested in doing research. At the same time, at the Milwaukee County Zoo, the first resident veterinarian was being troubled by a large number of sick reptiles. This concern for diseased reptiles and their care led to the Mount Mary College Zoo Microbiology Research Project.

Working with a faculty member, students interested in developing microbiological skills and helping solve the problem at the zoo began the zoo microbiology research project. The zoo cultured the reptiles and also helped finance the project through the purchase of microbiological materials used in the study. In all our curriculum development and thinking, we kept in mind three essential elements for quality undergraduate research:

1. Prepare the students to do research.
2. Suggest research topics that are of direct value to a community resource.
3. Find a source of funding.

The zoo project certainly met all of these requirements. With these aspects in mind, we developed an overall format, consistently adhered to for student data collection and analysis.

Data Collection: Each student received samples collected by zoo personnel for isolation, identification, and antibiotic sensitivity testing.

1. **Isolation**: The pharyngeal and cloacal cultures of the zoo's reptiles were streaked out on standard primary isolation media.
2. **Identification**: Standard microbiological identification of the isolates using standard media and micro-system.
3. **Antibiotic Sensitivity Test**: Kirby-Bauer and, later, MIC (minimum

inhibitory concentration) antibiotic sensitivity systems were used with a range of antibiotics on isolates.

Data Analysis: Use computer to input sort, and analyze data.

Data collection and analysis are an integral part of the student research experience. While data collection can be done routinely, a special approach is needed to provide a data analysis experience in an ongoing research project. Superbase 64, a computer data base program, provides the vehicle to select discreet portions of data so individual students can perform data analysis in small units. Thus, many students may be part of a larger study. The overall long term problem under study is: "The Patterns of Bacterial Isolates and their Antibiotic Sensitivities in Diseased and Normal Captive Reptiles at the Milwaukee County Zoo." Our students are a research team where, for each of the many problems, students are asked to follow three basic steps to accomplish data analysis:

Assemble data into charts and graphs.

Discuss the data in view of previous studies cited in the literature.

Draw conclusions based on data analysis.

Although our format has been consistent, it is a challenge to keep our results consistent. Many students necessarily introduce many errors even though, as the course instructor, I constantly monitor the students' results and techniques. I also offer encouragement with one persistent problem; there is no way to predict the amount of time working-up a culture sample will take. Collecting meaningful data takes time. This time gives students an awareness of what research entails, although some do not appreciate this particular lesson. We also find that accuracy of data, promptness of turning in results, especially where sick reptiles are concerned, and completeness of information vary from student to student. Grade contracts and evaluation of each work-up in writing help to correct these problems.

BENEFITS

The biggest plus, besides the educational benefits, the students derive from working on the zoo project is in helping to keep the zoo reptiles healthy. At times we keep an on-call list for people to come in and identify possible disease-causing bacteria and help determine effective antibiotic therapy. Although some of our zoo patients die, information after death helps to solve future problems. One of our most interesting successes was with an anorexic Iguana with a bacterial infection. With our help, it was cured and survived.

EVALUATION

In order to gain some information on the success of our first attempts at Zoo research, two types of informal evaluations were conducted. The first was a series of three questions to judge the student's perception of the zoo research experience as part of the clinical microbiology and immunology course. Some selected responses to three questions indicate we are fulfilling our goals with regards to benefiting the students.

What did you learn from your participation in the zoo research project in the area of microbiology?

"I developed good lab techniques, which include streaking plates, making media, obtaining good, isolated colonies, and general laboratory procedures.

I developed a healthy respect for the organisms with which I was working."

"The zoo research project taught us technical skills. The project gave me an opportunity to participate in research. Research can be fun, challenging, instructive, time consuming, hard work, satisfying, and worthwhile. It's exciting to explore areas that are unknown and potentially helpful to animals and possibly even man."

"It gave me a better understanding of the tests performed for microbiological identification. I think it sharpened my skills in culturing techniques, performing biochemical tests, and in identification procedures. I also gained an understanding of the microorganisms themselves which was very useful in Clinical Microbiology. It strengthened my knowledge of their biochemical activities."

"Enabled us to apply classroom knowledge; to have a better understanding of the biochemical tests and various media used, practice in identifying microorganisms under the microscope, and in learning microbiology protocol."

What special skills did you acquire that would be of use to you in another area?

"After participating in the program, I feel confident in making identifications of organisms. I am able to recognize certain characteristics and results of pertinent tests. I feel more at ease in a laboratory after performing this research."

"The research made me comfortable with instruments and techniques."

"Everything that I learned can be of some benefit to me in another field. I've acquired many skills that I think will be useful in the food industry in food microbiology. A lot of research is being done on microorganisms and enzymes."

Would you advise other students to participate in this project? Why?

"Yes - I would advise other students to participate in the project. The project lends itself to many aspects in research. It allows the student to apply previously learned techniques. It also teaches the student to explore new methodology, and search one's own mind for new and innovative ideas."

"Yes - I think that those who are interested in different aspects of microbiology would obtain a certain learning experience beneficial to them. Working everyday, as we did in the lab, perfected our skills and gave us an inside to the actual work experience needed in this field. I plan on participating whenever my schedule allows. (Hopefully every semester until I graduate). I also think it's good therapy when you feel like forgetting other studies and want a relaxing project to work on."

"Yes - great field experience to list on a resume. I really enjoyed the project, consequently, my enthusiasm and appreciation and interest in microbiology was greatly increased."

"Yes - I gained knowledge of testing procedures, good techniques so identification is possible, discipline to get the job done."

The second type of evaluation consisted of a check sheet on the quality of data analysis. Points were assigned to criteria related to three objectives of analysis. The results of the checklist evaluation indicates overall effective data analysis by the students. It also indicates they were weakest at discussing data in view of previous studies cited in the literature.

Objective 1: Assemble data into charts and graphs

The checklist indicates students do a very good job of assembling computer sorted data into clear charts. They rate well on the comprehensiveness of the data charts. Some students left out pertinent data.

Objective 2: Discuss the data in view of previous studies cited in the literature

Documentation is poor, while literature cited relative to the problem is fair. Depth of comparison of student data to literature is also fair.

Objective 3: Draw conclusions based on data analysis

Students were very good at arriving at conclusions supported by the data. They rated good at comparing information from different sources and at discussing the importance of the investigation.

UNIQUE OUTCOMES OF THE ZOO RESEARCH PROJECT

The immediate outcomes for the student's learning experience are varied. They not only achieve a greater competence in microbiological skills but also, in today's computer-driven world, they are provided with an excellent hands-on demonstration of the use and power of a computer to store and sort massive amounts of data.

This experience has given several students marketable skills for jobs in the food and cosmetic industries in the quality control and research and development areas. It has also proven helpful to those going on to graduate and professional schools.

The zoo and scientific community have benefited because the data collected from this project aids in a better understanding of the relationship between normal and disease-causing flora in captive reptiles. It also has resulted in more accurate antibiotic treatment of captive reptiles to help save these reptiles' lives.

Some of the microbiological, veterinary, and educational outcomes of this research have already been disseminated at regional, national, and international meetings. Further articles on data already collected are being planned.

This project provides a successful working model of science during a unique application not possible in a more traditional setting. As students develop basic research techniques, they gain education and skills for the world today and the future. This application is also beneficial to the scientific community for the original information it generates and to the zoo to help them maintain a healthy collection of captive reptiles. Our students are not just taking a course, they are doing science and a service to the community.

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Chapter 3

Unity Of Life--Introductory Biology For Majors

by

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Valparaiso University, a private, Lutheran affiliated school in Northwest Indiana, includes a College of Arts and Sciences with approximately 1800 students. Our Department of Biology has seven professors, one part-time instructor, and 125 majors. We offer introductory courses for students with differing carer goals. Unity of Life, the subject of this description, is intended for science majors and premeds. The two other introductory biology courses meet the special needs of allied health students (potential nurses, physical trainers and dietitians, for example) and nonscience majors seeking to fulfill their general education requirements.

THE CURRICULUM FOR BIOLOGY MAJORS

Unity of Life, the first of three required core courses for biology majors, treats molecules, cell components, glycolysis, respiration, photosynthesis, cell division, genetics, and the tissues and organ systems of typical angiosperms and vertebrates. The second course of the core, Diversity of Life, reviews the major phyla along with some population genetics and ecology. After completing Genetics, the third core course, students select intermediate and advanced courses appropriate to their goals. A total of twenty five Biology credits fulfills the minimum for a Bachelor of Science degree, provided that a second major is taken in another science. Thirty two hours are required for a biology major when it is coupled with a non-science major or minor in another science.

THE INTRODUCTORY COURSE

Unity of Life, a four credit course offered every fall semester, includes three fifty-minute lectures and one two and one-half hour laboratory each week. Two professors share the lectures and take one or more laboratory sections each. The structure of the lecture is not unusual, but a special independent project is required in the laboratory.

We hope to expand the "organized body of facts" concept of science held by most freshmen students to include "a mechanism for acquiring and reexamining facts." We lay the foundation for this in the first lecture by emphasizing the scientific method and outlining a plan of work for the laboratory. This laboratory program has been designed so that most meetings contain fewer of the traditional observations and demonstrations (which are not described here) and include a significant experimental component. The laboratory program includes a requirement that each student design and carry out an independent research project, keep a notebook to record the methods and observations, and write (on a word processor) a concise scientific paper describing the project. The details of this assignment are explained verbally in laboratory and supported by handouts.

SELECTED PROJECT HANDOUTS

Independent Laboratory Investigation

Purpose: To provide each young scientist the opportunity to perform an individualized laboratory investigation which will develop abilities of logical thinking, keen observation, appropriate measurement, analysis and expression.

Assignment: Each student will design, execute and report upon a well-planned, independent laboratory experiment based upon the study of seeds or young plants. This experiment will examine critically an hypothesis on the nature or behavior of living plants. The hypothesis must be explained in terms of known biological principles so that it may be understood by the scientific community. The professors will make available to each student the seeds, pots, planters, greenhouse space, and standard glassware, chemicals, equipment and other supplies necessary.

Schedule:

Lab Meeting 3: Each student will be given two bean seeds inside a 35 x 10 mm plastic petri dish. Water these when you get home and watch what happens to them. Record in your laboratory notebook any observations you think necessary.

Lab Meeting 4: Dissection of variety of sprouted seeds and young plants to learn their anatomy. Assignment of the following handouts: An Introduction to the Art of Scientific Investigation, Sample Questions and Proposal for Independent Research (all included below).

Lab Meeting 5: The Proposal for Independent Research is due. Your professor will consult with you privately on your proposal. He may reject the proposal and insist that it be rewritten, or ask for additions and clarifications. He may have some hints that will make your project easier or more significant. If the professor forgets to tell you where you may find the supplies or equipment you need, be sure to remind him. As soon as you have the professor's approval, you can begin your experiment.

Lab Meeting 6: By the end of this laboratory period, everyone should be experimenting.

Lab Meeting 12: Experimentation must be completed this week.

Lab Meeting 13: Notebooks and written scientific reports are due. We provide students with a handout describing appropriate formats for this paper.

An Introduction to the Art of Scientific Investigation

1. Spend a little time thinking about seeds. Read about them in your text or in "Physiology of Seeds" or in any book that catches your eye as you browse through the stacks. Determine the important parts of a seed (it might help to read ahead in your text book). Develop a mental outline of what the seed does as it germinates and grows.
2. Some aspect of seed behavior should begin to interest you. You will probably know more about this aspect than others, although it may remain mysterious. Look at the sheet of sample questions. Ask yourself those or similar questions about how or why seeds act the way they do. Ask your roommates and lab partners. Try to develop answers to the most

interesting questions. If you find that these questions are unanswerable, modify them so that they may permit you to get at the answer.

3. For one of these questions, you may have two or several reasonable, alternative answers. It helps if these alternatives include all possibilities. Assume that one of the answers is the correct one and express that answer as a declarative sentence. This is the <u>Hypothesis</u>.
4. Design an experiment that will turn out one way if the hypothesis is valid and a different way if any of the alternatives are valid. This is the <u>critical test</u>. It is unlikely that even the most skilled investigator will develop a good critical test without rehashing steps 1-4.
5. Evaluate the hypothesis and critical test by the following criteria: a) Is the hypothesis consistent with all the other things you know about seeds? b) Does the hypothesis make a novel (to you) prediction about what will happen under your experimental conditions? c) Is the hypothesis testable? For this course, given the constraints of time, equipment and space, will you be able to complete this experiment and still pass your midterms? d) Is the potential knowledge to be gained by doing your test the most useful and interesting to which you can aspire, given the constraints outlined above? If your evaluation of a-d) is favorable, continue to step 6. If you are not certain, do not be afraid of rethinking steps 1-5. Additional time spent here will make the rest of your project easier and more successful.
6. Fill out the <u>Proposal for Independent Research</u> and make an appointment to discuss that proposal with your professor.

For more information on investigative science (and many interesting anecdotes) you may wish to read <u>The Art of Scientific Investigation</u> by W.I.B. Beveridge.

SAMPLE RESEARCH QUESTIONS

Do stems grow toward light or away from gravity?
Do roots grow toward gravity or away from light?

Why does a dry seed swell in water? Does the seed expend metabolic energy in this process?

If you drill a hole in the seed coat, would that harm the seed?
Do the root and stem always emerge from the same places in every bean seed? Is that the path of least resistance?

Does acid rain affect seeds?

If a seed were kept constantly rotating, would it grow normally? Why or why not?
If a seed were kept constantly shaking, would it grow normally? Why or why not?

Is there any water in seeds <u>before</u> you plant them?

Do seeds grow as fast in the dark as they do in the light? Do all measurements of rate of growth measure the same thing?

What does a cotyledon do? What would happen to a young bean plant if you cut off one of its cotyledons?

Will your plants grow faster if you water them with sugar water?

Does a plant germinate (or grow) by an increase in cell size or number? How could you tell?

Why won't most land plants grow in water?
Why can't you irrigate a farm with salt water?

Can a plant absorb water through its leaves?

Why does a tree (or woody plant) die when you "girdle" it?
When a plant is girdled, what part of the plant suffers first?

What percent of a plant is water? Do plants growing in dark, dim or fully lighted conditions contain the same percentage of water?

Do plants watered with salt water have the same amount of water inside them as plants watered with pure water?

Do treatments that kill fungi on the surfaces of seeds sometimes kill the embryo inside the seed?

How could you tell if a seed is alive without waiting for it to germinate?

Proposal for Independent Research
Name ____________________________
Local Phone_________________________
Hypothesis:

How do you propose to make a critical test of this hypothesis? What is your experimental design?

What equipment and suppiies will you require?

(In the original handout, adequate space is left for student responses.)

Date 1st conference: Date approved:

ESSENTIAL FEATURES OF THE PROJECT

Explicit, Written Proposals: In the first year that we required an independent project, we simply asked students to turn in written proposals for their experiment. Many students were unable to produce a proposal with these directions. Few of the proposals completed contained a hypothesis, none had a list of essential equipment and supplies. We had failed to prepare our students for their first conference and, as a result, six hours (24 students X 15 minutes) of the professor's time was wasted. The new form explicitly demands a hypothesis, a critical test, and a list of materials. These terms are not totally mysterious to the students; all are described in lecture, in laboratory handouts, and in verbal laboratory instructions.

Independent Design and Experimentation: The volume of work for both student and professor would certainly be reduced if students were directed to work in teams of two or four, but hard work for a significant gain is a bargain. If thirty percent of our students could not produce a good proposal after the second conference, then research teams would be appropriate. However, since a few hints are sufficient and necessary in most cases, then the difficulties of independent work seem supportable. If most students presented beautiful proposals at the first conference, I would conclude that there was an insufficient challenge or that there was a listing of successful student research projects in the library (or frat house). Independent effort forces a student to be responsible for his own work; the grade is not determined by the lab partner's performance. This helps the professor see who did the work and who deserves credit or correction.

15 minute individual conferences and 10 minute follow up: The overwhelming majority of students are pleased to have a private meeting with their professor; there is surprisingly little shyness or embarrassment. We see a wide variety of performance levels as a few students arrive with an excellent hypothesis and test while the majority propose complex or difficult methods to examine trivial hypotheses. The latter are asked for a more elegant experiment: one which demonstrates significant principles with simple technical means. Even sensitive feelings are little hurt by a request for more elegance.

An occasional student can not distinguish between a critical experiment and a detailed series of observations. In all cases, the student is encouraged for the effort. Gentle questions and incomplete suggestions often prompt the student to rework any shortcomings during the first conference. In this case, we do not schedule a second meeting. If the problems require an extensive rewrite, a second meeting is essential. A very few students need (or at least want) the professor to impose a hypothesis and test, leaving them to work out minor details. I usually give these students some hints and then allow them to flounder for a few days. If they show little progress at the second meeting, I will design a project for them rather than allow them to fall impossibly far behind. I hope that performing an experiment by rote this year may lead them to design capability in Genetics experiments during the third course.

Numerous Minor Activities and Deadlines: "Independent experimental project" seems like a life sentence to some freshman, but dividing the work up into small tasks makes it look much easier. Assigning lots of time, a written proposal and two conferences to the planning stages prevents most students from falling behind or starting a complex experiment with a deficient hypothesis. During regular laboratory meetings, the professors also make a point to informally ask students (particularly those who appear less motivated or gifted) about their progress, so most students try to have something new to say each laboratory period.

Professor Availability: Students need much help and advice on their projects at odd times during the day and a careful reading of their proposals and projects also takes a long time. Teaching load credits assigned to the laboratory must realistically reflect the time involved, but other kinds of support can certainly help. Our laboratories are limited to 24 students per section with a student teaching aid assigned to each scheduled laboratory and to some of the more popular times for independent research. A part-time technician is also available to wash glassware and to prepare solutions. All of these help to isolate the professor from routine questions and low level work, enabling him to spend additional time on the more difficult problems facing the novice investigators.

Restriction of Experimental Material: Having everyone work on seeds places limits on the kinds of supplies, equipment and background information which the professor must provide. The seeds themselves are inexpensive and convenient to purchase, germinate, and grow. Because much information is available on seeds in the primary, review, and popular literature in the fields of science, agriculture, and economics, most students are able to find a topic of interest to them. We initially advised students to use large, leguminous seeds because they were easy to see and dissect. Unfortunately they are also relatively slow to germinate and likely to support bacterial and fungal contamination when grown in vitro. Smaller seeds, especially radish, germinate very quickly, rarely become contaminated, and permit large sample sizes.

Open Laboratories: Designing a critical experiment is sufficiently challenging for most of our students without asking them to tailor their methodologies to fit our laboratory schedule. Fortunately, our students are sufficiently responsible and our campus sufficiently secure to permit keeping the laboratory and greenhouse open from 8 a.m. to 5 p.m. Monday through Friday.

SUCCESS OF THE PROJECT

Our best students turn in remarkably good papers. While most papers are good, the quality of the papers is not the best expression for the value of this exercise. The projects are valuable because the students think they are significant and enjoy them. Most students are able to find some concept that excites their imaginations. One example (that also excited the faculty) was the student who found that seeds treated briefly with microwaves (he used the microwave oven in the dormitory) would germinate faster than the controls. Virtually all students develop a technique which they comprehend, master, and come to enjoy.

The students work hard on their projects, in and outside of the scheduled lab period. The responsibility given them in the open laboratory is satisfying to many as is the professional/personal relationship they develop with the professor. I still remember fondly the student who shook hands with me at the end of each of our several conferences. I had tried to treat him as a young colleague, and the handshake was an appropriate response. Finally, professors of the other core courses report that students coming from Unity of Life are motivated and industrious.

SHORTCOMINGS AND FUTURE IMPROVEMENTS

When the independent project was first added to the laboratory, too many traditional observations and demonstrations were retained. None of these were valueless, but their volume was simply too great to be communicated effectively. One exercise required students to learn to recognize ten angiosperm cell types, histology of typical dicot stems (three examples), monocot stems (one example), dicot roots (two examples), monocot roots (two examples) and monocot leaf (one example), and take a practical laboratory examination. This assignment was not popular and student retention of plant histology was not good. We hope that our next errors will be in retaining slightly too little material and that students who finish the observations early will spend that much more time on their projects.

The research project requires much work and is a highly significant element of the laboratory grade, yet the project grade depends upon a single paper written in a style which is entirely new to most of our students. Furthermore, the handouts explaining how to report project results in scientific format were too vague with too few specific examples. Pertinent examples are not always easy to write because everyone is doing a different experiment.

In the future, instead of a single project we will assign two smaller projects. The first will be relatively minor and require all students to perform the same experiment with highly specific instructions provided by the professor. For this experiment, we have selected a modification of Demonstrating Koch's Postulates (Cronholm and Neff, 1978, published in Carolina Tips 41: 21-22). The original paper recommends roaches as experimental subjects, but we find that crickets work equally well, are less objectionable, and are very easily obtained at local bait stores.

In this experiment, students inject crickets with *Serratia marcescens* (a strain with an unusual identifying coloration is employed), recover the suspected pathogen from a dead cricket, and then culture it. The passage of the deadly (to a cricket) microbe from *in vitro* to *in vivo* culture (along with adequate controls) is accomplished several times, establishing that the pigmented microbe is the cause of a specific disease. Handouts to support writing up the cricket experiment can be quite detailed, giving the freshman a highly structured writing exercise.

The second project undertaken would necessarily be less ambitious than it is now (three weeks are required to complete the cricket work), but retain its independent character. The experience of learning the rationale of the cricket experiment and following the directions for reporting upon it (not to mention receiving the professor's written responses to the paper) should support more active independence in the second project. However we modify this project, we will continue to teach investigative science.

Chapter 4

Introductory Biology: Science As A Way Of Knowing

by

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Science education is in a crisis! Choose any point in time and someone is making that statement. The message is always the same. Some constituency claims that science education is a disaster because it does not satisfy its needs. When American scientists are in great demand, as they were after Sputnik or as they are now in the development of the Strategic Defense Initiative and in AIDS research, we hear that there are serious flaws in our system of producing scientists. When some other nation advances more rapidly in science and technology we hear that their system of producing scientists should be copied. At the other extreme we are challenged by those who think we teach too much science and should be curbed in our efforts to present the scientific viewpoints on such topics as evolution.

While all these external forces are pressing for change in science education there are internal forces at work. The competition for students, the changes in curricula, changes within the workplace of the profession, shifting emphasis within the discipline of science; all these have an impact upon the teaching process and content of science courses. Scientists have been more active recently in studying science teaching and are adding their voice to the mountains of recommendations. If everyone has been crying crisis and demanding change for years why haven't we solved the problem? Perhaps there isn't really a problem. Perhaps there are many problems which we don't understand. Perhaps we know the answer but can't afford the solution. Perhaps there are solutions but they take time to work.

I'd like to describe some perceived problems with science education and offer suggestions which have improved the teaching of biology at Orange County Community College. I assert that there is no perfect message to be included in the content of a biology course nor any perfect method to deliver that message. But, I think it is important to know what your message is and that every resource be applied to improve its delivery. It is the method of science to share information and test its application to new situations and it is to that end that I would like to share my observations in teaching the science of biology.

THE COLLEGE

Orange County Community College was founded in 1950 making it one of the oldest community colleges in New York State. Like most community colleges it provides a variety of transfer programs to four year institutions as well a number of technical curricula designed for direct entry into the job market. The Biological and Health Science Division, one of five, is organized into seven departments:

Biology
Dental Hygiene

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Health, Physical Education and Recreation
Laboratory Technology
Nursing
Occupational Therapy Assistant
Physical Therapy Assistant

We offer General Biology, a two semester sequence for liberal arts students and Human Biology, a two semester introduction for students in the allied health curricula. In addition, the department offers a two semester course in zoology and two semesters of botany, originally designed for biology majors. Additional sophomore level courses are available in genetics, comparative vertebrate anatomy, anatomy and physiology, parasitology, and embryology. Special interest courses are offered in field natural history, nutrition, oceanography, forensic biology, avian biology, and dinosaurs.

HISTORY OF THE GENERAL BIOLOGY COURSE

During the 25 years I have taught in this department a number of trends have been apparent here and at other two and four year institutions across the country. In the sixties we experienced a growing enrollment in all areas of the department. The service courses in human biology and general biology had the bulk of the students but a healthy population of biology majors kept the sophomore level courses going. We experienced an abundance of quality and quantity in our students. There was a separation of biology majors into the botany and zoology courses, allied health students into human biology and liberal arts students into the biology course. The general biology course was a reflection of the botany and zoology courses which, in turn, were traditionally oriented as descriptive survey courses, strong on classification and structure and fact oriented.

As many as seven different instructors were involved in the course during the year, something that required extensive correlation and created much discussion. The course resisted pressures for change which were active through the sixties. We flirted with the molecular approach, we tried big books, small books, books to supplement and books to complement but never really abandoned the descriptive survey approach as the backbone of the course. Since the course was taught by so many different faculty there was no selective pressure for it to evolve in a particular direction so it shifted little from its original form.

After a peak in the early seventies the student population began to decline. Before the decline the course was consolidated into large lecture sections and the number of instructors in the lecture part of the course was reduced. At one point it was team taught by a biochemist, a zoologist, and a botanist (myself). It was at this time that the course made a significant shift. We divided the first semester into three equal parts; the chemical and physical basis of life, a survey of the animal kingdom, and a survey of the plant kingdom. The second semester covered organismic biology, genetics and ecology with emphasis decreasing in that order.

In the first semester each instructor taught the third of the course that was his specialty but the other two instructors were present to assist in AV materials, note and attendance taking and preparing exam questions from the lecture presentations. But they also did one unintentional but very important thing, they asked questions and occasionally provoked arguments by challenging certain points made by the lecturer. This started spontaneously to try to stir up interest and stimulate students in the large lecture halls. From student surveys and discussions with students we found some students were disturbed to hear a faculty member challenged to present the observations or data for a statement just made. If we questioned something how could the student know if it was right or wrong? They expected every statement made to be absolute truth to be accepted without question. Other students were encouraged to ask their own questions and apparently were secure enough to accept that there were things still in the process of becoming truth, that hypotheses once accepted could be rejected or that their instructor didn't know everything and should be careful to separate evidence from opinion.

After that brief experiment with team teaching in the early seventies the student population turned sharply downward, with the drop in biology majors being particularly noticeable. The decline affected majors and liberal arts students more than nursing and allied health which had to absorb the faculty previously involved in the general biology course. Since botanists are less easily absorbed into biology courses intended for nurses I began to teach most and finally all the sections of general biology.

Selective pressure began to work more constantly and the course began to evolve in a particular direction but definitely influenced by the colleagues and experiences of the previous twenty years. Now, if I asked why some topic was being taught or questioned the method there was no answer but my own and the answer was often, "because this is the way we've always done it and it would take great effort to change." Not very satisfactory answers but, if great effort was going to be required to make changes, it was important that the changes be carefully thought out. What should be included in the course content? How could that content be delivered best?

The first decision was to remove the plant and animal survey from the first semester and consolidate the topics common to plants and animals. This semester would deal with the unity of life with topics like the chemical and physical basis for life, the cell and its structures, respiration, photosynthesis, protein synthesis, mitosis, meiosis and genetics. The second semester remained organismic biology but with more time devoted to the plant portion. This change created some problems for the lab part of the first semester.

Previously we spent most of the labs displaying the diversity of the plant and animal phyla and dissecting some members characteristic of the various classes. Some new approach seemed necessary in lab to parallel the topics in lecture but nothing seemed quite what we wanted. Like almost everyone else we had borrowed or modified exercises produced by others and created some of our own. Like everyone else we learned that good lab exercises tend to be created out of the special circumstances of faculty and facilities that prevail in a department. We had a theme for the lecture, the unity of life, but we needed a theme for the lab that would tie it to the lecture in a complementary fashion.

I'm not sure how the answer arrived but I'm sure its seeds were sown in the long hours of discussions about lecture and laboratory objectives held during the team teaching days of the early seventies. During the early eighties the theme of the process of science began to become more prominent. While the amount of information exploded in biology and the emphasis shifted through "molecular", "ecological" or "genetic" phases, the PROCESS generating this knowledge had not changed and we never really taught this process.

It seemed to me that we were teaching the results of the method without really teaching the method of scientific inquiry itself and we were not relating scientific knowledge to the other types of knowledge we required in our degrees. The students did not see what they were learning as being relevant to their decision-making process. What was needed was a course where both the process of science and the products of science could be presented as related to other knowledge the student was gaining and that this package of knowledge would be invaluable in the decisions the student would make in life.

The course, General Biology I, that resulted attempts to teach basic information common to all life as well as the process of scientific inquiry which produced it. For example, instead of having a lesson on the scientific method someplace in the course, the course would have the theme of scientific inquiry imbedded throughout.

THE LECTURE

In the beginning of the course we discuss the concept of "knowing" and how we come to know anything. (The introductory chapter in Guttman and Hopkins' text, Understanding Biology, published by Harcourt, Brace and Jovanovich is an excellent source.)

We describe knowledge as being analytic (true by definition) or synthetic (acquired by authority, intuition or observation and hypothesis testing), and try to demonstrate the difference through examples suggested by the class. Try asking a first day class, "Does anybody here know anything?" Total silence reigns! Eventually you can get someone to admit to knowing their name and you have a beginning. Students usually begin to see how much they depend upon authority for the knowledge they have.

If you can get some discussion going you can find examples of things students know because they feel right to them. This can get you into those areas of knowledge which we believe because they seem right to us. Somewhere in this discussion a difference of opinion will arise or you can create one and it becomes apparent to students that different perceptions of the truth based upon different authorities and intuitions can lead to conflicts which are difficult or impossible to resolve. Many examples of local or global differences can be cited. This discussion can become as lengthy and vigorous as you like but eventually you must introduce "observation and hypothesis testing" as another way of knowing that is very valuable because of its internal self correcting nature. Here's the point where the elements of the scientific method can be introduced and its components explained. I usually give the introduction the historic approach using the paradigm shift from a geocentric to a heliocentric solar system.

In this section of the course we ask students to be critical of what they know and are asked to know. We want them to be able to recognize whether knowledge is based upon authority, intuition or observation and hypothesis testing and that for those things based upon the scientific method of inquiry it is entirely proper to ask for the observations which support the hypothesis. We also attempt to assure them that the scientific method of knowing is not the only way - that many questions are beyond its reach. The discussion that follows usually draws out examples of unverifiable or unfalsifiable hypotheses which are temporarily or permanently beyond our ability to observe.

These introductory discussions can be very effective in setting the tone and level of the course. I often hear students saying, "We never talked about things like that in high school!" Not a bad beginning for a course in higher education. Students begin to understand the ways in which their knowledge affects their decision making process. For the first time in my teaching experience I've felt I was addressing directly those objectives stated for our college degrees. The subject matter for the rest of the course is presented with constant reference to the process by which the knowledge was gained.

THE LABORATORY

Ideally, the laboratory is the place where students do science. It should give the opportunity to form and test hypothesis by observation and experiment. More often, though, students follow the recipe created by someone else and little reflection goes into the forming of questions, hypotheses, and the design of experiments to test them. The result is that students think science is merely following directions very carefully so that you get the right results. We offer the following alternative laboratory exercises to support the lecture approach.

Scientific Method Activity

Our laboratory which parallels the lecture introduction, "Science As A Way of Knowing" demonstrates that observation and hypothesis testing is a process common to human thought and not some special technique employed by scientists. Students work in pairs in solving a problem by whatever method they choose. Their problem is to determine the contents of a small pillbox - without opening the box. They keep a list of the steps they follow in solving the puzzle and have but 15 minutes of a two hour lab to solve the problem. We have been using this lab for so long we can't recall its origin except that it was in a manual once used in the course. This is a good beginning lab because it needs little preparation, can be modified easily, and it introduces students to the course and to each other quickly and in a non-threatening way. Besides, you can have a lot of fun with the discussion.

Students will approach this problem in certain reliable ways but there are enough surprises to keep it interesting for the instructors. When students ask me questions about their problem I refuse to answer on the grounds that when doing science you don't have someone sitting in the corner ready to tell you when you are right or wrong you must depend upon your observations and experiments to do that for you. Their task is to show me evidence, convincing me of their answer. Opportunities exist to discuss the nature of observation, perceptions, hypotheses, biases, and error during the summary of the lab.

Observations Activity

For years we had done the traditional microscope lab with letter "e", crossed threads, and common objects. We found that as years went by we had very few students who needed to learn at this level. Many had already done the traditional exercises one or more times and were bored with the lab. Now, we have a slightly new approach.

The traditional lab is still in the lab manual, available for those students who need a first experience. We provide all the materials in the lab and make the lab available out of class through our departmental Learning Resources Center. This room, staffed by an adjunct faculty member seven hours a day, provides facilities for audio and video tapes, computer programs, printed materials, and demonstrations placed there by faculty in our biology courses. Students can also receive faculty and peer tutoring through this facility. If a student needs more instruction and practice with the microscopes they are more

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willing to get it privately out of class than expose their ignorance in a class where the great majority already have the skill. The objective of the lab is to demonstrate how the ability to observe the very small led to the cell theory - a theme being developed at the same time in lecture. We can show how any hypotheses about the nature of cells remain in the category of nonverifiable until the ability to observe cells is made possible by the microscope.

In the lab we compare the operation and limitations of the dissecting and compound microscopes. We talk about the circumstances requiring the various techniques of staining, squashing, sectioning, and lighting and how these techniques reduce limitations to observation. In the last half of the lab we visit our electron microscopy suite where students can see the transmission and scanning electron microscopes and how their techniques relate to the light microscopes. Students seem to appreciate seeing these instruments which are responsible for so many of the pictures in their texts.

Experiment and Date Analysis Activity

We try to do other classical labs with a changed emphasis. When we study photosynthesis and respiration we measure and compare dissolved oxygen and carbon dioxide in water samples containing goldfish or Elodea with control bottles. The emphasis is once again on the process. Before the lab is begun, students suggest hypotheses about photosynthesis and respiration that can be tested. We work with students, outlining restrictions that may influence selection of the experiment chosen. They find out that it's one thing to suggest a measurement of the amount of oxygen or carbon dioxide absorbed or produced but quite another thing to figure out how to measure it.

After they complete the measurements of dissolved gases they find they have accumulated a lot of numbers. Now, they must draw conclusions from these data. Each student is given data from all other groups and all other labs and asked to analyze the data and make conclusions.

They are evaluated on the basis of their ability to summarize the data, draw conclusions from it, and present those conclusions clearly. What conclusions they draw is not the critical element in the evaluation! Students struggle with this one a lot. They eventually discover they need to deal with questions like: Is this variation significant? Can I lump data from different experiments? How much data is enough? Which data are comparable? They discover that visual representations like graphs are more meaningful than ranks of numbers and that some graphs are better than others.

I want students to understand that data must be processed and that answers don't flow clean and pure from each experiment. In this lab the objective is to show that experiments must be designed to test hypotheses and that data from the experiments must be evaluated to determine if the hypothesis is supported, rejected or if it is a case for "back to the lab" to gather more data.

Communication Activity

This laboratory, perhaps our only original one, demonstrates the communication of information in science. Here we want students to learn how to tap scientific information when it is needed to solve a problem. We want students to understand that when the scientific process has produced results these results are distributed to others. We examine who those "others" are and how the communication takes place. We start with the student instead of the scientist and ask, "How do scientists communicate to you?" Usually the response is through the media such as television, magazines, and newspapers.

I give students an article taken from their local newspaper. This article announces that a team of scientists from the Centers for Disease Control has determined that some of our meat is contaminated by strains of Salmonella bacteria which are resistant to antibiotics and that consumption of contaminated meat has led to disease and death. These scientists further contend that these resistant strains are produced by feeding low levels of antibiotics to our farm animals. We suggest to the students that they have just finished breakfast, which included some meat, when they read this article.

In the discussion that follows we ask whether they believe the article or not. We relate this to earlier work on knowing by authority, intuition, or observation and hypothesis testing, and ask them what they think should be done about the problem or whether they think there is a problem or not. Usually you can find someone in the class who feels food additives are wrong and should be stopped. Usually someone will suggest that the authorities (the FDA) wouldn't let people put things into our food if it was harmful and others will accept the report as valid on the basis of the newspaper article. In this discussion an opportunity will arise to show that the observations supporting the hypotheses are not included in the article. What the students have is, at best, a second-hand account. They have been made aware of a problem but really don't have the data.

I then give them a full page article taken from Time Magazine dated about one week later than the newspaper article. Although giving more details and still a second-hand account, this one identifies where the observation and hypothesis testing can be found, The New England Journal of Medicine. I then provide students with the original article. As the students trace the information to the source they learn to appreciate the distinction between scientific publications and those the public usually reads. We analyze the parts of a scientific paper and explain abstracts, materials and methods, citations, and the value of references. In addition, they learn how to retrieve information from reference sources, how to distinguish between opinions and observations, how to determine who makes the decisions in matters which affect them and how to influence that decision-making process through the political process.

This two hour lab gives them one example of a real problem solving situation where the role of science is vital. As an out-of-class assignment each student must find a similar article and trace it to its source. They must provide me with a list of steps they took in their search and give me a copy of the original journal article which prompted the news article.

During the first few years of the evolution of this exercise I had one unusually good section with some very exciting students. At one point in the discussion I was making the point that communication in science takes many avenues. Scientists communicate with each other in ways different from how they communicate to us and we, in turn, communicate with scientists in our own ways. I asked for examples of how we communicated, expecting them to name some of the indirect ways citizens influence the scientists and their activities. One of my students asked if we could communicate directly with scientists by letter or phone and I admitted that might be possible since their addresses are recorded at the end of the journal articles. Some of the students found the address of the scientist at Centers for Disease Control who had written the study on Salmonella which we used in our lab and wrote him asking for information. Dr. Scott Holmberg personally answered each request and included reprints and testimony concerning the study problem. One student even called Dr. Holmberg and spoke to him! I never expected them to carry the exercise in scientific communication that far but I'm very pleased to say that every request for information was received with courtesy and patience. If all scientists and scientific agencies responded to the public the way the people at CDC did to my students science would never have to worry about an image problem. I received many reprints, data and even copies of testimony before congressional committees all of which have expanded the amount of data on the "Salmonella problem" which, by the way, remains unresolved.

The lab takes a real problem affecting the lives of the students and uses it as a vehicle to demonstrate how knowledge in general and scientific knowledge in particular can be mobilized to influence the decision making process.

THE EXPERIMENT

The final five weeks of the laboratory involves the application of the methods taught earlier. Students conduct breeding experiments with Drosophila to solve the mode of inheritance of an unknown trait present in a culture of flies. They must compare their flies with cultures of normal flies and determine how they differ. I usually give them some help by telling them the trait affects the eye, wing or body but they have to use their own abilities to observe with the microscope to determine the trait. At this point in the course they do not have a background in genetics but this is not important. (After all Mendel didn't know much genetics before he started his experiments either). Students are instructed on how to breed the flies and some pertinent techniques.

By the time the experiment is concluded they have had genetics in lecture so they can usually solve the problem. I only insist that their data support the hypothesis they suggest. I am not concerned with what the results **should have been!** For example, if a student mated wingless flies to winged flies and got winged flies throughout the F1 and F2 generations the results are certainly not the expected but all the student need do is provide a hypothesis consistent with the data to receive credit. If they present alternative hypotheses I ask them to suggest an experiment or experiments which might test the hypothesis. I often find the students get more out of failures than successes. When I hear students asking, dejectedly, "What should I have gotten?", I tell them, "Your results are a reality. They are exactly what should have happened when you did what you did." We usually can use this as an introduction to the importance of precision in keeping records of procedures and the value of repeating experiments.

SOME FINAL THOUGHTS

The approval for changing the biology course in the ways described above was given in 1982 and implementation began in 1983. In 1984 a colleague handed me a copy of a publication from the American Society of Zoologists entitled, "Science as a Way of Knowing." I also received a copy of the same article reprinted in the September/October issue of the Journal of College Science Teaching. It was a source of comfort that I was not alone in valuing this approach and seeing its place in an introductory liberal arts biology course but it's unfortunate that I hadn't seen these sooner - it would have saved some time.

It is not necessary for someone to duplicate this course to adopt the same objectives. I'm convinced there are many effective ways of teaching science but for my students in my institution and with me as their teacher I submit that this is the best approach I've found over the last 25 years.

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Chapter 5

Field Experiences In Biology

by

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Molloy College is a Catholic co-educational college sponsored by the Sisters of St. Dominic of Amityville. Since its founding in 1955, Molloy has grown dramatically and now numbers over 5,000 alumni and approximately 1,600 students. The College awards degrees in 35 majors including Biology and Cardio-Respiratory Sciences. Our students are drawn from Long Island communities and about 90% of them work at local part-time jobs to help defray their expenses. Within a 15 mile radius of our institution are three large universities, C. W. Post, Hofstra and Adelphi, but students are attracted to us because of their preference for a smaller college with a more personal and religious atmosphere as well as for the programs which we offer.

OUR GOALS

Over the years we have tried to expand the vistas of our campus and our students' knowledge of professional career opportunities while applying their learning to specific field sites. In this spirit, we instituted an internship program for our biology majors. During the field experience course students acquire practical experience through on-job voluntary work in off-campus facilities such as research, hospital, county and private laboratories.

By completing a three semester hour internship, we expect students to:

- **Gain** knowledge of the work of an agency through observation and hands-on experience.
- **Experience** doing biology-related work in an agency outside college, bridging the gap between the academic and professional worlds.
- **Be able** to choose a career based on actual experience.
- **Learn** through contact with professionals in the field.

Too many students are concerned merely with earning a college degree with no idea how they may use their education in the future. On the other hand, students who have an experience in the real world of work often orient their thinking and crystallize their aspirations toward an attainable career goal.

THE PROGRAM

This course requires 80 hours minimum of Laboratory work and 5 hours of class time. Most students do the clinical work in the summer and meet for the 5 hours of Seminar during the fall term. Prerequisite courses depend on the criteria specified by cooperating agencies. Normally, by the end of the sophomore year, our students have taken Inorganic and Organic Chemistry, General Biology, Bacteriology and Genetics, which are sufficient to prepare them for the laboratory work of most agencies. The Board of Health desires a background in Hematology and Immunology, so Juniors are better able to handle this experience in the summer prior to their Senior year.

Initially, locating appropriate agencies where our students could obtain a worthwhile experience took much time. Some of the area hospitals were already committed to other colleges to train their medical technology students and were unwilling to add to their workload. However, many agencies, other than hospitals, were available and were pleased to be associated with a college program. The question of insurance coverage for the students was raised, but quickly settled by the terms of the college's accident and health insurance for each student, since it provided 24 hour coverage on or off campus. In only one case, paid employees had to be briefed concerning their role as instructor, guide, and assistant to our novice students, so as to allay their fears that these volunteer college people might threaten their jobs.

The Director of the program contacts the agency and arranges for student interns and the individual student confirms the application and arranges an interview, if requested. The determination of starting and ending dates, daily work hours, and assigned tasks, as well as the expectations of both parties are addressed by the student during the interview with the Director of the Agency. During the field experience proper, the student is expected to observe, learn techniques, engage in the laboratory work of the agency, and pursue pertinent research. All agencies have source materials that are relevant to their areas and the students are directed to consult these as well as library holdings.

Every student must keep a notebook which includes a log of days (dates and hours) spent in the agency, a listing of daily activities, detailed descriptions of procedures (performed or demonstrated), and the researched information (with bibliography) related to the subject area of the agency. This notebook is read by the director of the agency and then given to the college supervisor for final grading. Students are also expected to share their experience via an oral presentation of about 20 minutes in length during the seminar hours set aside for this purpose.

In my dealings with these students, I am constantly reminded that we cannot take anything for granted and that some applicants for these internships must be coached as to their behavior in a job situation. In this respect, I have also taken the advice of alumni who have had the field experience and made their own suggestions for the neophytes. Hence, orally and in writing, I stress the following points:

Don't look for a teacher or tutor. You're on your own to observe and learn what you can and benefit yourself from available resources. You will be expected to perform after adequate explanation, so attention to instructions is a priority. This is a work situtation, and the employees have their own tasks to perform. Be helpful where you can, be patient until they are free, and be sensitive so as not to impede the work of the agency.

This experience is more serious than any course in that a mistake counts. Ask questions when in doubt. (This was deemed essential after one student blundered her way through a test for rubella on 100 specimens, and it cost the lab personnel an extra 3 hours of work to correct the error. The student claimed that she wasn't sure of the procedure, but wouldn't ask for further clarification).

The agency will evaluate you on the following points:

General performance - Are you careful, accurate, precise, not sloppy?

Cooperative spirit -	Do you ask if you can do anything; do you volunteer for extra work? (I learned that one student in the Medical Examiner's Office would clean the refrigerator to help the workers, and this was her own idea, - very gladly accepted).
Sense of responsibility -	Are you prompt? Call and excuse yourself if you are sick, ask questions if you are not sure, be ready to admit your ignorance.
Willingness to learn -	Do you observe the work without prompting? Do you do extra research and ask questions, not just to be inquisitive but to learn?
General attitude -	Do you show interest? Are you courteous, ambitious, pleasant, eager, and sensitive to the needs of those around you?

This will be one of the most important courses you ever take to ready you for work after graduation. Give it your best!

Topics covered in our course are synonymous with the types of agencies frequented by our students.

Agency	Type of Work
Medical Examiner's Office of Nassau and Suffolk Counties	Toxicological analysis using instrumentation to determine type and quantity of drugs and/or poisons.
Long Island Blood Services	Component separation for platelets, albumin, etc.; serological testing.
Tackapausha Natural History Museum and Preserve	Preparing skeletal specimens; participating in museum exhibits; museum guide and teacher of classes.
Mercy Hospital - Cardiopulmonary	Pulmonary function studies; O_2 therapy; arterial blood gases.
Hospital Laboratories - St. John's, Queens; Mercy; South Nassau; North Shore; Winthrop	Hematology, Histology, Chemistry, Microbiology, Urinalysis, Physical Therapy.
Howard Johnson's Food Commissary	Bacterial tests, fat and protein analysis of food products.
Nassau County Department of Health	Rubella and viral testing; microbial work - V. D., food poisoning.
New York Ocean Science Laboratory	Work with mariculture, cultivation of lobsters, algae of the sea.
Lifeline for Wildlife,	Care of sick animals and birds of

Stony Point, N.Y.	the wild; feed them and clean cages.
Old Westbury Gardens	Propagation and transplantation of plants; floral arrangements; greenhouse and outdoor work with flowers.
Franklin General Hospital	Pre-Med program in clinical areas of the hospital.
Sloan Kettering Institute for Cancer Research, N.Y.C.	Work with senior scientist on experiments related to cancer of liver or other projects.

As our program has become known, special requests are received, and thus it happened that one of our students mapped the streets of an entire village, located and identified each tree, checked for diseased vegetation and made recommendations for replacement of trees. For this she was awarded a plaque by the Incorporated Village of Bellerose. Another student joined a group from a neighboring University to survey many acres of marshlands near Jones Beach for the purpose of identifying and quantifying the fish, birds, amphibia, crustaceans and other life in the area. The Professor in charge recommended our student to the university administration and she received a partial scholarship for graduate work.

Students may request a field experience in an agency of their own choosing, provided of course, that it meets the approval of the College Director. For example, one student wished to accompany her parents to their vacation site, and asked if she could volunteer at a hospital there. After inquiries were made and permission of the hospital received, she was allowed to do this. During her stay, an epidemic broke out on the vacation island and the medical personnel were grateful for her extra help in the laboratory since hundreds of specimens had to be checked in the fight against the spread of the disease.

We advertise the program among the biology majors and provide times for interviews with the program director. As students respond, I ascertain their career interests (physical therapy, teaching, laboratory work, research), and inquire about their background courses in science and mathematics. Then, I telephone or visit agencies to explain the program (if new), and request positions for our volunteers. When I obtain permission from the agency, a student information sheet with name, address, telephone and background science and math courses is sent to the respective agencies. At that time I prepare students for what is expected and involved with their experience in the world of scientific work.

This internship prepares students for job interviews and gives them a readiness for task-oriented, paying positions. Competencies in relating to fellow workers and in responsibilities to management are developed with guidance, and all the fruits of an internship or apprenticeship are realized. In the interaction with workers in the agency, students gain considerable knowledge of the field, possible advancements in it, and direction as to the path they must follow to acquire the proper credentials as a professional.

All of the agencies use highly sophisticated, specialized and expensive equipment in their work. Colleges could not afford such machines, nor would it be advisable to purchase one that, for example, just analyzes 60 blood samples an hour for 125 chemical components. Our students learn to operate these machines and interpret their computerized results, thus adding immeasurably to the proficiencies gained in a normal college laboratory.

Students make enriching contacts with professionals in the field who not only provide jobs when possible, but supply letters of reference and, by their advice and encouragement, support our students. The students themselves realize the importance of such an experience and highly recommend it to underclassmen. Biology Department alumni have assisted greatly in recommending agencies and, in many cases, have obtained permission of their employers to take students into their own job situations.

At least one supervisory visit is made to the laboratory while the student is working, in order that he or she may perform and explain some of the techniques learned and explain the theory associated with them. This visit also gives the Director of the agency a chance to discuss the student's performance as well as to recommend changes or additions to the program. One such suggestion, on which we acted, was to increase the number of hours that the student had to minimally complete at the agency, in order to experience a greater impact of the work accomplished by the agency. Agency Directors also complete a written evaluation for the purpose of grading the students. Final grades are computed from notebooks of students, evaluation of the agency, and oral presentation of material which the student gleaned from the experience.

In order to stimulate other students to take advantage of this course, arrangements are made to have the students represent their agencies with exhibits of notebooks and photographs taken at their workplace (with permission of agency), oral expositions of different types of experience given to a General Biology class of Freshmen, and open discussions conducted at a meeting of the Science Club. The enthusiastic participants in the field experience are best fitted to engender an eager response from fellow majors. Faculty advisers also lend their support in promoting this worthy project.

EVALUATION

Student reactions, both written and oral, plus the reports of the agencies involved, provide the criteria by which a college Director can ascertain whether our goals have been achieved. For instance, one goal is the enabling of students to choose a career based on actual experience. One of five students working in a Cardiopulmonary unit of a hospital was plagued with emotional and physical signs of ill health resulting in absenteeism. We finally realized that this young lady was affected adversely by the hospital environment and, after consultation, she recognized this and turned to her first attraction, the teaching of biology. Many discover their careers through the experience, but others decide against the one originally selected.

A large number of summer experiences are followed by offers of part-time jobs for those still in college and full-time employment after graduation. The agency personnel have the opportunity to get to know our students and how they perform, two aspects which are critical to job offers. Two interns have received graduate scholarships in toxicology at St. John's University and one in Biology at Hofstra University on the recommendation of the Director of the Agency where they spent only five weeks.

In a unique situation, one of our students was asked to show her intern notebook to a job interviewer for a pharmaceutical company. The interviewer was not only impressed, but discovered that many of the machines, so meticulously described in her work, were also used in his firm. After she was

ERIC

employed, they asked her to leave the notebook on her desk as a valuable resource for fellow employees. She has since moved on to the Cold Spring Harbor Biological Laboratory, but her notebook has stayed behind.

Students agree that this experience gives them a self-confidence in facing the future after graduation. They are no longer fearful of how they will adapt to a working situation and they realize, from experience, that their studies have prepared them to perform well when employed. Truly, with new self-assurance, they have bridged the gap between the academic and professional worlds.

THE FUTURE

This course, inaugurated in 1971, is still increasing its student adherents. We are always considering and searching for new agencies and new types of experience to benefit our students and satisfy their varied interests.

After the internship, students return, highly motivated, to take more science electives and computer courses. They show more serious application to their studies and more direction in course selections.

Faculty now express a desire to attend the oral presentations where students give an account of their experiences. Thus, these presentations are scheduled at convenient times and the faculty notified of their occurrence. Some teachers also visit the agencies to obtain first-hand information on the current work and investigations of these laboratories.

At times the faculty has suggested making this course mandatory. So far we have not done so, because we feel a required course does not evoke the same motivation from a student as an optional one, and we want eager and enthusiastic students to bring Molloy College's reputation to the marketplace.

Chapter 6

Project INHALE--Cardiopulmonary Physiology

by

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Project INHALE (Intermittent Nonexhausting Heart and Lung Exercise), an addition to Anatomy and Physiology II at Suffolk Community College, takes the form of a voluntary ten-week aerobic training experiment. Documenting the effects of progressive cardiopulmonary exercise, students perform directly and intimately, both as subjects and experimenters, in research and the process of science. They experience the manner in which scientific data is collected, analyzed, and interpreted while receiving the physical health benefits inherent in the experiment. The project, generated as part of a larger restructuring of the course, enhances the involvement of the students and the effectiveness of the various instructional media and teaching techniques.

THE COLLEGE

Suffolk County Community College, a three-campus unit of the State University of New York, has a Western Campus on a 200-acre site in Brentwood, Long Island. The college enrolls 5000 full and part-time students whose mean age is 27. The school has a large mature adult population with the traditional student, 17-19 years old, comprising only 22% of enrollees.

THE COURSE

Anatomy and Physiology II enrolls about 250 students a year and is taught as part of a two-semester sequence by two biology faculty members of the Department of Natural Sciences. The course plays a central part in the training of nurses, physical therapists and other allied health students. In the nursing curriculum, it co-exists with microbiology, general and developmental psychology, and sociology as a core course.

An important elective for bioscience majors with an interest in medicine, dentistry, and other health professions there is some overlap with the cell and molecular coverage in the two-term biology course for majors. But, sufficient divergence warrants recommending the course to those with a clinical slant.

As general goals, we familiarize students with traditional concepts and vocabulary in a way that is highly student involved and process oriented. Then, as the principal objective we present human design in the context of a wholly integrated, self-regulating complex of cells, tissues, organs, and organ systems. A great deal of emphasis is placed on correlating form with function and placing this and other big ideas within the unifying framework of homeostasis. The content for this framework is spelled out in a list of cognitive objectives distributed on a regular basis throughout the course. Thus, students are given concrete expectations to provide orientation and direction. We omit highly detailed treatments of intermediary metabolism, finding an overview far more effective than reams of easily confused and forgotten fine points. Although pathologic conditions are stressed, many common diseases are excluded because of time constraints.

Another major objective is to engender respect for the process of science. Too often, students' perceptions of the manner in which scientific data is acquired is naive or misconceived. The course strategy directly involves students in an appropriately designed experiment to learn first-hand the rewards (and limitations) of scientific methodology. An appreciation of the systematic process of inquiry in turn fosters critical thinking and a higher level of intellectual freedom. Presentations stress how our knowledge of physiology is continually expanding and that theories are useful (but not absolute) constructs likely to be recast in the light of new findings. To do this, we provide hard evidence of the ongoing evolution of scientific information by supplying current literature references pertaining to classroom topics, along with a steady inflow of topical information from the popular sources, including newspapers (especially the N.Y. Times) and magazines (notably Science and Scientific American).

Another goal derives from our concern for an additional obstacle to success in this course -- a weak grasp of the biological lexicon and of the English language itself. Students tend to devote much of their time to whole word memorization rather than prefix, root, and suffix association. The complexity of biomedical terminology demands a holistic approach, one that is quite foreign to most of the students. Frequent laments include, "Why does spelling count?" and "We can't memorize all these terms!" These complaints stem from their deeply rooted tendency to ignore patterns and common threads within the linguistic fabric. They likewise fail to appreciate that well-chosen terms with a consistent and logical structure are ultimately more useful than vapid, nontechnical language.

Anatomy and Physiology II, organized into three hours lecture and three hours laboratory per week, has optional recitations and lab reviews periodically outside of regular class time. Other options include writing a monograph (on a relevant topic of the student's choosing) and participating in a forum debating a case study in anatomy. In the latter medium, argumentation opens students' minds to opposing viewpoints and demands an insightful analysis. Far too many students perceive anatomical pathology in absolute and inflexible terms. Encouraging different interpretations from the same body of evidence is a useful pedagogic device.

Students a'so study human anatomy first-hand at a cadaver dissection lab (SUNY at Stony Brook-Department of Anatomical Sciences) and at an autopsy (Suffolk County Medical Examiner's Office). In the 10 years since I began offering these options, the feedback has been overwhelmingly positive. In the course evaluation, many participants cite the postmortem examination as an invaluable part of their education. These visits make for indelible learning experiences as they vividly integrate the fragmented presentations in the classroom.

Contributing to the students' success, the sharing of the instructor's enthusiasm for the subject drives the lecture and spills over into the recitations. While good lectures go a long way, the great lecture offers embellishments including visual aids that dramatize and stir the imagination. Particulary useful are outsized (sometimes poster-sized) photos on foamcore and 35mm slides that take the student into the depths of human structure (scanning electron micrographs are a real motivation to all but the most jaded or uninterested).

AV catalogs are routinely scoured for short, poignant films. Personally produced videos and slides are used in class or in the library. We avoid complex visuals at all cost -- students gain little from crowded graphics. Slides, for example, never exceed six or seven lines of information.

PROJECT INHALE

While the entire course incorporates effective teaching methodology based on my fifteen years of experience in teaching the course, project INHALE has been particularly successful in bringing together these pedagogical elements in an innovative format. The INHALE project underscores how a protocol for hypothesis testing should be assembled. It was, in effect, designed as a vehicle to explain experimental design.

A second major objective of INHALE and, fortunately, one which can coexist beautifully with the first, is promoting cardiopulmonary fitness as a personal goal. Various measures of physical fitness (endurance testing, resting heart rate, body fat-to-lean ratio, and cardiac risk assessment profiles), demonstrate how much leverage a modest weekly investment of time and energy can provide. This is a great opportunity to drive home the premise that learning the workings of human physiology can be approached in innovative and dynamic ways. The impact of this experience is invigorating both intellectually and physically.

My middle-aged students, who outnumbered young adults by a wide margin, are eager to engage in a research project which mandates regular aerobic exercise. The older students are strongly motivated to get more from the study than a mere heightened awareness of cardio pulmonary physiology. For them, active participation holds the promise of slowing down the aging process and revitalizing sluggish (and in some cases, hypertensive) circulations.

Serving in the dual role of subject/investigator, students in the voluntary ten-week aerobic training experiment document the effects of progressive cardiopulmonary exercise.

Funded originally by a SUNY Faculty Grant for the Improvement of Undergraduate Instruction as well as support from the College, we want students to:

*__Learn__ fundamental principles of cardiopulmonary physiology.

*__Make__ cardiopulmonary adaptations to regular aerobic exercise through direct student participation.

*See how a scientific investigation is properly conducted.

Students first obtain clearance from their physician before engaging in any strenuous exercise. Moreover, sedentary individuals ease into the program by performing a series of light exercises for two to four weeks prior to their formal debut. An absolute minimum of discomfort guards against any untoward reaction during the mandatory beginning fitness test. In addition, lung capacity, blood pressure, and heart rate parameters are measured for all participants before the training program officially gets under way.

Last semester, 29 students distinguished themselves as INHALE graduates. All satisfied the minimum criteria for aerobic training, by completing three sessions per week during which heart rate was elevated to a computed "target

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zone" rate for no less than 15 minutes per session. The target zone, a personalized guideline, sets intensity limits during each exercise session. The lower limit is the threshold above which beneficial aerobic changes can be expected. The upper limit ensures that the exercise is indeed nonexhausting.

Students were instructed how to take their pulse rate manually during their exercise routine to encourage compliance with the guidelines. To keep motivation high, subjects were permitted to select whichever exercise they preferred as long as it satisfied the heart target zone criteria. The most popular cardiopulmonary pursuits were jogging and bicycling. Group results were quite encouraging.

Student Activity (N=29)
Mean Number of Weeks of Training: 10.2
Mean Number of Exercise Days per Week: 3.3
Mean Number of Target Zone Minutes per Session = 20.6

Table 1 shows some additional data we collected. Heart rate was measured by each subject upon arising in the morning and averaged over two consecutive days before and after training. Resting heart rate decreased during aerobic training program, usually one beat per minute per week for the first six to eight weeks. This improvement is especially dramatic for previously sedentary individuals. Consequently, heart rate changes provide a convenient index to measure training outcome. Using a paired t-test, we determined that the decrease in resting heart rate was significant. This training effect reflected a strengthening of heart muscle tissue, more blood pumped per beat, and consequently, less strain on the cardiovascular system.

Vital capacity was determined by spirometry. Training produced an appreciable increase in the quantity of air that could be inspired and expelled with maximal effort. This outcome is interpreted as a result of increased chest muscle strength and efficiency, resulting in improved functional lung capacity.

Analysis of blood pressure data showed a significant drop in systolic pressure but no change in the diastolic level. The latter observation is explained by the fact that the vast majority of subjects were normotensive for this variable, that is, their diastolic pressure readings were within the normal range. Normotensive readings are not expected to change substantially in response to regular exercise. When changes do occur, as in the sytstolic readings, improved blood vessel elasticity is believed to be responsible.

Maximal oxygen uptake, the most reliable indicator of cardiopulmonary fitness, is defined as the quantity of oxygen the heart and lungs can deliver to the tissues during maximal effort. Because it would be impractical--and for some, hazardous--to measure this variable directly, two submaximal tests were employed. Each subject was given the choice of either a run/jog test where distance covered over time is recorded (Cooper method), or cycle ergometry, a test comparable to pedaling a stationary bicycle (performed at the Pulmonary Function Laboratory at University Hospital, SUNY at Stony Brook).

It should be emphasized that these tests yield a predicted VO_2 max that may differ considerably from the actual value. This is accounted for by differences in mechanical efficiency among subjects and other uncontrolled variables. Thus, students were cautioned against taking oxygen uptake scores at

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face value or comparing them with the scores of other subjects. However, for the purpose of assessing the cardiopulmonary training effect for individual subjects, the method is very useful. Participants served as their own controls and could rely on the before and after measurements to gauge their progress.

Table 1
INHALE Results
N=29

Factor	Pre	Post
Heart Rate	67.6	61.3*
Systolic B P	119.3	115.1*
Diastolic B P	80.0	78.4
VC	3.5	3.7*

HR = heart rate, VC = (lung) capacity, BP = blood pressure
*significant at p <.01

Because of the limitations of the submaximal tests, no attempt was made to draw conclusions from grouped data using parametric statistics. Outcomes were analyzed by the nonparametric sign test. By this method, the before and after differences were judged to be significant at the .05 level. (The average increase was 17%). Increased oxygen-carrying capacity is attributed to a combination of increased heart output and greater lung capacity.

SOME STUDENT REACTIONS

Assessment of student learning was made via a research paper which included the hypotheses, a discussion of basic cardiopulmonary physiology, methods used, and the tabulation and interpretation of results. A bibliography requiring familiarity with the literature in applied physiology was distributed. Students liked this project and learned from it.

"Acting as the subject and researcher gave better insight and interest to the topic".

"The project was an interesting experience from the standpoint of seeing firsthand how some physiologic principles work as well as feeling their effects."

"(In) a study of this type, the results are more important, the research and interpretation is looked at more closely due to the personal involvement."

"...the increase in my VO_2 max and physical endurance has enabled this student to devote long hours to research papers."

While measuring the success of a course is difficult to do in a wholly objective manner, several criteria have been applied that reasonably reflect the impact of INHALE and Anatomy and Physiology II. First, student feedback in the post-term evaluations is extremely favorable. These unsigned questionnaires depict the course as well-organized, interesting, and offering a much greater than average return on one's intellectual investment. Input from faculty teaching higher level courses for which Anatomy and Physiology II is a prerequisite has also been very positive.

Within the INHALE cohort, performance on a special cardiopulmonary diagnostic test is higher than the norm. INHALErs also have demonstrated a superior ability to integrate principles of heart/lung anatomy and physiology. The required project report offered more evidence of their grasp of the subject matter and comprehension of scientific methodology. By any standard, INHALE's non-traditional approach was an unqualified success.

EVALUATION

Success in Anatomy and Physiology II can be measured in several ways. For some, surviving the demanding sixteen-week regimen with a passing grade is a triumph. Certainly there are intangible barometers. A student leaving with renewed enthusiasm for the body's marvelous integration of cells and systems is a sign of effective teaching.

THE FUTURE

Anticipated changes center on expanding the student participation regime of INHALE to other organ systems. The value of **engaging** students in the learning process is, I believe, the most important lesson to emerge from Anatomy and Physiology II.

The introductory course - Anatomy and Physiology I - has benefited from several of the pedagogic models introduced in II. Self-paced tutorial modules and videotapes have been added to the Learning Center. The INHALE results have been packaged in a color slide set and are readily available to other instructors. The INHALE documentation is also transferrable to our Aerobics course. INHALE works and we will continue to use, modify, and appreciate it.

Chapter 7

Applied Chemistry For The Non-Scientist

by

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The University of Lowell is one of three state universities in the Commonwealth of Massachusetts. Its roots are in the strong history of its two predecessor institutions: Lowell Technological Institute, founded in 1895 as a textile school; and Lowell State College, chartered in 1894 as a teacher training institution. The University's seven colleges enroll about 13,000 students per year; eighty percent are undergraduates.

Applied Chemistry for the Non-Scientist has been offered at the University of Lowell, in one form or another, since 1972, with Ms. Smith generally teaching the Fall semester and Ms. Kelley the Spring semester. Initially, there were several sections, sometimes large. Now, we have but one section each semester since the College of Management Science chose to block schedule most of its freshmen into a biology course to meet the students' core science requirement. We limit current enrollment to twenty-five students per semester in order to provide the students with opportunities to conduct hands-on chemical activities during regular classes.

Over the semesters we have offered the course we and the students have engaged in a number of different types of activities, developed as instructional tools for teaching chemistry to non-science majors. These activities are somewhat unusual compared to the format of a traditional chemistry course and it is this departure that we feel contributes greatly to the effectiveness of this course for its particular audience.

COURSE GOAL

Regardless of changes in enrollment and activities, the goal of the course has remained unwavering and clearly spelled out in the syllabus each semester:
Each student will learn to think scientifically while learning the basic principles of chemistry. The purpose is for the student to become able to apply both chemical principles and the scientific method to current theoretical and practical problems.
By "learning to think scientifically" we mean the student:

- **Observes** phenomena and records what has been observed.
- **Distinguishes** between verified facts and opinion.
- **Manipulates** and controls variables and formulates hypotheses for what is observed.
- **Connects** concepts about the particle nature of matter with macro physical and chemical properties of matter familiar in everyday living.

ORIGIN OF THE COURSE

Applied Chemistry for the Non-Scientist began with both departmental and University concerns. We originally proposed this course out of our belief that all informed citizens need to be knowledgeable about the basic principles of chemistry in order to make their own informed decisions about issues and choices facing each of us. We saw that existing introductory chemistry courses did not spend any appreciable amount of time on the application of chemical principles or their connection to the familiar and the everyday.

In our judgement, introductory chemistry courses are traditionally focused on covering a certain number of topics within a limited time period. This makes it difficult for teachers to devote course time to developing the students' conscious awareness of either the process by which knowledge is developed in science or the relationship between a concept being studied and the many applications it has in our daily lives. Our colleagues in the Chemistry Department were supportive and continue to be supportive of our offering this course.

In 1982, the University initiated its core requirement that all undergraduates have exposure to the principle modes of thought in the areas of science, social studies, and the fine arts and humanities. Applied Chemistry for Non-Scientists was accepted as a course which met the requirement for exploring how science helps a person develop and use knowledge. The course was also accepted as meeting the requirement of a laboratory science, though it has no formal, separate laboratory component. The core requirement for science was to include a science laboratory, to permit the students to experience experimentation. Since students in Applied Chemistry for Non-Scientists have the opportunity to try out various aspects of experimentation in the classroom, the course was considered to meet the requirement.

THE COURSE - APPLIED CHEMISTRY FOR NON-SCIENTISTS

This course teaches the traditional content of introductory chemistry in an applied context that is effective in its ability to promote comprehension of chemical principles. An additional goal is for the students to be able to then use these principles, as an informed citizen, to evaluate current chemically related issues in the popular media.

By naming the course Applied Chemistry for Non-Scientists we intended to communicate to the University community something about both the content and the audience for whom the course was designed. While we would have preferred the simpler Applied Chemistry, "for Non-Scientists" was added to make it clear to registering students that the course meets their University core science requirement.

We have experimented with various texts for our course, but have found only two which meet our needs in covering basic chemical principles in adequate depth for student comprehension, while at the same time providing information on the applications of principles:

Miller, G. Tyler, Jr. Chemistry: A Contemporary Approach. Wadsworth Publishing Company, Inc., Belmont, CA, 1976.

Jones, Mark M, et al. Chemistry, Man and Society. 4th ed., Saunders College Publishing, Philadelphia, 1983.

At the time of this writing, both of these texts have become available in updated, 1987 editions.

The content of the course can vary significantly from one semester to the next but there is a core of material which is always covered. (After this is completed the students select the topics to be covered in the remainder of the semester.)

Some of the topics the students have often chosen to cover in the remaining time are:

Air and water pollution;
Energy resources;
Food additives and pesticides;
Drugs;
Toxic substances;
Polymers;
Biochemistry.

Our fundamental commitment is to the students' comprehending the fundamental relationship between particle properties and the behavior of matter on the macro or visible scale and the scientific process. We cover fewer topics in any semester in which a class demonstrates need for time and additional activities to ensure comprehension. Calculations are generally limited to those involved in metric conversions; in simple formula and reaction relationships based on the mole; and in the relationship between pH, hydronium ion, and hydroxide ion concentrations.

SPECIAL FEATURES OF THE COURSE

While we have a number of in-class, hands-on mini-experiments of 10-15 minutes duration which develop students' understanding of the scientific process, this paper will focus on library assignments and tests designed to link course content with its application.

Using Library Resources in the Course

Within the first two weeks of the course, we schedule a class meeting in the University library with the University's User Education Coordinator who has educational background in sociology and experience in a pharmaceutical library. She captures the students' interest in determining how the library's science and technology resources can help them and is quite convincing as a non scientist in communicating to them that chemical information is of value to them and can be fruitfully used by them.

Course assignments using the library have been varied.

During some semesters each student writes a major paper and then presents their findings to the class. Usually the student selects the topic. At times, however, a theme such as the chemistry of food has been chosen for the class by the instructor. The students must explore their subject in some depth. The focus has to be narrow enough for the student to be able to explore technical and chemical aspects of the issue/problem/topic with comprehension. For example, rather than "Air Pollution" a student would focus on "Photochemical Smog" or "SO_2 and Acid Rain," examining the chemical reactions which produce the pollution and those which cause damage to the environment. Rather than "Solar Energy" students have written analyses of specific technologies. In one case the student was enterprising enough to make a solar collecting device to operate a buzzer using a light bulb, a coffee can, and a solar "Super" cell obtained from Edmund Scientific.

In recent semesters, instead of one major paper, the students have had several library mini-assignments, averaging one every two weeks. These have been tailored to the course content. For example, students have been asked to find an article relating to electron transfer reactions. They have come back with photocopies of magazine articles on issues of interest to themselves: e.g. explaining automobile corrosion (a major concern in the northeast), or how batteries and fuel cells operate. For articles related to radioactivity they have found information on astronomy, geology, the uses of radioactive isotopes in medicine, and the technical issues involved in the pros and cons of nuclear power.

Advantages of the different types of assignments.

The assignment of a major paper has been very valuable to students who wish to explore topics of personal interest. They have been encouraged to explore, motivated by a topic of their own choosing. They have written about the chemistry of photography, wine making, hair and hair products, the athlete's diet, lead poisoning. One of our better papers was on the chemical waste from tanning and other industries in Woburn, Massachusetts. The student, who was a resident of Woburn, carefully researched the identity of the chemicals and the incidence of health problems among people living near the wells providing the city's water. Students have written about the effects of alcohol on the body. They have explored the workings and technical aspects of birth control pills.

When the papers were all on the same theme, the class was able to explore both the depth and breadth of the topic. For example, when the theme was food, students researched and shared information on various food additives, nutrition, and issues related to food production.

There are, also, major advantages to the use of the library mini-assignments. Students become knowledgeable about finding a variety of types of technical information and evaluating their sources for bias. This is clearly an advantage for fulfilling their roles as informed citizens. With mini-assignments, over the course of the semester they are exposed to much more varied information about applications of chemistry. These applications relate to their course content, giving them the connection, as they go along, between what they are learning and its meaning for them.

The types of library assignments given can be quite varied. They can involve having students find and bring to class information on two sides of an issue, such as the use of nuclear power plants as a source of electricity. We have found it important, with any library assignment, to have the students share their information with the class. In so doing, the individual doing the sharing gains a clearer understanding of what was read. At the same time, the remaining class members are exposed to more information than they would obtain on their own.

Testing

In recent semesters, we have been more apt to give the students frequent short tests, to help develop their skills in expressing themselves clearly and accurately. Where possible, the questions are structured to avoid student memorization of facts or definitions without comprehension. For example, students might be asked to describe one way in which atoms and molecules are alike and one way in which they differ. Students must use their own words to answer this type of question.

Where questions might be related to something the students have seen in class, there is usually something built into the question that was not part of the original activity, e.g. "Explain why solid sodium chloride does not conduct electricity, while sodium chloride dissolved in water does conduct electricity." Since the students did not observe the lack of conductivity of the solid, nor was it something discussed in class, they must think about what they know about the particles in each sample and try to draw conclusions.

If the library mini-assignments are due on the day of a test, interesting, individualized test content can result. For example, if the students have returned with information and articles on radioactive isotopes they can be asked both specific and open-ended questions:

> "**Write** a complete nuclear equation for the decay of one of your isotopes."
>
> "**Explain** the role of radioactive isotopes in the article you found."
>
> "**Describe** the relationship between the work described in your article and the scientific method."

We credit the information students have found and shared with broadening our own knowledge on many applications of chemistry.

While some questions on each test refer to chemical applications, because of course tradition and goals the entire final exam is based on articles from current magazine and newspaper articles. While short tests include both short answer and brief essay questions, the final exam is primarily multiple choice, with some fill in the blanks. The students may always use their Sargent-Welch Periodic Tables as a reference.

The press has become more interested in covering science topics, so that it is becoming easier to locate articles that span the areas we wish to cover in testing the students for overall grasp of course material. In addition, events sometimes time themselves all too well.

The accident at Chernobyl occurred in early May of 1986. Both then and at its anniversary, one year later, there were numerous articles about fallout, reactor containment, and so forth in the news. It was easy to duplicate some of the articles and then ask pertinent questions. An article entitled "Chernobyl offers a unique lab" in the April 27, 1987 Boston Globe, provided the basis for nine of the forty-four questions on the May 13, 1987 final exam. There were questions on radioactivity, reactors, the metric system, chemical and physical properties, and the technical accuracy of a statement in the article. For example, students were asked the question, "Which of these metal cations is commonly present in milk or cheese, $Ag+$, Ca^{2+}, Hg^{2+}, or CO_3^{2-}?" While we never discussed the contents of milk or cheese, either by process of elimination based on thinking about the properties of the ions listed or by general knowledge most students were able to select Ca^{2+}. The next, related question then had to do with their understanding of periodicity and their ability to use both the article and their periodic table as resources: "Give the formula and mass number for one radioactive isotope which could come from Chernobyl and take the place of the cation you just chose, in cheese and in bones." Another multiple choice question on this same article asked the students to speculate on the probable reason for boric acid being sprayed on the Chernobyl core, given our expectation of their awareness that boron is used in reactor control rods.

ERIC

EVIDENCE OF SUCCESS

The students have spoken freely of what they have gained from the course. Those who stated their fear of science at the beginning of the course, or who avoided meeting their science requirement until their senior year, have left the course speaking of their pleasure in discovering they understand and can explain some science and technology to friends and family. Students have asked if they could take another chemistry course. Some have decided, as a result of their success in the course, to major in science or engineering.

One of us has given students the same set of questions at the beginning and end of the course. Questions have related to course content, e.g. "What is a mole?" or "What is hard water." All students do better on the post-test than on the pre-test, impressed with what they have learned.

CHANGES FOR THE COURSE

Core requirements are again under review at the University of Lowell so the role the course will play with respect to meeting core requirements may change. We are not clear on the effect this will have on the course. But, we would like to include more of each of the following:

Hands-on, in-class experiments, to clarify and illustrate scientific principles and the scientific process;

Metacognition, having the students collectively examine and analyze their thinking processes, to improve their thinking skills;

Debates (with some students obtaining information on the pros and others the cons of issues) to improve the students' abilities to make judgments about the objectivity and accuracy of information they find.

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Chapter 8

Problem Solving In Analytical Chemistry

by

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Trinity College, a Liberal Arts College of about 1700 students, has a strong commitment to the sciences as demonstrated by the number of graduates in the sciences who pursue graduate education in these areas. The Chemistry Department offers majors in chemistry and biochemistry accredited to meet the standards of the American Chemical Society. Trinity normally places in the top 20% nationally in total numbers of ACS certified majors graduating each year. The majority of these students choose to continue their education in either graduate or professional programs.

At Trinity College courses in analytical chemistry and instrumental analysis are offered to students in their junior and senior years. Offering these courses to more advanced students than is normal in a chemistry program provides a greater level of knowledge and sophistication on the part of the students and allows course depth to be more advanced and innovative.

The major departure from the normal in analytical chemistry courses is the structuring of the curriculum around a major project similar to that which a student might encounter as a professional chemist. These projects involve identifying real life analytical problems, researching the relevant literature, conducting analytical procedures to gain information pertaining to the problem, and reporting the results as a professional chemist might.

GOALS OF THE COURSES

For students to know the discipline of Analytical Chemistry, they must have an understanding of chemical equilibria; an introduction to the process of analysis, from collecting a sample to analyzing and reporting the results; and an understanding of both the theory and practice of the use of modern instrumentation. Further goals, specifically pertinent to the use of the problem solving approach, are the ability to use chemical literature, to write a critical evaluation of literature references, to use this information to actually do an experiment, and to make both written and oral reports of the results.

In the evolution of this course over a period of several years, we observed that students did not really understand the need to review the literature and that even if they did (based on constructing a paper based on the literature) they had little real understanding of how the reading could be translated into the laboratory. Another major deficiency, which appears to be common to most undergraduate curricula, is that virtually all course laboratories involve standard laboratory activities. While the level of direction provided may vary, it is clear to everyone involved that the student is going through a process that the professor had laid out in advance. This situation does not exist in real chemical research and the ultimate goal of these courses is to provide an experience closer to that of the working scientist in this regard.

DESCRIPTION OF PROJECT ACTIVITIES

In each course, students are required to complete a project which extends throughout the entire semester. Students complete the laboratory component of these projects at the end of the term after using all of the specific techniques and instruments required for their projects. Table 1 shows list of the steps each student must complete. Each step is completed based on a table of deadlines appropriately spaced throughout the semester.

TABLE 1
Steps in Student Project Laboratory

Identify specific questions in which the student has an interest.
Conduct a detailed literature search to find ways in which the question can be answered in the laboratory.
Prepare a draft proposal for carrying out the project.
Revise the proposal for the project.
Carry out the laboratory investigation.
Report the results at an open "Poster Session".

In addition to the primary student projects, the normal laboratory experiments also contain some project components. These are included primarily for their motivational value. Each of the standard experiments has two parts. In the first part the student analyzes an unknown for which the professor is confident of the correct value. This provides a direct measure of the student's laboratory technique. The second part of each lab involves the analysis of a substance supplied by the student. The experiments that take this format are listed in Table 2. Typical student-supplied materials have included an analysis of fatty acid in "butter" in the student dining area, analysis of calcium in various dairy products, analysis of sugar content of a range of beverages, analysis of fluoride in toothpaste, and analysis of caffeine in coffee from various food services areas on campus.

In these brief experiments the students gain some experience with analysis of products of interest to them. The motivational goals of these exercises seem to be met. At the same time, activities serve to evaluate the quality of analytical technique and allow improvement. They also maintain a high level of student interest in the laboratory.

TABLE 2
Analytical Chemistry Experiments with Product Analysis

Determination of Calcium by EDTA Titration
Determination of Sugars by Periodate Oxidation
Gas Chromatographic Determination of Fatty Acids in Oils Using the Internal Standard Method
Liquid Chromatographic Determination of Analgesic Compounds by the Method of Standard Addition
Potentiometric Determinations Using Ion Selective Electrodes and Calibration Curves

Coulometric Determination of Vitamin C with Biamperometric Endpoint Detection

DISCUSSION OF PROJECT

The selection of specific questions is done in the first week of the term and takes the form of a letter from the student to the professor. This is limited to one page. In Analytical Chemistry the students must restrict themselves to questions in the form of "How Much...?" as these are easiest to answer within the context of the topics covered during the course. Each student submits a minimum of two questions and explains the reason for a personal interest in the answers.

Upon receipt of the student letters, the professor responds with suggestions as to which of the student's questions is most amenable to resolution with the instrumentation and methodology readily available. Most questions seem to focus on consumer products. Some typical examples from the last few years are listed in Table 3.

TABLE 3
Typical Topics for Student Projects

How much Vitamin D is really in milk?
Which brand of beer contains the most alcohol?
How much sugar is present in various wines?
What acids are present in wine?
How much aspartame and its degradation products are present in soda?
How does the nicotine content of regular and low tar cigarettes compare?
How much free sodium hydroxide is present in bath soaps?
What is the calcium content of hamburger and steak?
How much cholesterol is present in foods?
How much fluoride is present in various dental preparations?
How much free chlorine is present in municipal drinking water?
How much calcium is present in orange juice?
How much caffeine is present in soda?
How much caffeine is present in chocolate?

Since some of the projects are best conducted by more than one student, students are grouped by their interests to collaborate on the laboratory portion of their projects. In the course "Instrumental Analysis", all research topics focus on trace lead analysis. Therefore, the questions are in a sense predefined. For this course, the students are given several reference articles on the history and importance of lead pollution. Then, they choose literature research topics from a list designed to insure that at least one person in the class is an "expert" on every aspect of the analytical process. In this project, the entire class works together on a single topic, giving all students an experience working as part of a research group. As a secondary benefit, we identify leadership ability among the students. Experience has shown that the student with the best grades in traditional courses is often not the leader in the projects.

When students know more about the intricacies of trace metal analysis they begin to refine the choice of question. After the completion of the initial literature research, the class meets and chooses a specific hypothesis to be tested related to trace metals. A list of the types of trace analysis questions selected by past classes is shown in Table 4.

TABLE 4
Trace Lead Analysis Projects

Is there a correlation between lead levels in soil and vegetation between urban and rural areas?

Is there an increase in lead levels in the Connecticut river as the river moves past Hartford?

Which types of infant formulas expose babies to the lowest lead burden?

Does the processing of tobacco in the production of low tar cigarettes increase the lead in the end product?

What is the lead level in wines from various sources?

Are lead levels in canned tuna affected by the type of can used?

Is the level of lead in reservoirs related to the location of the reservoir relative to road and other lead sources?

Once each student has identified a project, the class is instructed in the techniques of literature searching through both hardcopy and computer access to Chemical Abstracts. One common difficulty that the students have in the analysis of consumer products is the lack of literature on some procedures. The enthusiasm of the students by this time, however, usually leads to creative solutions. One group which was attempting to study aspartame in sodas, for example, called several national beverage companies and the manufacturer of aspartame to obtain information. Many students have discovered the need to be aggressive and creative about finding all of the necessary resources.

The format of the research proposal is based on that used by the American Chemical Society-Petroleum Research Fund. It begins with a brief description of the significance of the proposed study followed by an extensive review of the pertinent literature. Finally, the students detail the exact approach they feel is justified based on the literature. Students may choose to follow a literature method exactly or may propose their own approach. In some instances, the students have chosen to evaluate several alternative methods in the laboratory prior to analysis of their actual samples.

The primary feature of the evaluation of the proposals is the involvement of the student's peers in the process. The initial draft proposal must have been formally critiqued by at least one other student in the class and revised to address the critique prior to submission to the professor. After review by the professor an additional peer review and revision is required before final submission. The students are encouraged to devote considerable energy to the peer review process through a grade sharing mechanism. Each student receives 75% of their grade on the strength of their own proposal and the other 25% on the value of their work as a peer reviewer as shown by the grade obtained by the student they reviewed.

The parallels between the student's project and the actual practice of chemistry are made specific by example. The students are given access to research proposals written by the professor. The process of writing an article for publication and the reviews received are also discussed. This is a direct outcome of the professor actively publishing original research and serving on the editorial board of professional journals.

The experimental work normally occupies 3 to 4 laboratory periods for four hours each. During the entire process of selecting and refining their projects, we advise students to keep the expectations within reasonable limits. For projects that appear reasonably simple, we encourage them to include either a large number of samples or to verify various aspects of the analytical procedure. The analysis of alcohol in beer for instance, is quite straightforward, a student can analyze a large number of brands. The analysis of calcium in meat by wet chemical methods, however, must be limited to a very few samples.

The major problem encountered in a project experiment such as this is that things frequently do not work as expected. One of the major lessons that the students learn from the exercise is the difficulty of replicating a literature procedure. Usually, however, students do perceive some positive results from the laboratory experience even in the worst cases and even when students do not answer their original questions.

A second difficulty is the impossibility of estimating exactly how long each project will take. Thus some students find they need extra laboratory time to complete their projects. We normally have been able to accommodate this need. The enthusiasm of the students for their projects is usually sufficient so that they are eager to spend the additional time required. In only one case did a student ever become discouraged and asked to give up. The best example of student enthusiasm was an effort to concentrate the lead from river water using ion exchange resins. The students constructed a massive apparatus to pass 10 gallons of water through the resins. Due to the poor equipment available, the device needed constant attention for several days. The students took shifts literally around the clock to keep the project working. The class enthusiasm was so great that all efforts to convince the students to find simpler alternatives were rejected.

The final part of any scientific investigation is to report the results. Having experimented with both written and oral reports to the class, the use of an open "Poster Session" format has proved to be the most useful. The session is run much like those at professional meetings. Each student or group is allocated a fixed amount of wall space to display their results. The session is advertised to the college as a whole and to other groups in the community who may be interested. Specifically, we have attempted to interest high school science students in attending.

The additional peer pressure of a public presentation of the results seems to enhance the quality of the presentation considerably. At the same time, the more relaxed environment of a poster session relative to formal talks is less threatening. Usually a large number of people can be attracted to attend a poster session generating a large audience for the student's work.

EVIDENCE FOR SUCCESS

That this approach is a success is based on the evaluation by the students after the course is finished. The projects have been consistently popular in spite of the large investment of time and energy they require. Students get a sense of accomplishment that is impossible with the traditional experiments. Students also learn something about the nature of the scientific endeavor that is not obtained from other types of lab experiences.

From the point of view of the professor, the projects allow for a much clearer assessment of the strengths and weaknesses of the students as they apply to realistic situations. It is particularly instructive to compare students' work

ERIC

on their projects with the quality of their work in the traditional laboratory environment. In many instances average students have proven to have leadership and organization qualities far better than those of the students who perform better in the traditional material. These observations are not surprising and have been validated in many cases by the outstanding graduate work done by these "average" students. In summary, the project laboratory environment provides learning in a situation that more closely matches the real world of scientific endeavor. Thus, it allows the students to match their skills and interests more closely to what they will experience outside the academic environment.

The success of the project approach at the advanced level has lead to the evaluation of similar approaches in introductory courses. We are developing an interdisciplinary laboratory in Chemistry, Physics, and Biology, which uses the project approach on a smaller scale by asking the students to design their own experimental protocols based on a simple discussion of the goals and available materials. This course is currently being tested on a pilot basis as a science honors program called the Interdisciplinary Science Program. The activities that prove successful in this program will eventually be incorporated into the instruction of all students in introductory courses.

The use of the Poster Session format for reporting student results has also become popular as a result of the success in these courses. The same format is now used for students in undergraduate research both in chemistry and in other science departments. The proliferation of such sessions may eventually require coordination into a local symposium within the sciences each semester.

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Chapter 9

Physical Sciences In Outdoor Experiential Education

by

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Linfield College, a co-educational, residential, liberal arts college has an enrollment of about 1200 students from diverse backgrounds and locations. This year's freshmen come from fifteen different states and eleven countries. The curriculum combines general education study (which constitutes about one-third of the student's total program) with major work from one of the twenty-one academic departments of the College. Members of the College community often refer to the "Linfield Experience," described in the College Catalog as "people learning, growing, and building together in an environment of caring and helping."

The inclusion within Linfield's general education core curriculum of a requirement for studying the physical sciences has been justified by the statement that "the well-being of the earth and mankind requires that citizens acquire an understanding of their physical environment and a feeling of responsibility for it." Students may currently meet their physical science core requirements by completing a standard entry level course in chemistry, physics, or by electing an introductory survey course in geology, meteorology, astronomy, or environmental sciences - physical. The course described in this paper, Outdoor Environmental Studies/Geophysical, has been proposed as an alternative way to meet the general education physical science requirement. It is presently a 5 credit hour elective course which counts toward the 125 hours necessary for graduation.

OUTDOOR COURSES

Outdoor experiential education courses offer excellent opportunities for teaching basic and applied physical sciences to non-science majors. Commonly several weeks in duration and emphasizing learning by doing, such courses provide students opportunities to become closely acquainted with their physical environment and to become familiar with some of the laws, theories, concepts, tools and applications of the basic sciences. For some students the active outdoor setting and the opportunity to learn through applied laboratory experiences makes learning about the physical sciences more palatable, stimulating, and interesting than it would be in the more traditional setting.

Two of the best known of the independent outdoor schools are the National Outdoor Leadership School (NOLS) and Outward Bound (OB). Both of these organizations have evolved into schools which offer wide selections of outdoor experiences for people fourteen years of age and older. These schools recognize and use both learning in the out-of-doors and learning about outdoor living and recreational skills. Information is available in the literature which testifies to the success of these schools in teaching outdoor living and recreational skills as well as enhancing personal growth and development, interpersonal effectiveness, and environmental awareness and conservation.

The Linfield College outdoor course, Outdoor Environmental Studies-Geophysical, has enjoyed major input from NOLS and OB with respect to both goals and techniques of achieving course goals. By capitalizing on the special knowledge and interest of the instructors in the outdoor experience, I believe we have succeeded in achieving the educational advantages mentioned above. By using the wilderness classroom to teach concepts of both content and philosophy of physical sciences we have strengthened other important dimensions of learning for the non-science major as well.

My convictions regarding the potential of the extended outdoor course format for teaching basic and applied physical sciences to non-science majors have grown and developed as a result of participation in such courses as a student and an instructor over the last fifteen years. In my capacity as Professor of Chemistry at Linfield College, I have also been involved in teaching physical science core courses in the more traditional classroom setting.

My initiation into the world of outdoor education came in 1973 through participation in a one-year pilot program titled "Linfield Out-of-Doors". Developed cooperatively by the faculty of Linfield College and the staff of the Northwest Outward Bound School (NOBS), it included a brief orientation for interested Linfield students and faculty in the spring, a three-week mountaineering course in the summer, and a pilot outdoor freshman orientation program in the fall. The stated objectives of the program followed NOBS goals closely and included: development of personal awareness of nature and self and the relationship between the two; discovery of the essential needs of man; motivation of students toward greater involvement, including academic achievement; and development of interpersonal skills that would contribute to the effectiveness of the college experience. The success of the pilot program caused Linfield College to incorporate features of it as regular parts of its offerings, in particular, an annual outdoor freshman orientation week.

After the pilot project, Linfield faculty continued to offer summer and winter extended outdoor experiences similar to those demonstrated in the pilot project. To broaden our viewpoint about outdoor education and to improve our outdoor knowledge and skills, several Linfield faculty have requested and received staff development funds from Linfield to attend courses at NOLS. I have had the good fortune to attend several of these courses, including the Instructor's Course, and to work for NOLS as an instructor at their Wyoming, WAshington, and Alaska branch schools. We have experienced at NOLS a dedication to backcountry conservation, an excellent teaching staff, a desire to teach people safe backcountry recreational skills, and an outdoor course format that encourages teaching and learning about the environment in which one lives. It is within a similar format that I have been experimenting with the teaching of the physical sciences to non-science majors.

THE COURSE

The academic year at Linfield is broken into a Fall Semester which ends before Christmas, a Winter Term, and a Spring Semester. During the four week Winter Term students are limited to one academic course. The class lasts for 28 days in January and early February and consists of ten students and two instructors (class size is limited by the policies of the U.S. Forest Service, Deschutes National Forest). The class meets in the Central Oregon Cascades, employing as a base camp a Linfield College cabin near the boundary of the

Three Sisters Wilderness Area. The cabin is primitive with no electricity or plumbing.

Although there are neither academic nor skills prerequisites for the course, good health and physical condition are essential. Students apply for the limited number of places in the course and instructors are able to select participants on the basis of their past academic performance and an interview to determine their level of interest and maturity. Students are required to read two books before the course begins (Items 1 and 2 on the reading list) and then to do selected readings from other books during the course.

Because of uncertainties with the winter weather and the exact circumstances the students will encounter their first day in the field, the initial two days of the course are spent on the McMinnville campus. Priority activities of these days include checking and issuing essential clothing and equipment, making sure students have the necessary knowledge concerning use and care of the equipment they might need during their first days in the field, and making sure students are prepared for the environmental hazards they may encounter immediately in the field. Daily schedules for days in the field are pre-planned; however, winter weather often forces schedule modifications.

Supplies are stored at the cabin before snowfall makes it inaccessible to automobiles. Then, the class returns to the cabin several times during the course for supplies and cabin-based activities. While traveling and living in the backcountry, students sleep and eat in living groups of three or four. They are responsible, under supervision of the instructors, for their food preparation, shelter, and care of their equipment. The course is graded pass-fail. Completion of the course results in a passing grade. Upon completion, we want students to have gained:

- **Knowledge** and to have developed judgement and skills essential to safe, enjoyable, and environmentally responsible living and traveling in the winter mountain backcountry.
- **Skills** associated with alpine and nordic skiing and to a lesser extent, those associated with rock climbing.
- **Awareness of** self and nature, to have identified personal limits, and to have recognized one's roles in society and responsibilities to self and others.
- **Capacities** for responding to and effectiveness in communicating with others and for forming constructive, cooperative relationships around common projects.
- **Familiarity** with new fields which may stimulate further study or creative activity.

(These goals have evolved from our early association with Outward Bound and some phrases are quoted directly from OB literature.)

A variety of methods are used to attain the course goals. We have lecture-discussion classes that emphasize skills acquisition and development. These are activity oriented and can be characterized as "discuss, demonstrate, and do," followed by performance evaluation and further practice. Other classes emphasize theory and principles on which performance in the skills and safety in the backcountry depend. We make opportunities for individuals and groups to practice skills and apply knowledge through problem solving. Students develop judgment through simulations and actually planning and participating in activities that have been studied and practiced. Group discussion helps to assess critically individual and group performance. We encourage self-evaluation by questioning and working individually with students. We always have impromptu classes when special opportunities for observation and discussion are presented by the environment. Students make or aid in presentations on selected subjects, showing their knowledge and skills.

Table 1 outlines topics which must be addressed to meet course objectives. Some items in the list, such as use of equipment, are treated briefly and may involve simply a demonstration, practice, and evaluation. Other items may provide material and reason for several classes and continued attention throughout the course. While the order in which topics are taught varies with the weather encountered during a particular course, we give initial priority to the basics of food, clothing, shelter, safety, and comfort. Winter backcountry travel techniques are normally covered next. We estimate the minimum instructional hours involved in adequately covering the topics in Table 1 at 85 hours, not including additional hours needed for skills practice.

Table 2 outlines some of the physical laws, concepts, properties, and instruments that are used or taught in an effort to enhance understanding or enjoyment of the topics outlined in Table 1. Some items in Table 2 are much more pervasive than others. For example, I like to build several classes around the concept of energy and energy transfer. This emphasis can begin with the initial discussion of cold injury awareness and carry through clothing selection and use, shelters, nutrition, and trail technique. Later classes emphasize cold injury prevention and treatment, and the energy storage capabilities of modern climbing ropes and large masses of snow positioned on hillsides.

In the winter setting, the snow pack provides many opportunities for study and measurement, all related directly to safe and enjoyable winter use of the backcountry. Skiers should be concerned with the mechanical properties of snow, its metamorphosis, and the processes that occur inside the snowpack as part of this metamorphosis. In this subject area students use instruments, make measurements, observe changes in crystal morphology, construct graphs, interpret data, and make predictions. This work is better understood if they have gained familiarity with the basic states of matter and properties such as heats of fusion and vaporization and vapor pressure.

Table 1

An Outline of Topics That Must Be Covered To Meet Course Objectives

On Campus:

Course orientation	Stove care and use
Cold injury awareness	Pack packing and lifting
Tent care and use	Foot care

Basic Winter Camping Skills and Knowledge:

Clothing selection and use	
Shelter selection, placement, construction, Quin-zhees, Igloos, snow caves	
Snow kitchens	Personal comfort, staying warm and dry, body comfort control
Basic cooking	
Basic nutrition, food selection and use	
Campsite selection	Waste disposal, sanitation, hygiene
Fires in the backcountry	Backcountry ethics

First Aid Skills and Knowledge:

Cold related injuries, prevention	Skeletal systems injuries, splinting
Fundamentals, quick check, CPR	
Secondary survey	Head, neck, spine injuries
Shock	Evacuation, emergency procedures
Soft tissues injuries, burns	

Litter construction and use	Extended care under back-country circumstances

Backcountry Travel Techniques and Knowledge:

Skiing with pack and sled	Avalanche hazard evaluation
Trail technique	River and stream crossings
Navigation, map and compass	General hazard evaluation
Route selection	Expedition planning
Time control plans	

Environme¬tal Awareness; Selected Topics from:

Meteorology	Geology
Flora	Land use planning
Astronomy	Snow mechanics and metamorphoses

Group Dynamics:

Expedition behavior	Leadership and decision making

Special Skills:

Learning sequence, alpine skiing	Learning sequence, rock climbing
Learning sequence, nordic skiing	
Care of special skills equipment	

Table 2
Laws, Theories, Concepts, Properties, Tools

Laws:

Newton's laws of motion	Newton's law of gravitation
First law of thermodynamics	Fourier's law of heat conduction
Second law of thermodynamics	Dalton's law of partial pressures

Basic Concepts:

force	temperature	conduction
mass	gradient	convection
velocity	insulators	evaporation
acceleration	conductors	respiration
vector	states of matter	radiation
energy	diffusion	crystal
work	experimental uncertainty	heat

Instruments:

compass	transceiver	hand lens
thermometer	clinimeter	
altimeter-barometer	balance	

Measurements:

compass bearings	temperature
density	slope

Measurable Properties:

stress	strain	heat of fusion	angles
melting point	boiling point	reaction rate	heat of vaporization
vapor pressure	elasticity	thermal conductivity	
center of gravity	friction	relative humidity	specific heat
density	weight	energy	
atmospheric pressure		temperature	

Both of the major skills areas of the course, skiing and rockclimbing, provide opportunities to teach students the basic concepts of force, mass, and motion and some applications in the areas of statics and dynamics. Knowledge of concepts does not necessarily improve participation skills in these endeavors but does improve participant safety.

COMMENTS, EVALUATIONS, CONCLUSIONS

A major strength of the course is the laboratory approach or "learning by doing", as opposed to listening to lecture or reading another person's description of the world we live in. The course, by its nature, improves interpersonal effectiveness and helps individuals realize the importance of their responsibilities to self and others. The course is not conducive to exploring the micro theory of our universe quantitatively. Nor is the course conducive to exposing students to modern precision scientific instrumentation like the analytical balance or the spectrometer. However, in truth, neither are most general education science courses.

As part of the course students can measure snow densities, hardness, and temperature, measure altitude with a barometer, slope angle with a clinimeter and learn about experimental reproducibility and uncertainty through repeated observations and analysis of data. They can also experience how force is related to acceleration and learn about how their safety can be dependent upon their understanding the principles behind pulley systems and statics. They can also learn about creative and constructive use of leisure time, a legitimate educational goal since early in this century.

A significant problem associated with extended outdoor courses, and in particular with winter courses, is equipment expense. Because most students do not have the clothing and equipment needed for extended backcountry comfort and safety, the College must furnish these items. Requests through normal budgetary channels must compete with requests from all traditional areas. At Linfield, problems of expense have been solved by persevering in normal budgetary channels, seeking funds from outside grant sources, and seeking help from alumni. Although the course is expensive compared to traditional classroom instruction, it provides unique educational experiences for the participants. A possible alternative way to provide quality experiential education to students, without expenditure of funds for staff development and equipment, would be to seek a formal relationship with an established outdoor school to provide services.

Another course problem is time. Participation in only one of these courses is enough to make one realize to what extent time is consumed by basic living activities under primitive circumstances. This reality is an important learning experience for students but it also dictates that the instructors be selective and use available time efficiently in order to provide a quality learning experience.

Much has been written in the literature of outdoor experiential education about the use of stress in achieving goals. In our course there is no attempt by staff to contrive or artificially generate stress. We recognized that extended winter outdoor courses are naturally physically and emotionally demanding. Most days begin at 6:00 a.m. and end near 10:00 p.m. There is little free time or opportunity to be alone. Every attempt is made to apprise students of the format and demands of the course during student interviews and selection. The intended result of the selection process is to have a class of motivated, emotionally mature, academically successful, physically capable students who are eager to participate in a learning adventure. It should be clear that our intent is not to deal with the emotionally disturbed, the non-achiever, or the physically handicapped.

Special teacher preparation and selection for outdoor courses is essential. Teachers must have the knowledge and skills necessary for leading the course and,

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more importantly, the judgement to design and carry out a course that achieves course goals safely.

EVALUATION

We have not attempted to evaluate by quantitatively comparing the learning achievements in the physical sciences of these students with the achievements of a control group who have covered similar material in a more traditional setting. That might be an interesting project for a properly qualified team of researchers. Student evaluations of the course speak most often to a feeling of enhanced self worth, e.g., "I feel good about myself as a result of what I've done here."

A question raised by our Academic Dean was, "what fraction of the course credit can legitimately be allocated to physical science as opposed to physical education or health"? The answer is, in traditional terms based on numbers of hours allocated in the different areas, about 1/5 or 2/5. Given an audience of general education, non-science majors, however, and considering long term retained and useful learning about one's environment and the physical sciences, I believe the hours of instruction in the outdoor setting are more effective than those in the traditional classroom.

In summary, my intent in this paper has been to point out some non-traditional opportunities for teaching selected topics from the physical sciences to non-science majors. Further, based on my personal experience, I believe that for some students the backcountry can be an appropriate environment for achieving some of the accepted goals of education more effectively than can be done in the traditional classroom.

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Chapter 10

Land Use and Planning from an Applied Perspective

by

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THE COLLEGE

The State University College at Cortland offers programs of study in the liberal arts and a number of professional fields. The College views both liberal and professional education as integral to its mission and believes that all study which teaches students to think prepares them for earning a living as well as living a full life. The College is committed to excellence in all that it undertakes - teaching, research, and service to the community. The College also aims to help students develop the skills and attitudes needed to pursue personal excellence.

With an enrollment of about 5,600 undergraduate students, State University College at Cortland is small enough that students can get to know one another and their professors easily. Cortland's faculty is characterized by men and women who like to teach and whose enthusiasm for their subjects is contagious. Instruction, even at the freshman level, is by professors, rarely by graduate assistants. The College grants more teaching certificates than any other New York college. Undergraduate students in the sciences as a matter of course use the instruments in the College's well equipped laboratories for their academic work.

LAND USE AND PLANNING COURSE

During the environmental movement of the 1970's, members of the Department of Geology developed several courses in the field of applied geology, - one entitled "Land Use and Planning." This course was designed as an elective for students in any concentration, but recommended for students majoring in environmental science, urban studies, and geography. Since the first offering, the enrollment has increased from less than ten per semester to closed sections with every seat filled. Many of the students enrolled today are majoring in geography (Land Use and Planning is required for the B. S. in geography) or recreation and leisure studies.

The College encourages departments to offer new courses under a "topics" heading until the course demonstrates enrollment. The Department of Geology offered Land Use and Planning for several years under the topics heading before applying for more permanent status. The Curriculum Committee rejected it as a geology course because "it was too interdisciplinary" and should not be taught by geologists. The course outline was revised so that the lecture headings reflected the geological basis of each lecture and the materials re-submitted to the Curriculum Committee. The second submission was successful. The course has evolved from a seminar format to basically a standard lecture course.

THE COURSE

Land use and planning at State University College at Cortland attempts to demonstrate that land is a fragile, natural resource and the role of the planner is to identify constraints as well as opportunities for development offered by the landscape. The ultimate goal of planning is to provide a quality environment in which to live, good food to eat, clean air to breathe, and clear water to drink. The goal of the course is to acquaint the student with methods of planning and provide real problems to be solved using these methods. In the last three years I have used the "guided design" method for the students to work in teams and be responsible for more of their own learning. Wales and Stager (1977, p1.1) states "that the student who works through an ascending order of well designed problems, the student who is actively seeking solutions to problems rather than passively assimilating knowledge, will emerge not only better educated, but far stronger intellectually."

At the State University College at Cortland we recognize the value of outdoor and environmental education. Opportunities for study and field work have expanded greatly and many of the College's academic departments, and this course in particular, now make use of three adjunct campuses which the College has developed to support outdoor and environmental education programs.

Huntington Memorial Camp forms the major portion of the College's Outdoor Education Center at Raquette Lake, in the Adirondacks. The center, 150 miles from the main campus, provides an outstanding natural setting for more than 2500 resident students to participate in instructional programs each year. These programs emphasize the use of the out-of-doors in ecologically constructive ways.

The College's 170 acre Hoxie Gorge campus, only a 15-minute drive from Cortland, is a nature preserve used principally for short term field work in the natural sciences and outdoor education. Field station facilities accommodate up to 45 students at a time. Hoxie Gorge has a variety of characteristics, including hills, forests, and abandoned farm land, and bordered on two sides by 2,600 acres of State Forest lands.

State University College at Cortland has the only major geological field facility in the State University of New York system. The Brauer Memorial Field Research Station, located on the famed Helderberg Escarpment, is an area known to geologists as a classic region of fossiliferous limestone and shale formations of Devonian age. The 33 acre site contains classroom, dining and sleeping accommodations for 48 students and is used by the geology departments at Cortland and other State University Colleges as a base for studies of the Catskill Mountains, Mid-Hudson Valley, and Taconic Range.

The three adjunct campuses allow land use and planning students to study each of the major land-use categories and observe the impact of change on the land. At the Raquette Lake setting, in the middle of New York State's Adirondack "forever wild" Park, students see first hand the impact that humans have on a wilderness environment - from acid rain deposition to over use of the mountain trails. At the Hoxie Gorge campus, we observe encroachment of nature on abandoned farms and in contrast to the Brauer Memorial Field Research station, Albany's urban expansion across the Hudson lowlands.

Land Use and Planning can be divided into four basic headings:

Tools of the planner - topographic and geologic maps, aerial photos

Earth materials - rocks and soils

Events - floods, earthquakes and similar processes

Regulations and evaluation - laws and results

The first few weeks of the semester are used to view films of planned and unplanned developments and the procedures of planning. During this time, the class learns or reviews the nature of rocks because our dependence on rock is so basic that safe and efficient land use requires a quantitative knowledge of rock properties. Soils are collected on a field trip where the class observes soil-related hazards, limitations and opportunities. The soil samples are analyzed and classified in the laboratory. The analyses are later applied to the semester's project.

Weather as it relates to land use is considered because one goal of the planner is protecting structures from cold in the winter, heat in the summer, and adverse winds. Storms occur on fairly regular intervals related to atmospheric circulation, but destruction from such storms is increasing with increasing regularity because of a general disregard of sound land-use planning. The class examines hydrographs and computes flood frequency.

Land ownership does not give owners actual control of all uses of the land. Hawaii is the only state which has statewide zoning. Many reasons are normally cited for enactment of the land-use law, but the class learns that the main reason can be traced to the State's physical setting - volcanic mountains, fragile slopes, northeasterly trade winds, limited water supply and the impact increased population would have on the land, water, utilities and agriculture.

Our potential for producing change is growing at an amazing rate, but we have shown little awareness of the outcome. Our record on Earth shows more tendency to destroy than to improve the environment. Several examples of problem awareness and program implementation to improve the environment are examined. Examples range from citizen group action to county government's buying development rights.

In many ways this course follows a traditional format. The author lectures and examines, students complete project assignments and write reports. In a significant departure of this course from the norm, the project assignments relate to a single topic of timely interest and significance to the community. Most of my lectures relate to my actual experiences as a planner, especially in water and mineral resource evaluation.

The students are assigned an on-going project which is completed in steps as the course progresseses through the basic materials.

Most projects are a direct outcome of my professional experiences. The Projects are different each year. Three years ago, the County was developing a new sanitary landfill and the project took the students through the steps of evaluation of potential sites. The following year, the class evaluated a relocation plan for a major highway in the community. Last year a new housing development was analyzed. The project this year evaluates a proposed mine operation. Each project has been timely, in the news each week and in the vicinity to allow students to visit, collect samples, take photos, and include these materials in reports.

The course is in a constant state of flux. Each year we identify a new project and lecture/class demonstrations/field trips relate to the project for that particular semester. Exercises on soils and hydrogeology are being changed now and other exercises may be changed in the future. These exercises still ask students to complete various testing procedures but the student will then prepare text and graphics as if the materials were to be presented to a local planning board.

I have collected a series of video tapes treating various aspects of planning. These tapes are available in college media centers at times appropriate for the topics covered in lecture. Rather than a commercial text I use materials prepared locally. These materials are not yet ready for publication but utilization in class provides criticism necessary to improve content before submitting to a publisher.

EVALUATION

The response to the course has been favorable but the most satisfying aspect is the number of students who have gone on to internships in planning with public agencies and the number electing planning as a major in graduate schools. But, as the course instructor, I am concerned because some of the students come into the course with a minimum background in the physical sciences and these students can attain only limited success. I believe that my professional work and research combined with real-life projects in the region where the class can see first hand, motivates and stimulates interest for the duration of the class and beyond. Students call, visit and write years later asking about the outcome of the project - were their recommendations the same as those followed in the community?

Our College statement that "....faculty....whose enthusiasm for their subjects is contagious" may be true, for I have had many students pursue the subject much further even though several are not professional planners. It has, however, been difficult and disappointing trying to motivate some students to perform in the seminar sessions.

While well received by the students the impact of Land Use and Planning has been limited overall at the college. Two gratifying results, however, have been the addition of the course into the required category for the B. S. in geography, recognition by a few faculty that exercises can be designed from real-life problems, and undergraduate students can make a contribution to the solution of community problems.

Chapter 11

Mentors In Science

by

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Brown University, located in Providence, Rhode Island and founded in 1764, is a university-college comprising an undergraduate college, a graduate school and a medical school. In 1986 our largest enrollment was in the college, where 5541 undergraduate degree candidates included 2900 males and 966 Blacks, Asians, Hispanics, and Native Americans. The students' families are predominantly middle-class and approximately 25-30% are from New England. About 60% of the students major in the humanities, arts, and social studies: they are the special focus of this paper.

At Brown, undergraduate students must fulfill requirements with regard to their major or concentration, written English, residence, and total number of credits. However, there are no core or distribution requirements. The philosophy behind this was stated by the Curriculum Review Committee in 1985.

> .... the student's desire to learn is at the core of education. It is freedom of choice about what to take and when to take it that makes the classroom atmosphere at Brown so rewarding for both faculty and students. Freedom of choice is, moreover, itself part of the educational process, for with it students develop a sense of responsibility for reasoned and deliberate decisions about their individual intellectual development. It is precisely the experience of such independence that prepares students for the interdependence upon which all community and social relationships must be built. Such freedom would be idle were real choices not available ....

Throughout their undergraduate careers students are carefully and systematically advised about the importance of taking a broad distribution of courses drawn from the arts, humanities, social studies and the sciences. Thus, in spite of the freedom which would allow a student to graduate without ever having taken a single course in science and technology, most students take several such courses. Among the non-science concentrators in the Class of 1986 over 50% took four or more courses in science and technology. The challenge is both to increase this percentage and to enhance the experience of students in the science and technology courses. The Science Mentor Program was developed to meet both these goals.

OUR GOALS

The Science Mentor Program addresses the needs of three overlapping categories of students: those with restricted backgrounds in science, those uneasy about science courses, and those who wish to discuss science and technology in a small group. The Science Mentor Groups, offered as extra weekly sessions, are led by Science Mentors with strong backgrounds in science, teaching experience, and responsiveness to the needs of students. Over a period of three semesters Science Mentor Groups were instituted in several established courses with large enrollments (70-130 students) in biology, computer science, and geology. Science Mentors organized activities as supplements in these courses. These included laboratory sessions and demonstrations, field trips, review sessions, and discussions of some of the broader issues raised by the scientific discipline. Students responded favorably to this extra component of the course and to the additional contact that it brought with the Science Mentor, the course material, and the faculty. As Program Director, I worked closely with the Science Mentors and attended many of the group meetings.

One of the immediate goals of the Science Mentor Program was to reach some of the students who usually avoid science courses and to learn more about them, their views of science, and their reactions to innovations in science teaching. In seeking to do this an underlying concern was the decline of education in mathematics, science, and technology. There is widespread agreement that this decline bodes ill for the economic life of the nation and will severely affect the democratic process when citizens are required to vote on complex technological issues. A major component of this problem is the gap between those with training in science and technology and those without. Some of the latter have graduated from college without having taken a single course in mathematics, science, or technology. Even where one or more of these courses is mandated through core or distribution requirements, students may meet the requirements without having been fully engaged by the discipline.

THE SCIENCE MENTOR PROGRAM

This Program was first bought to the attention of students through an article in the campus newspaper and through academic advisers. Students known to be apprehensive about science or who had avoided taking science and technology courses were particularly ncouraged to participate. During one of the early class meetings of a participating course students received a description of the Science Mentor Program, including some of the activities planned for the semester. Students interested in participating filled out a tear sheet with their name, box number, and telephone number. They were then contacted by the Science Mentor to arrange the first group meeting. Students not attending this meeting were reminded about the Program by telephone.

Several problems occurred when we first began. The Science Mentor contacted students who in the first or second class meeting had expressed an interest in participating in the Science Mentor Program. Unfortunately, at Brown there is often a lot of turnover from this first lecture - some students will "shop around" in at least 6 or 7 courses during the first week of the semester, and may not attend a particular course again while others will join a course after the first or second meeting.

A second problem was that the Science Mentor Program was deliberately portrayed in a manner which did not emphasize how helpful it might be to the students' performance in the course. The faculty of the courses and I were afraid that any suggestions that participation might, for example, improve the students' overall grades, could lead to people participating in the program for this reason alone and could cause resentment among those students who, for various reasons, were unable to attend the weekly Science Mentor Group.

The third problem was that the initial information sheet about the program requested that students who participated in this program should attend all meetings of the group throughout the semester and should keep a record of their principal activities and ideas relating to the course and to their evolving concepts about science. This seemed a perfectly reasonable request and the student who gained most in the program did participate in all the meetings and did keep a record. However, given that the program was new, that students did not know exactly what to expect and what they would gain, this commitment probably seemed too onerous and may have deterred some students from joining the group.

Drawing on these experiences, we subsequently waited to describe the Science Mentor Program at the third or fourth class meeting when the composition of the class had settled down. Students received a short brochure describing student experiences from Science Mentor Groups in the past and outlining events which are especially attractive to the students, such as a tour of research facilities or a small group discussion with the faculty from the course. These involvements with the faculty and research facilities gave the Program legitimacy in the eyes of the students. In later semesters of this experimental program, the initial description of the Program did not emphasize that students should keep a record of their activities, but this aspect was raised in the second or third meeting of the Science Mentor Group. A special form developed for this purpose gave students a framework for their comments. Our experience has been that students are not reticent about expressing their opinions in this way, even when they were reluctant to write them down.

The topics covered in the Science Mentor Groups were an extension of the usual activities of the class. However, the extra time available allowed the faculty member to test out ideas for new exercises, allowed the Science Mentor to discuss wider aspects of the course material, and allowed the students to raise questions which they might be reluctant to ask before the entire class. For example, in both Biomed 12 and Geology 1 students examined material taught in the course that related to evolution and then discussed papers supporting and opposing creationism. In both these courses students analyzed the nature of scientific research and the place of science in a liberal arts curriculum. In Biomed 12 students read and discussed papers not covered in the course, for example, articles by Stephen J. Gould, and attended a seminar by Professor Cooper on the nature of the neuronal network which they then discussed with the Science Mentor.

In both Biomed 6 and 12 the Science Mentor reviewed material before examinations and discussed the graded exams upon their return to the students. Other topics covered in the Biomed Science Mentor Groups included: disease, health, genetics, hunger and exercise. There were laboratory visits to see demonstrations of a transmission electron microscope, use of light microscopy to identify algae and protozoa, and films, such as, "The Ascent of Man" and "Protists", followed by discussions.

The Science Mentor for Biomed 6 was able to supplement some of the material offered in the course by presenting an account of endochondral ossification when a description of this process was omitted from the bone lecture due to time constraints. He discussed concepts with his students at other times when he detected they were having difficulty in understanding the material from the lectures. For example, he gave them a presentation on glycolysis, the Krebs Cycle, and oxidative phosphorylation which

...provided them with considerably more detail than had been previously presented. I certainly did not attempt to list the names of all the intermediates, or the enzymes, but gave only pertinent conceptual information, such as the number of carbons in the intermediates and the sites of production of ATP. I concentrated on where the energy was and what form it was in as we traced it from the carbon-carbon bonds of glucose to the protons passing through the $F_1 - F_0$ complex.

At another stage, when he detected that members of his group had not understood action potential physiology, he developed a review session where:

I did not simply review the material presented in class. I took a new angle on it. I discussed basic thermodynamic energy concepts in order to enable the students to grasp the concepts of gradients across membranes. I discussed order and entropy as well as potential energy and work. I used the analogy of water turning a waterwheel. Clearly, the notion of ion gradients across membranes is predominant in many areas of physiology. Thus, we were able to utilize these basic concepts later on, during discussions on blood pressure and oxidative phosphorylation.

This idea of choosing some basic principles and returning to them time and time again during meetings of the group has proven to be very valuable. Another useful approach, both in the class lectures and in the Science Mentor Group, reinforced the knowledge of physiology by describing the effects of diseases which disturb the normal functioning of the body. A student commented, "It's really interesting to hear about the diseases affecting the different mechanisms of the body as we learn about the functions of the body, because the diseases become more logical and understandable. I think this will be the best thing I get from this class."

Our Science Mentors have noted, that students now are more likely to see biology to be an active science with 'hot' topics and involvement in interesting research rather than merely an endless array of picky facts to be memorized. And, the small group settings and flexibility given the mentors meant that topics could be covered as need is perceived.

The Science Mentor in Computer Science 1 (who was also a teaching assistant in this course), started the semester activities with discussions on computer terminology. Then, each student brought in an advertisement for a computer and explained the jargon about its capabilities to the others. In presenting their ad and answering questions, students revealed their true understanding. Then, the Mentor could instruct as appropriate. When graphics was being taught in the course, the mentor group went to the Computer Science Department, where graduate students demonstrated various graphics techniques and students experimented with Macpaint on the MacIntoshes. One Mentor group watched some episodes of the telecourse "The New Literacy", discussing each showing. In this way the students had opportunity to learn about and comment on such topics as programming, graphics, and privacy issues.

In another group, a computer science major gave hints on his ideas about the best ways of approaching the writing of programs. This material was not always covered in the Computer Science class and included how to conceptualize the assignment and how to assemble the final documentation.

One of the high points one semester was a talk by a Brown graduate now working at Lucasfilm. His personal account of the production and use of graphics in the movie industry stimulated student enthusiasm about their experiences. They all felt that the Science Mentor Group in Computer Science should continue. A first year student commented after meeting the guest lecturers that they helped to dispel her negative stereotype of computer scientists. Another student said she bought a Mac because everyone else was buying them - and had no clue what to do with it besides draw pictures. Through her Mentor group she learned programs to use in her concentration (Classics). Now, she also knows she can just use a program without having to program anything. One Science Mentor noted that his students came to terms with using computers in their daily lives. While they may never have to touch a computer again, each is able to deal with one effectively and comfortably.

SOME ORIGINS

My involvement with these activities began several months before the Science Mentor Program was instituted. I applied to the Association of American Colleges for a Quill Award in their program of direct grants to encourage liberal learning for scientific awareness. Funding was also obtained from the Provost and the Dean of the College at Brown University. This enabled us to pay the Science Mentors the same amount as teaching assistants ($500 per semester) and to meet other expenses such as photocopying. Overall, the Program proved to be a relatively inexpensive one since there was no compensation for participating faculty or for the Program Director.

All courses chosen for this Program were well established, most with enrollments in excess of 100. We thought the Science Mentor Program would be attractive to students in these courses by providing additional activities and support in a small group situation. I contacted the faculty of these courses before the semester began and discussed the concepts of the Science Mentor Program with them. Individual faculty nominated Science Mentors for the courses. Often the Science Mentor had been a teaching assistant for the course or was an applicant to be a teaching assistant. In two courses the Science Mentor also served as a teaching assistant and this arrangement worked very well.

The Science Mentors, mostly undergraduates, were interviewed by the faculty of the course and me, and the concepts of the program were discussed with them. Science Mentors met weekly with their groups throughout the semester. Occasionally the Science Mentors met at other times with individual students or groups of students. The Science Mentor Groups generally took place in the evening and lasted for approximately 1 1/2 hours, but some meetings lasted longer and some were held during the day. I attended many of the Group meetings, heard reports from the Science Mentors each week and met with them at the end of the semester to evaluate the program.

From January 1985 to May 1986 Science Mentors taught in six different courses relating to nutrition, physiology, biology, geology, and computer science. All but one of these courses were directed primarily towards non-science concentrators.

SOME BENEFITS

Clearly the success of the Program hinges on the Science Mentors and so I chose knowledgeable and intellectually acute students who enjoyed collaborating with faculty and working closely with their peers. I tried to be readily available to them - to discuss any problems or to share their enthusiasm for the Science Mentor Group's activities - while at the same time allowing them a high degree of independence in planning activities and in conducting their groups. The appropriate degree of my involvement varied between Science Mentors at different stages during the semester, for example, during the first weeks of the last semester I met with them more often and attended their meetings more frequently than later in the semester.

As a result, students in the Science Mentor Program gained a number of benefits from their exposure to issues which were additional to those covered in the regular course but which were of direct relevance to the subject matter of the course. Students reported more intellectual involvement in the course, a better understanding of the course material, and even better grades in the course as a result of their involvement in the Science Mentor Program. A student commented on the effect which the Science Mentor Program and Geology I had on her attitude towards science. She said that prior to the course she had believed that science is nearsighted and that it "peers at the world through an electron microscope, looking for answers it will never find and coming up with more questions instead." But then she observed, "Now I am not sure. Sometimes science does seem nearsighted, but this class is not at all like that. It is about the whole picture, things interacting and affecting people, and vice versa." Another student in Geology 1 observed, "Overall, the enthusiasm of the Science Mentor, his availability and dedication to the group have made the Science Mentor Program a memorable and valuable experience. Through the program, I have made new friends, and I have developed a serious interest in geology. Even though I will not be majoring in geology, I intend to take additional courses in the discipline."

Through their experience of working closely with the students, the Science Mentors determined which aspects of the course were confusing and which were most useful to the students. This information was usually discussed with the course instructors. Additionally, the extra labs, demonstrations, field trips and discussions allowed the Science Mentor to test out exercises and concepts which might be included in these course on a later occasion. In doing so, the mentors gained valuable teaching experience and learned by having to explain. Professors often complain about not getting to know very many of the students on an individual basis. While labs establish a smaller-group atmosphere four or five times during the semester, 30 students in a lab section is really too many to allow us to know our students well. Since we don't have enough TA support to have smaller sections and no longer have mandatory discussion sections, voluntary programs such as the Science Mentor Program are an excellent solution. Our students receive extra attention, our mentors gain opportunities, and our faculty see more motivation and understanding.

Although the number of students in each of the Science Mentor Groups has been small, those who have participated welcomed the opportunity to explore issues with each other and with the Science Mentor. While the small numbers of students involved make statistical inferences difficult, the proportion of women attending the Science Mentor Groups was higher than their proportion in class as a whole. This suggests that the Science Mentor Groups can help overcome the gender gap often noted in science courses. Dr. Jan Harding, a Director of the British "Girls and Technological Education" project, commented (New Scientist 99: 754, 1983) that "The feminist philosophy sees the development of science and technology as a particularly male enterprise, aggressive, controlling, abstracting, and 'objective'...". To some this may seem an extreme description, but the fact the Science Mentor Program is the antithesis of the characteristics which Dr. Harding describes, suggests that it may be particularly appealing to some women. Certainly this possibility will be carefully monitored in the future. Given the importance of attracting women to science courses and giving them support within these courses, this may prove to be one of the most important aspects of the program.

Because of the small sample size, we cannot really infer anything about the ratio of majority to minority students but we will study the appeal of this program to minorities, since they, like women, are underrepresented in science. In choosing Science Mentors both women and minority students should be well represented to provide role models.

THE FUTURE

In the future the Science Mentor Program at Brown may be directed towards enhancing science for both majors and non-science majors with a special emphasis towards encouraging women and minorities to take science and technology courses and perhaps even to major in one of these disciplines. The collaborative association between the Science Mentors and faculty suggests an additional mentoring relationship, namely, one that would serve the Science Mentors themselves and would encourage them towards careers in science. We envision a continuum through the undergraduate years in which students who have been Science Mentors would later work with a faculty member on a research project. Throughout this time, whether as Science Mentors or researchers, (or possibly both simultaneously) students would meet as a group to discuss science issues with the faculty and visiting scientists. Thus, at a formative stage in their lives, these students would become part of a community of scientists. This recognition of their scientific and teaching abilities, and their acceptance as colleagues should be important for the students and should be particularly encouraging for students who need assurance about their abilities and their place in science and technology.

It is apparent that the Science Mentor Program meets a number of diverse needs: it is attractive to many students, including some who are "science-avoiders", it provides Science Mentors the opportunity to be imaginative in their teaching, and it allows the faculty to test out new ideas for improving their courses. The balance of these different effects will vary in different circumstances but the conclusion from a variety of different courses is that thee Science Mentor Program can be a useful addition to science and technology courses.

The Science Mentor Program was designed to be applicable to science and technology courses irrespective of the overall composition of the curriculum (for example, whether there is a core curriculum or distribution requirements, or not) and the experience at Brown suggests that there was nothing about the Program that was uniquely suited to our curriculum and students. Further experimentation with this Program at other colleges should be very worthwhile.

Chapter 12

Interdisciplinary Interactive Video

by

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At Columbia State, human anatomy and physiology, taught by the Biology Department, is part of the core curriculum for the nursing program as well as programs in Radiologic Technology and Respiratory Care. Health science students need a strong background in human structure and function to help prepare them to be well-informed and safe health care practitioners.

Many of the concepts and principles taught in anatomy and physiology are directly related to skills taught in health science programs. Usually, however, students are exposed to these related content areas in anatomy and physiology independently from their health science courses which makes the transfer of learning between these disciplines more abstract and difficult for them.

CENTER OF EMPHASIS PROJECT

While the nursing department relies heavily on the biological sciences to provide the background related to human structure and function, traditionally there has been very little dialogue among faculty in these disciplines regarding content and sequence. Students were automatically expected to know how to transfer knowledge and to apply what they learned in anatomy and physiology to clinical nursing situations.

To solve this lack of dialogue, we developed the Center of Emphasis. The central focus of Columbia State's Center of Emphasis is on the production of state-of-the-art instructional media delievered in a laboratory setting.

The Center of Emphasis brought nursing and biology faculty together to determine content areas that were related and appropriate for instruction using an interactive format. By sharing resources, expertise, and experience, our intent is to develop an academic environment which enables our students to learn more effectively and efficiently both nursing skills and concepts and related biological structure and function.

This project integrates, where applicable, our nursing and anatomy and physiology curricula to accomplish a common goal of providing a sound and enriched educational environment for our students. This project is unique in providing our students with creative interdisciplinary teaching modules on human anatomy and physiology and related nursing skills. We combine concepts that are common to both disciplines and incorporate the related content into interactive video programs. With this interdisciplinary approach to instruction, we expect that our students will better understand and comprehend the relationships between human structure, function, and health care.

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Legislature. Funding was awarded based on acceptance of a competitive grant proposal submitted in 1985.

INTERACTIVE VIDEOS

While the production of media programs continues to be an ongoing project, the Center has already developed an interdisciplinary video series for the nursing department on preparation and administration of injections, including the relevant anatomy and physiology. We have also developed an interactive video series on the human skeletal system and cat anatomy to be used by students in the human anatomy and physiology program. Students viewing these programs watch a segment of videotape then answer questions by touching the appropriate box on the screen. If the response is correct, the computer continues with the program. If a response is incorrect, the computer will access the precise part of the tape where the content of the question was discussed. We use a variety of teaching methods in our video programming including linear video, animation, high resolution graphics, and a variety of highlighting techniques.

As our Allied Health students view the interactive video tapes and Computer Assisted Instruction (CAI) programs, they apply the knowledge of what they have learned to hands-on experience via both campus laboratory clinical training and hospital training. We feel our students will be better practitioners with enhanced decision-making capabilities following their increased overall understanding of the interrelationships between human anatomy and physiology and clinical nursing training.

Many of our interactive instructional video programs are taped, in part, in hospital and clinical laboratory environments. The Center of Emphasis provides our students with "real life" instruction in biology and health care that will provide them the opportunity not only to learn proper nursing procedure but to apply this knowledge to actual clinical situations. In short, the media programs we develop supplement classroom instruction to better prepare nursing and biology students in their academic and technical pursuits. The transfer of learning from one discipline to another and the overall understanding and comprehension of their studies is greatly enhanced.

GOALS

We want our instruction to use innovative and creative techniques to enhance the transfer of learning between courses. In doing so we want students to experience:

*Hands-on and media-based laboratory activities in all clinical nursing courses and in anatomy and physiology.

*Interactive video and CAI modules in nursing and human anatomy and physiology which focus on similar concepts with emphasis on transfer of learning. For example, the nursing component of the module will focus on particular skills while the anatomy and physiology component will focus on the biological principles related to those skills.

*An open laboratory concept focusing on competency-based education. This expertise includes a program director to oversee the implementation and operation of the Center; curriculum specialists recruited from faculty in nursing and biology who are responsible for developing learning modules and multimedia materials; media specialists and computer programmers for program development; consultants to provide expertise on media and computer program production, as well as discipline and instructional matters; a clerical support person; and laboratory assistants who monitor laboratories, assist students, and maintain supplies.

In providing these experiences we must develop, modify, or acquire:

•**Instructional materials** for each campus nursing laboratory and anatomy and physiology course which will provide a variety of learning styles in assisting students to accomplish required competencies.

•**Records management** systems to monitor student progress for both on-campus and in-hospital clinical laboratories.

•**Facilities** to support newly-designed laboratory activities.

•**Equipment and materials** needed for the production of video and CAI programs and laboratory demonstration supplies.

•**Self-teaching work stations** in the laboratory which students use to view video and CAI programs, as well as other teaching aides.

Once we have these capabilities, we will begin to assist in the instruction of students in other campus disciplines including General Biology, Respiratory Care, Radiologic Technology, Industrial Technology, Electronics, History, Economics, Psychology, and other programs, using similar innovative techniques.

DEVELOPMENT OF THE PROJECT

During the 1986-87 academic year, we began development of the Center of Emphasis at Columbia State Community College. Prior to development of our interactive video programs we needed to augment and upgrade our campus media production facility. We evaluated and acquired technical equipment that would allow us to develop high quality state-of-the-art video programs. New video cameras, character and graphic generators, editing systems, and other hardware were incorporated into our existing media production center.

The process of determining which types of hardware to use, integrating the equipment to develop the types of video programs we envisioned, and solving the numerous technical problems we encountered along the way was challenging and not without problems. Since there are few educational institutions involved with the production and delivery of interactive video programs, we had few resources to rely on. After one year we solved most of the problems and were able to produce the type of high quality videos we expected. In fact, we were able to modify some of our production equipment to perform functions, such as animation, that were not designed by the manufacturer.

Based on our previous experience in developing linear video tape programs in the biological sciences, we began development of interactive video programs for use in the Center of Emphasis. We designed our production facility to have the technological flexibility to develop creative instruction not only in biology and nursing but for other campus disciplines as well.

Once we determined the skills and content areas that were common to the anatomy and physiology and nursing curricula, we developed scripts for the interactive learning modules. Each script is storyboarded so all aspects of production are clearly understood by the technical staff who develop the module. Completed interdisciplinary learning modules are used in a laboratory setting as a supplement to traditional instruction. In addition, other learning modules were developed to teach concepts specific to each academic discipline. To supplement instruction we also use, where appropriate, commercial media programs and educational software following evaluation by faculty.

The programs we develop are primarily interactive video programs, although we also are involved with developing CAI programs. These programs are tailor-made to teach the specific content areas we deliver to our students at Columbia State.

Currently, we are in our second year of development. The first year was devoted primarily to researching, evaluating and purchasing media production hardware, authoring systems, computers, monitors, VCR's, software packages and other support equipment needed to develop video programming within the limits of our budget. To date, we have developed several interactive video programs used by instructors in both the nursing and biology departments to supplement student instruction.

Student volunteers are recruited to view and evaluate completed media programs before we make the programs available for classroom use. Volunteers include both students who have never been exposed to the program module content and those who have been previously exposed to the material in a traditional classroom setting. The naive group evaluates the program for understanding and comprehension of the material, while the group previously exposed to the material reports on whether or not they think the interactive video programs enhance understanding and comprehension. If either group has difficulty in understanding program content, modifications are made in the programs before they are made available for general course use.

LABORATORY IMPLEMENTATION OF VIDEOS

The Center of Emphasis laboratory has twenty-four workstations to allow students to view both the programs we develop and those we purchase commercially. Each workstation consists of a computer, high resolution touch screen monitor, and videotape player. We also have workstations for students attending classes at an off-campus site.

It is difficult in a traditional lab situation for the instructor to monitor effectively students in the time allowed. In our Center students may view the instructional tapes as many times as is necessary to understand the content; however, the instructor is still available for assistance while the tapes actually serve as a private tutor.

Students use the Center facilities during scheduled and nonscheduled or open periods. Upon entering the Center laboratory, the student is issued a videotape and floppy disk for the program desired. The student is then assigned to a workstation to view the program. A lab assistant or instructor helps the students with any problems or questions that arise. A post-examination is given to the student to determine understanding and comprehension of the lesson and the score is incorporated into their overall course requirements for which the viewed program applies. Also, each program viewed in the Center is evaluated by students. They may write comments, criticisms, or ideas on evaluation forms and place them in a suggestion box in the laboratory. Replies to their comments, which are posted near the box, frequently lead to program modifications by the staff and improvement of our facilities.

EVALUATION

We have been encouraged by evaluations from students who have viewed the interactive video programs. They generally report that their understanding of the material is improved with this method of instruction. In fact, nearly all the students who had previous traditional exposure to the content material before viewing the tapes reported that they wished these programs were available to them when they were enrolled in the course that included the program subject matter.

We are confident that the techniques employed to assist our biology and nursing students will be as effective in the future when media and CAI programs are developed for other campus disciplines.

CONCLUSION

The main function of our Center of Emphasis is to provide our students with the opportunity to become proficient in nursing skills and procedures in a setting that promotes competency-based interdisciplinary instruction, independence and problem solving, and clinical proficiency. The Center of Emphasis has expanded the campus laboratory component of the nursing program to include more complex nursing skills instruction so that all students have enhanced opportunity for demonstration, learning of concepts and principles, as well as the development of psychomotor skills. Our instructional programs facilitate the direct application of knowledge. Consequently, as students study selected nursing skills and procedures they also learn the appropriate anatomy and physiology principles that provide the rationale for those skills.

Chapter 13

Clinical Applications Projects for Health-Science Students

by

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Clinical Applications Projects (CAPs) are short-term activities included in the laboratory experiences of a microbiology course for health-science students. Most of these students plan careers in either nursing or dental hygiene and are completing the first year of their programs, including a two-quarter sequence in anatomy and physiology and at least one quarter of chemistry.

Clayton State, a senior college unit of the University System of Georgia, was converted recently from a junior college unit. Located in south metropolital Atlanta, we enroll approximmmately 3500 students, all of whom commute. Most students enrolled in the microbiology course are candidates for an associate degree in either nursing or dental hygiene.

OUR GOALS

We provide experiences which will allow students to develop:

- **Understanding** of critical concepts, processes and factual information in microbiology;
- **Knowledge** of resources for finding the solution to problems that relate to microbiology; and
- **Ability** to utilize knowledge of microbiology in critical study and for making intelligent decisions in professional life.

While the CAPs help the students to achieve all goals, they also are designed to focus on using microbiology in professional life.

THE FUNCTION OF CLINICAL APPLICATION PROJECT

We used to hear questions like "Why was I told to carry out this procedure in clinic today? How is this procedure related to our class lecture....there seems to be a connection." At the same time, we noticed traditional laboratory exercises identifying unknowns were time-consuming, expensive, and frustrating for students who did not plan to study more microbiology. We saw a need for experiences which would enable students to gain better understanding of how a basic science like microbiology can be used in clinical practice. Now, students study microbiology for understanding their own clinical fields and to be better able to solve problems within that field.

The projects that I have developed as part of the introductory microbiology course allow health-science students to apply principles of microbiology to a problem in a simulated or actual clinical situation. Clinical Application Projects replace the more classical study of the "unknowns" included in many other microbiology courses.

CAPs FOR NURSING STUDENTS

Approximately twenty-five students are usually enrolled in a laboratory section and are supervised by one instructor and about 70 nursing students are working on CAPs at a given time. Nursing students (and students planning to become nursing students) are presented unknowns isolated from simulated patients. No more than two students in the same laboratory section have the same patient. The unknowns are opportunistic pathogens, many of which are the etiologic agents of common hospital-acquired infections. Many students already have had first-hand experience working with real patients who have similar infections. Because these organisms are only opportunistic pathogens and are attenuated, beginning students have sufficient skill to work with them without endangering themselves or others. In fact, most of the organisms are those that students have used to learn the basic microbiological techniques during the earlier part of the course. I usually include: Pseudomonas aeruginosa, Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus mitis, Proteus vulgaris, Candida albicans, and E. coli.

Students are given, along with their isolated unknown, a brief description of the patient and symptoms. The simulations are researched and developed using descriptions of disease syndromes from a variety of sources including faculty in the clinical areas. In developing the projects, I reinforce principles and processes emphasized in both microbiology and the clinical area and stress the interaction between problem-solving skills in the basic and clinical sciences. Two typical CAP simulations are given below as examples. The first is for Pseudomonas aeruginosa and the second is for Staphylococcus aureus.

Patient No. 1

Isolated from the blood of patient, age 56. Patient has been undergoing dialysis.

Symptoms:

1. fever
2. chills

Patient No. 2

Isolated from the blood of patient, age 8. At age 7, child suffered a compound fracture of the proximal tibia.

Symptoms:

1. chills
2. fever
3. pain, redness, swelling in knee
4. WBC = 15,000

Nursing students are guided in their study by the following steps presented in a handout with the unknown culture and patient description.

Design valid procedures for identifying the organism.

Carry out the procedures to the extent possible.

Identify the organism.

Identify a probable disease and discuss it in relation to the causative organism.

Students are given further guidance in planning their methodology for identifying the unknown, helping them integrate the nursing with the microbiology. Each student has a four-step problem-solving procedure on the nursing process, an application of precise problem-solving methods to particular nursing situations. The end product of the use of the nursing process in clinical practice is the written care plan which provides the direction for patient nursing care. The four steps of the nursing process are:

Assessment--Assessment includes three separate activities; data collection, data organization, and nursing diagnosis.

Planning--Planning includes three phases; setting priorities, writing goals, and planning nursing actions.

Implementation--Activities included in the implementation phase are validating the care plan, giving nursing care, and continued data collection.

Evaluation--Evaluation includes reassessment of the care plan and evaluation of goal achievement.

Those of us from the basic sciences immediately recognize the nursing process as a specific modification of the scientific method or the processes of science. The CAPs then can serve as tools to allow students to see both commonalities in methods of solving problems as well as in the application of concepts and principles. Students report their study of the unknown based on the following the four steps which present a synthesis of the nursing process and scientific methodology.

Synthesis Steps:

Assess the situation. (Describe the problem and hypothesize about its cause.)

Plan methods needed to attack the problem. (Describe the procedures to be used.)

Implement the plan in 2 above. (Carry out procedures and collect data.)

Evaluate the results in 3 above. (Give conclusions and plans for further action.)

Students respond to each of these four synthesis steps in their final report. They must still practice the use of pure culture techniques, choose and use differential media and stains, and evaluate their results. The scope is, however, much narrower than for traditional studies of unknowns. Students are working in the context of patient care and the burden of understanding the use of a multiplicity of techniques seems lighter to them. They are not just solving a problem for their microbiology professor but rather helping their patient.

The relationship between the organism and the disease is studied last based on information obtained in references. The disease study includes four aspects of the disease: symptoms, syndrome, epidemiology, and treatment. This is the last part of the CAPs study and is obviously theoretical.

The time frame for individual projects for nursing students is given below.

Week 1	Get isolated culture and patient Make stains Subculture
Week 2	Continue to sub-culture and research
Week 3	Write report

In the written report, the student identifies the unknown organism (at least to genus), describes the procedures used to identify the organism, identifies the disease caused by the organism, and provides information about the disease and its treatment. Students work independently on their projects during their assigned laboratory periods. References in both the laboratory and the library are used for the identification of the organism and the disease that the patient is suspected to have.

Students use a microcomputer program to check the accuracy of their strategies in attacking their problem. This branching program is designed so that if the students are proceeding with inappropriate tests for identifying their unknown they will be told and given a hint for continuing on the right track. Sometimes they are referred back to the instructor or to references, if they are recognized to be weak in some of the basic principles. The response to the microcomputer has been very positive. It has turned out to be a time saver for some students as they are guided into the appropriate actions and away from those that are not needed. I have also heard students comparing the use of the lab microcomputer to their use of the hospital's computer terminal for ordering supplies, patient histories, and ohter information. The additional use of the computer in the lab helps to make them more confident in their ability to use it in clinical situations.

CAPs require a minimum of preparation on the part of the laboratory staff. Students request media (e.g. blood agar, EMB agar, motility agar) in writing including a statement of why they think they need it. This justification drastically cuts down the unnecessary use of media, lowering both expenses and preparation time. It should be noted that most organisms, media, and techniques required for CAPs have been introduced and used in the six weeks of laboratory experiences completed prior to starting CAPs. The few exceptions are explained by the laboratory instructor and references are provided. The patient diseases have been discussed in lecture and studied in the text. Nursing students feel quite confident in their ability to pursue a CAP because they are familiar with all the components in other contexts. The nursing students, through carrying out CAPS, are able to see how knowledge of microbiology and scientific problem solving can be used in clinical situations and indeed become part of the nursing process. To quote a student: "This makes it all make sense."

CAPs FOR DENTAL HYGIENE STUDENTS

CAPs also are used for dental hygiene students to give the students first-hand experience in the study of the microbiology of the oral cavity. These students do not use simulated patients. Organisms are collected under a variety of conditions in the campus dental hygiene clinic supervised by dental hygiene faculty and an on-campus dentist. Some students elect to conduct their project in a private dentist's office away from the campus after they secure permission from the dentist and patient. Either experience is valuable in the training of students in patient education. The student dental hygienist explains why the procedure is important and then proceeds with the projects, both in the clinic and in the assigned microbiology laboratory period. Projects are completed in two to three weeks.

CAPs for dental hygiene students are carried out using the following objectives:

*Determine the level of microbial pollution in the dental clinic.

•**Determine** the level of microbial contamination which rotary manipulation released from the patient's mouth.

In our laboratory dental hygiene students analyze microbes found in the clinic environment and those released from their patients' mouths during several types of rotary manipulation (e.g. scaling, drilling, cavitron). Like nursing students, they prepare a written report of their work.

Dental hygiene students get very excited about the projects. They are amazed at the diversity of organisms found in the mouths of their patients and are especially impressed with the need for the aseptic techniques in the clinic. In this project they get living proof of poor technique! Students study the literature on the microbiology of the mouth and relate their findings to it. This experience is valuable in helping students integrate basic microbiology with dental microbiology. Microbiology comes alive for these students and long after they finish the course they come back to me to tell me how they enjoyed the work and learned from their projects. They even understand now why they have to cut their fingernails short and wear a mask.

CONCLUSION

Both nursing and dental hygiene students have responded positively to the CAPs experience. The quality of the reports is high. Only about two percent of the nursing students will miss their unknown and incomplete projects from dental hygiene students are unknown! Students always pursue some sort of further study with their patients.

CAPs projects have been used by several microbiology professors and each has found them to help students better understand the relationship between microbes, health, and disease. A watchful eye is kept for possibilities for new simulations and experiences for CAPs. Although students are obviously not able to study particular organisms in great detail in this study, they are able to experience the excitement of scientific investigation in the context of a real or simulated clinical situation. We plan to continue using CAPS in the laboratories. They are fun and effective for both teaching and learning.

Chapter 14

People and the Environment

by

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Oglala Lakota College, a tribally chartered college on the Pine Ridge Indian Reservation in South Dakota, presents two unique problems for science teaching. First, science courses are taught in small college centers across the reservation. Second, since our student body consists primarily of Lakota (Sioux) people, science needs to be taught from a different cultural perspective. Even though our student body and the college setting is unique, the science experience at OLC does have many problems in common with other rural, small colleges across the nation. The course, People and the Environment, is a example of how we have addressed these problems.

THE COLLEGE

Oglala Lakota College has an intriguing history of accomplishing the impossible. Although experts at the Bureau of Indiana Affairs (BIA) and higher education in the state felt that an Indian reservation could never support a community college, the college was established in 1971 when the federal government allowed Indian tribes to charter their own community colleges. We are now a fully accredited four year institution. The college started as adult education classes taught in homes to prepare people for their General Equivalency Diplomas. Though G.E.D. study is still an important component, today the college offers six Vocational Certificates, thirteen Associate degree programs, three Bachelor degree programs, and a limited number of graduate courses. We are the second largest college situated on an Indian reservation with a student enrollment of 1,000. Last year we graduated just over 120. The faculty has grown from an all volunteer staff to a full-time teaching staff of 36, one quarter of them with earned doctorates. The college is recognized as a leader in Indian Higher Education, with a history of many firsts, including the first accredited nursing program on a reservation.

The goals of the college are three-fold. The first two goals deal with increasing employment of the tribal members and improvement of tribal leadership. The third goal is to help preserve the Lakota culture. OLC is unique in its incorporation of the Lakota perspective into all aspects of the college from its form of governance to course content. All faculty members are expected to bring the Lakota perspective, when appropriate, into their courses. Attempts to achieve this goal have been fundamental in increasing our student retention rates. The BIA reports a 90% drop-out rate for Indian students at traditional colleges while OLC has a 72% retention rate. Students comment that at OLC they can remain "Indian" while getting an education. While the emphasis on Lakota culture makes OLC unique, it does share many of the problems of other small colleges in rural settings.

The fact that the college is situated in a rurally isolated and poverty stricken region possess several problems for the college in trying to bring higher education to the population. The major problem is trying to deliver education to 80,000 people scattered over 7,000 square miles. Students lack the funds and often the means to drive long distances to classes. Therefore, the college takes the classes to the students. The college has centers in each of the nine major communities across the reservation. These consist of double-wide trailers or small buildings located in each community. In addition, the college has three extension centers in border communities off the reservation, including Rapid City. Each center is staffed by a director, counselor and GED tutor. The faculty travel to the centers to teach their classes. Since the average distance between centers is 60 miles, classes are taught just once a week for a three-hour block of time. The science classes all require labs, so they are taught for a four-hour block, two hours of lecture and two hours of lab. The standard load for the faculty is 3-4 classes per semester. The average driving distance is 500-700 miles per week. Despite all of the disadvantages of a decentralized system, OLC could not begin to meet the educational needs of the reservation with any other method.

Another major problem for teaching science classes is the lack of financial support for the institution. Tuition and fees need to be kept very low since the majority of the students are living well below the poverty level. Therefore, the major financial support is from federal funding for tribal colleges (Tribal Controlled College Bill, PL 99-428) which must be approved by the federal legislature every three years. This means that the college must always operate on a bare-bones budget. Science classes are largely maintained by student lab fees. Ten years ago, OLC had an NSF grant to establish and equip a science lab. The funds were used to furnish a science lab and purchase the basic equipment for beginning science courses. However, the core science courses, such as People and the Environment, are taught in the college centers, not at the science lab. It would be inappropriate to ask all of the students to drive up to 60 miles one way to the central lab to take a course. This means that lab activities for the core courses need to be designed for centers with limited electricity and running water supplies, limited space to work or store equipment, portability of equipment in the back of the instructor's car over rough dirt roads, and simplicity of design to meet time and space constraints. We try as much as possible to use materials for labs that can be purchased at the local hardware or grocery store. Our lab materials are homemade, but this seems to lessen the students' anxiety. I've noticed an increased apprehension in students when I've brought sophisticated equipment into the classroom.

THE STUDENTS

The majority of OLC's students are typical of the many adult students found in our nation's community colleges who come to the college with weak academic backgrounds and poor study skills. Almost half of our students are GED graduates who have dropped out of school between the 7th and 11th grades. The typical student is a single mother in her late twenties or early thirties who is returning to school in order to gain employment so her children may have a better life. Unlike most traditional college students, OLC students usually live in substandard homes either in HEW cluster housing or in isolated rural homes, and they have incomes that are below the normal substance level. It is often difficult for students to find enough money to be able to drive to classes.

Our students present special problems for the science instructor that are typical for adult students. First, their average reading level is between the sixth and ninth grade level. Many science texts are written at the thirteenth or higher level. Even those texts that are written at the lower level still contain scientific jargon, which always presents problems for the students. Second, many of the students have rudimentary math skills along with math anxiety. Since ecology classes in particular require a lot of advance mathematics both the lack of skills and increased anxiety become a special problem. Third, the students are unable to fully express their ideas in written form. This creates a problem on written assignments and on essay tests. Fourth, the students have a real fear of science. This can become a paralyzing fear, for students who can do excellent work in other classes struggle in science courses. I often hear the students remark at the beginning of the semester that they will do poorly in the class because they have never been able to understand science. This is almost a self-fulfilling prophecy. Finally, a special problem we have at OLC is that some of the more traditional Indian students believe that science is strictly a part of the dominant culture. Often the only scientists they see are people working for federal agencies and any federal agency is viewed by these students as a threat to their land. It is not possible to successfully attack all of these problems for all of the students each semester, but the school's statistics indicate that more students have been successful in getting through science since the People and the Environment course replaced the traditional science survey course.

NEEDS FOR THE COURSE

All students at the college are required one science course in the general education core of their degree. It is the college's position that this science course should apply to the reservation, incorporate a Lakota perspective, and demonstrate how science works, preferably through laboratory activities. The course, People and the Environment, is one of three general science courses for non-majors recently developed to meet this need. The other two courses are Consumer Chemistry and Human Biology.

Three specific needs of the course were generated by the students. First, the course needed to be very practical, to deal with important problems of the reservation. The former general biology course covered the typical topics of cells, plant and animal physiology and diversity, ecology, genetics and evolution. It was viewed by the students as totally unrelated to their daily needs. Generally students saw the course as being too esoteric to retain their interests, and they were often overwhelmed by its theoretical approach. Therefore, the college needed a course that addressed local problems and concerns.

A second need of the students is to learn how to critically examine a perceived problem. Many people believe that the federal and private agencies that have been established to assist Native Americans have actually misrepresented their needs. This has led to a distrust of the very agencies that have the authority for evaluation of environmental issues. Any reports supporting development are seen as another attempt by the BIA to take away Indian lands. It has been my perception that in many of these issues people did not accept the technical evaluations because they did not have a good understanding of ecology and of how environmental assessments are made. In other instances public concerns arose over issues that were not true environmental problems. A major complicating factor in many of the environmental issues is the argument between the traditional Lakota perspectives of how the earth should be treated and the modern perspective of the earth as an item of capital to be used as a source of income. Therefore, it became apparent to me that our students needed to learn how to do complete scientific evaluation of environmental problems so they could differentiate between these two perspectives and better judge the issues being debated.

An often used example in class is the argument over the poisoning of prairie dogs. Viewed in its simplest terms, the poisoning of prairie dogs will help improve the rangelands so that ranchers can raise more cattle. Often students stop their analysis at this point. In class we bring up the possible impacts on the food web that the removal of one of its major members can have. Students explore the possible impact on the black-footed ferrets (an endangered species), hawks (tail feathers are used for traditional dance costumes), eagles (a sacred animal for the Lakotas), diversity of grasses and finally the loss of income to people employed to poison the prairie dogs. The outcome of the discussion depends on the character of the class, and whether the class members are traditional people or cattle ranchers.

A third need of the students is to learn how to bring about positive change in their lives. Native Americans have a long history of being treated as children by the various agencies or organizations on the reservations. Although in the past 35 years Indian people have started to take control of their own government, old habits both on the part of Indian people and the agencies are hard to break. Students often feel that there is no use in complaining because the tribal government has little control over the reservation. These students needed to learn how to bring about change and reforms in their own government. More precisely, they needed to learn about the various tribal regulations on environmental issues and how they can be enforced. If the regulations do not appear to be adequate, students then needed to learn how they can be changed.

THE COURSE

The course is divided into two main sections: general principles of ecology and man's impact on the environment. The semester is divided almost equally between these two main sections. The text for the course is Environmental Science: The Study of Interrelationships by Enger, Kormelink, Smith and Smith. The lab manual is one that I have developed from various sources. The text was chosen for several reasons. First, many of its illustrations are taken from the grasslands biome instead of the Eastern biomes. These are concepts to which my students can easily relate. Second, it has a whole chapter discussing the relationship between buffalo, Native Americans and Whites. Again this is another major concept to which my Indian students can relate. Third, the text is readable. The authors are able to communicate complex concepts of ecology without having to use complex sentence structures or relying on an excessive amount of jargon. It is a text written for students, not professors. The major drawback to the text is that the impact chapters largely deal with pollution problems common to cities and urban areas rather than to rural areas. This is a problem for all science teachers in rural areas.

Course Outline

The section on general ecology concepts is divided into two units. First, concepts of interrelationships including species relationships, food web, nutrient cycles and energy flow are emphasized. These concepts are illustrated by examples from the reservation. Particular attention is paid to how some of the ecology concepts of nature compare with the Lakota religious understanding fo the nature of the world. Additionally, we look at how these basic concepts can be used in making decisions on the reservation. For example, we develop the food web of the grasslands using prairie dogs, black-footed ferrets, cattle, coyotes, hawks, rattle snakes, and eagles. Then, we examine what might happen if the Tribe is successful in removing all of the prairie dogs from tribal lands: what impact could this have on coyote predation of calves or what impact could this have on the eagle population?

Laboratory activities in this section are designed to illustrate some of these basic concepts, and to make these abstract ideas more concrete. For example, we do some simple labs with photosynthesis to demonstrate the effects of light intensity and carbon dioxide concentrations on its rate. We then follow-up with a light bottle/dark bottle experiment in a nearby pond to demonstrate the idea of community productivity. We finish the unit with a simple analysis of a local community, either a grassland area or a river bottom. Those labs that require some mathematical calculations or statistical analysis have been put on a computer disk to eliminate the need for the students to have to do higher math.

The second unit discusses populations, both natural and human. We look at how natural populations grow and reach equilibrium with their environment. Then we examine the human population and its growth pattern. In one lab the students construct an age pyramid for the Indian population of South Dakota based on current census data and contrast it to the non-Indian population of the state. The Indian age pyramid is typical of a growing population, while that of the non-Indians in the state is of a population in decline. This is followed with a discussion of what the future might hold for the state of South Dakota.

The second section focuses on the impact of humans on the environment. This section is divided into four units; air pollution, water pollution, energy resources and natural resources. At this point the course becomes very specific to the reservation. We focus solely on the problems of the reservation and how they differ, if any, from other rural regions of the country. At this point we bring in the political, economic and cultural aspects of these problems. An attempt is made to compare the resource development of Indian reservations to similar problems in Third World Nations. The book Only One Earth by Timberlake serves as an excellent resource of how development can be community based and within good environmental guidelines. Students are assigned chapters out of this book to critique.

Labs in this section consist of evaluations of local water, air and natural resources. For example, students will bring in sterile water samples from their homes and perform the standard coliform analysis if they live in a community or nitrate test if they live in the country. Students examine the community's land-fill to see if it conforms to Tribal codes and explore the possibility that the land-fill could be contaminating the shallow aquifers many people use for water supplies. This is followed with a discussion of what the individual class members can do to reduce this potential health hazard.

EVOLUTION OF THE COURSE

This course has gone through a series of changes to reach its present form. Initially, it was very similar to many Man and His Environment courses being taught for non-majors. The major difference was that I concentrated on the ecology of the reservation. I did not discuss smog, but rather chronic low-level carbon monoxide poisoning. I did not discuss the plight of the whales but rather the plight of the black-footed ferret and the impact of prairie dog control on the ferrets. Labs were extremely limited because I had problems locating laboratory texts that did not require expensive equipment and statistical analysis.

Each semester students would bring to class information about some environmental concern that did not seem logical. For example, one student found a BIA report concerning water and sewage facilities for the communities on the reservation. The report was interesting in that the number of people/household was exactly the same for each of the communities! So the class decided to do a survey of their own community to see if the figures were accurate. The BIA report stated that there were 5.4 people/household. The students' informal survey found 7.5 people/household. This then lead to a discussion of how the report could have been generated, and what the impact of such a report could have on the safety of the community's water supply. So, students performed coliform tests of their water to see if it was indeed safe. Then students wanted to know which tribal or BIA office was responsible for testing water and what were the Tribal water codes.

The results of this investigation proved so interesting to the students that I incorporated similar investigations as a requirement of the course. Students choose an environmental issue that they believe to be a problem on the reservation. They have to 1) determine what the federal, state and tribal standards are for their concern; 2) find out how common the problem is in other regions of the United States; and 3) test to see if the problem is outside of the safe limits. For some tests, such as radon in basements, I use lab fees to have the State do the testing. It amazes me that each semester there are always students who still do not want to accept the fact that their water and air is safe, and I have yet to find a means of convincing them otherwise.

Sometimes the students want to investigate major problems that are beyond their abilities. In these instances we do the investigation as a class project. This fall the class studied a proposed munitions test site in the Black Hills. The company wants to test fire uranium coated armor-piercing shells. The people of the reservation are opposed to such use of the Black Hills for traditional religious reasons and are concerned about contamination of the area from the burning uranium on the shells. There is little information available from both the State and the company making the proposal. The class performed our normal lab exercises in community analysis at the proposed site and discussed what its impact might be to the biological community. When we discussed natural resources, we explored the possibilities of contamination of the ground and water supply by the uranium used at the site. Part of the class project is to make the information gathered available to the public and interested groups.

The format of the course seems to motivate the students. Since the course pulls heavily from the local environment for its examples and lab activities the students perceive that the course does relate to their needs. In class students are encouraged to bring up any questions that they may have about local issues. To encourage students to bring up their concerns the class is structured in a rather informal manner. Often these discussions begin during break time over a cup of coffee and a cigarette and are expanded upon during the remainder of the class period. Finally, the effort to integrate as much as possible of the Lakota perceptive helps the students to see that science is not necessarily a non-Indian domain. They see that traditional views are not entirely in conflict with the scientific view of the environment.

PROBLEMS WITH COURSE DEVELOPMENT

Two major problems have arisen during the development of the course. The first has been the development of the laboratory portion of the course. Labs have to be simplistic in nature because 1) they are taught in college centers which are not designed for lab work; 2) they have to be transported in the back of the instructor's car; 3) we have a very limited budget and minimal laboratory equipment; and 4) our students are easily intimidated by sophisticated equipment. I want the lab activities to help students to visualize basic concepts, to allow them to understand how science obtains its information and to get an idea of what an ecologist does in the field. The problem becomes one of developing activities that are not so simple that they are boring or so complex that the students are lost. I've taken many of my labs from lab manuals designed for a major's courses and have simplified them, but the necessary math calculations always present problems. My students do not work easily with numbers, nor are they able to translate numbers into concepts. Much of ecology today is founded in statistical analysis and it is hard to do field work in such a way that it has meaning without this necessary number crunching. However, this aspect of the lab always bothers the students. I have yet to come up with a totally satisfactory solution.

The second problem in the development of the course is in getting part-time faculty to implement the entire course. Like many colleges we are heavily dependent on part-time faculty. Most of our part-time instructors are secondary teachers. Though we do have some excellent part-time instructors, there is a tendency on the part of several to simply follow the text. They are very reluctant to get into discussions of the political, economical or cultural impact of various issues. There is also the logistic problem of getting lab equipment to the part-time instructors. Some of them would prefer not to do labs at all. Of course these sorts of attitudes greatly diminish the impact of the course.

IMPACT OF THE COURSE

People and the Environment has had important impact at Oglala Lakota College. There have been positive changes in the way science is taught in the core courses, in the way science is perceived by the students, and in the way science courses are viewed by other departments in the college.

Change in Teaching Philosophy

As the course has developed I have increasingly felt a need to incorporate non-traditional science topics. As increasingly greater amounts of non-science topics have become integrated into the course there has been a corresponding reduction of the amount of purely science topics we have time to discuss. For example, I have eliminated the chapter on world biomes in order to allow students time to discuss and examine the political, social, economic and religious impacts of proposed projects. The course has evolved from a technical science course into what I call a liberal arts science course.

Non-major science students need a different type of course than does a science major. Yes, they need to have a basic understanding of scientific principles, but they do not need to have a detailed understanding of photosynthesis, species competition, or theoretical analysis of population growth curves. Non-majors need to have a basic understanding of the scientific process and methods, but they do not need to become experts in field work. Most importantly, non-majors need to know how the sciences impact on their daily lives and how the scientific community's perception of the world contrasts to their own perceptions.

The format for this type of a non-majors course demands different classroom activities and changing roles for the science instructor. In order for students to be able to gain an understanding of the importance of science to them, it is necessary to provide time in the classroom for debate, and a critical evaluation of the student's personal beliefs. The instructor needs to become adept at argumentation, moderating discussion, and leading people through value clarification and assessment. Many of these are skills that science instructors need to develop.

Impact on Students and the Communities

It appears that this course is having a positive impact not only on the students, but also on the local communities. First, the number of science courses being requested each semester has greatly increased. Unlike most colleges where there is an established pattern for course offerings, we offer courses on a semester by semester basis determined by requests from each of the ten college centers. Before the college initiated this course only 3-4 core science courses were requested each semester. This past semester all but two centers were requesting core science courses and two classes were cancelled due to a lack of an instructor for the class. Second, the number of students who are taking their science course in the beginning of their program rather than their last semester has increased. In the past students put their required sciences course off to the very end, and took it only because they couldn't get their degree without the course. In many cases I have had students in class who had attempted the original science course with me several years previously. Every one of these students has finished the People and the Environment course and commented that it was an interesting and helpful class. Third, a number of students are now taking a second science course! We have an independent research class and students are using this class to investigate environmental concerns and issues of the communities. Finally, the student evaluations ard staff evaluations indicate that the course is meeting the needs of the students and the community.

Impact of the College

The course has also had an impact on the rest of the college. We are a very small institution and the boundary lines between disciplines are not very strong. The integrated nature of the People and Environment course lends it to team teaching situations. This past semester my class worked with a social studies class that examined the relationship between land and the power base. Both classes looked at the proposed munitions test site in the Black Hills issue previously mentioned. Each class shared their information with the other.

I believe that the college has had a great impact on the development of this course. The college's goal of incorporating a Lakota perspective into each course and of addressing each community's need has forced the development of this course into its current form. The small size of the faculty has allowed for much discussion between members of different departments allowing the integration of concepts and techniques. I have learned much about value assessments and methods of change from the social studies faculty, and about tribal history and religion from the Lakota studies faculty. All of this information has had a major impact on the success of the course.

CONCLUSION

Teaching science at Oglala Lakota College offers the instructor a challenge and a great deal of satisfaction. The challenges are: 1) to create a new format of science instruction that breaks away from the high technology of the normal university science lab, yet still gives the students a real sense of science; 2) to be able to distill the topics to their essences and communicate these ideas in simple language; 3) to be able to work with adults on an informal, one-to-one level; 4) to integrate aspects from other discipline in order to present a more holistic picture of ecology; 5) to be able to see the world from a different cultural perspective. Instructor's efforts to meet these challenges are rewarded when your students become motivated to initiate their own independent studies of environmental issues. I realized that this approach to science was successful when I was given a pair of traditionally beaded moccasins because I was "the only science teacher that ever made any sense to me." Though there are not many people teaching at Indian colleges, I believe that some of the problems we encounter here are similar to those of other small colleges and colleges with a large minority student population.

Chapter 15

Cooperative Education and Science

by

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"Until learning has tried itself out on life, it is not wisdom, but dreaming, or at best, opinion."

Arthur Morgan

Antioch College has always been a pioneering institution in designing and implementing innovative approaches in American higher education. Under its first president, Horace Mann, Antioch was the first college to admit women to an equal curriculum, and was one of the first colleges to admit blacks. Horace Mann's educational philosophy still influences Antioch today - that education is not merely of the mind, but involves the whole person and includes social concern and practical experience.

THE CENTER FOR COOPERATIVE EDUCATION

Arthur Morgan, President of Antioch, introduced cooperative education in 1921. Morgan believed that higher education must balance scholarship with life experiences; he established an effective combination of work and study that was the first co-op program established at a liberal arts college. To this day it continues as the most extensive co-op program offered in any liberal arts institution in the country.

Every Antioch student must participate in the plan of alternating work and study quarters. The curriculum and calendar at Antioch allow students to move through the undergraduate program with ease and effectiveness. The college operates on a year-round calendar with most new students starting in the fall and entering one of the two possible sequences of work and study quarters. These sequences maintain a balance between the numbers of students on campus and off during a given quarter. In this way the college makes maximum use of its facilities and faculty. Sequences, arranged so that students are on campus at different seasons of alternate years, fit a four-year graduation schedule. Most co-op jobs are for periods of three or six months.

The following is a representative four-year program for an Antioch student entering the fall; there are several variations on this basic model:

Year	Summer	Fall	Winter	Spring
1st	(Enter in Fall)	Study	Work	Study
2nd	Work	Work	Study	Study
3rd	Work	Study	Study	Work
4th	Work	Study	Work	Study

Undergraduate programs at Antioch lead to the Bachelor of Arts or Bachelor of Science degree. To qualify for graduation and to be awarded the bachelor's degree, students must successfully complete at least 160 academic credits and at least six co-op quarters for an additional 20 academic credits. Curriculum offerings are scheduled two years in advance so that students can plan their study programs effectively. Whenever conflict arises with a class they need, they can arrange a sequence change to allow them to reverse their assigned sequence, or conversely, when an unusual co-op opportunity presents itself, students may again change their assigned sequence.

Antioch's Center for Cooperative Education (CCE) works nationwide with hundreds of employers who hire Antioch students on a regular or seasonal basis CCE constantly seeks out new environments and new opportunities for students to work, accept responsibility, and explore various career interests while supporting themselves away from the campus for periods of three or six months.

Opportunities in Antioch's co-op program are extensive, both in job responsibility and geography. They work for such organizations as the Associated Press, the Library of Congress, the Field Museum, Great Smoky Mountains National Park, Apple Computer, National Institutes of Health, IBM, Yale University Medical School, and the Staten Island Advance newspaper. Antioch students are employed in hospitals, national parks, research centers, planning agencies, private industry, radio stations, and theaters, to name only a few settings. Many employers have maintained a continuing relationship with Antioch for ten years or more, some for much longer, even fifty years or more.

Participation in the co-op program offers many rewards to employers. Employers find that Antioch students are bright, highly motivated, and eager to learn. They adapt quickly and enthusiastically to new settings. They work hard, ask penetrating questions, and are a source of fresh ideas and new approaches. Employers of Antioch students recognize they have a stake in higher education. Co-op placements by Antioch offers them an opportunity to contribute to the education of young people in new and creative ways. Many employers look forward to introducing students to their particular field in the hope of encouraging vocational choice and developing a pool of future employees with relevant experience.

Selection of appropriate students for positions is managed by the faculty of the Center for Cooperative Education. A prospective employer develops a job description which specifies requirements for the job, salary, and other information to help students make realistic choices. The CCE faculty then evaluate candidates for each position using students' employment records, skills, and recommendations and forwards information about the most appropriate applicant to the employer. The decision to hire is then up to the employer.

Responsibilities for students and employers are generally the same as those of any employer-employee relationship. Students are expected to meet requirements for the job as set by the employer and employers are not obligated to keep a student who fails to live up to reasonable expectations. Antioch students need no special treatment but are integrated into the work environment. Students expect to learn from their involvement and benefit from an active interchange of evaluation and constructive criticism.

Students are compensated for their work, generally by a salary adequate for living, housing, and transportation costs as well as some savings. Salaries may differ because of the skill and experience required by the position, the regional cost of living, and other factors. For some jobs, other arrangements can be made as long as the student's basic living costs are covered.

The employer, as a member of Antioch's field faculty, provides supervision and training as necessary. Many students do an excellent job with little supervision or special training, while others need more guidance. The amount of each depends on the requirements of the job and the age, experience and skill of the student.

At the end of the work period each student produces a comprehensive co-op project and the employer submits an evaluation of the student's performance. This evaluation becomes part of the student's college record to be used in future counseling, evaluation and planning. If the evaluations of the employer, student and faculty member indicate an educationally successful work period, college credit is awarded for the experience.

The Antioch Center for Cooperative Education is staffed with a faculty of full-time professionals whose duties on the campus include counseling, advising and evaluating students in regards to their participation in the cooperative education program. Off-campus, they are responsible for locating appropriate employers and maintaining on-going relationships with them, placing students on the jobs according to their educational needs and qualifications. They regularly visit students and employers in the field in order to monitor student progress and to carry out in-service development with co-op employers.

THE INSTITUTE FOR SCIENCE AND TECHNOLOGY

In the late 1960's Antioch College reorganized its science instruction from a strictly departmental structure into the Science Institute (now called the Institute for Science and Technology). We made this change to foster interdisciplinary work within the sciences and to reduce interdisciplinary competition for resources. We still maintain disciplinary programs, but there are no official structures which at all resemble departments.

We offer B. A. and B. S. degrees in Biology, Chemistry, Computer Science, Mathematics, Physics, and several interdisciplinary programs: Biology/Chemistry, Environmental Science/Biology, Environmental Science/Geology, and Mathematics/Computer Science. Our graduates do what the science graduates of most good, small liberal arts schools do; they work in their fields or they go on to graduate or professional schools for further training. A recent study done at Franklin and Marshall University compared the Ph.D. rates of graduates of eight hundred and sixty-seven American colleges and universities for the period 1920-1980. Antioch ranked twenty-second in the physical sciences. We have kept track of twenty-one of the thirty graduates with a chemistry or chemistry/interdisciplinary degree since 1981. Of these nine have gone to medical school, five to graduate school, and the rest are working, although several are making plans to apply for advanced training.

The general education component of the co-op program is invaluable to our science students, giving them self confidence and worldly experience. Students use the program to help sharpen their career choices. For example, one student, a chemistry major, had a co-op job in a biology laboratory and decided to change her major to Biology/Chemistry. Of course, there are those examples of students who have made complete career changes based on a co-op job. Other students have learned a great deal about options within the field of medicine by working in hospitals and medical research laboratories. These experiences also teach students what to look for in a medical school.

The co-op program offers our students experiences and training that are simply not available in a small liberal arts college. One physics major found a research job at L'Ecole polytechnique in Paris. She co-authored a paper dealing with the application of NMR spectroscopy to an investigation of the rates of particular biochemical processes. A young man who was placed in Klaus Biemann's mass spectrometry laboratory at MIT came back to campus and for his senior project built his own mass spectrometer. (Unfortunately it did not work; we did not have an adequate vacuum system). We have placed students in a variety of laboratories at NIH, including that of Nobel Laureate Carlton Gajdusek.

The co-op program is most powerful when the career aspects and the resourcefulness training work together. One young woman, early in her Antioch career, was placed on a rather low-level job in a medical school research laboratory. She found out when the Gross Anatomy course was being given and started attending. Since it was early in the term the instructor did not know that she did not belong there. By the time the other students got around to asking her who she was, our student was on friendly terms with them and so nobody said anything. Thus, this second year Antioch student was able to dissect a cadaver in the standard medical school Gross Anatomy course. (Of course, she did not get credit for this.)

There are a number of other ways in which students' co-op experiences are brought back to campus. Our B. S. degree requires students to have two technical jobs in their major fields. The co-op project for these jobs must be a technical paper on the work. At Co-op "swap sessions" at the beginning of each quarter, a few students give formal reports to the other students and the faculty of the Institute. From time to time throughout the quarter students will report on their co-op jobs at meetings of the Science Interest Group (roughly the equivalent of the Science Club at other schools). There are often informal discussions of co-op jobs between advisor and advisee and in the classroom. One student, who worked in a cryogenics laboratory, could add a great deal to a classroom discussion of colligative properties.

In the Science Building, a "Co-op Job Board" lists the most recent science co-op jobs, brief descriptions of each job, and the names of students who have recently been at those jobs. In addition there is a map of the country with a numbered pin identifying each job on the list. Unfortunately, we have difficulty finding time and personnel to work on this board, and so it is not always up to date.

At Antioch we make a clear distinction between co-op credit and academic credit. A student may not obtain both for the same activity. We also have a five credit Senior Project requirement, a laboratory and/or library research project as a culminating educational experience in which the student focuses knowledge and analytical skills on a specific scientific problem. Students are not permitted to satisfy this requirement while on co-op, even if they do work that is different from, and above and beyond what the specific job requires. There are two reasons for this policy. First, the more student research done away from campus, the more in danger the Institute is of becoming moribund. Second, although it is infrequent, some off-campus research directors use undergraduate students as pairs of hands, not really teaching research skills to these students. Having research done on campus avoids this problem. However, some off-campus research experiences are so much better than anything that we can provide that there are occasional exceptions to the policy.

There are two areas in which we are working to improve the place of co-op education in our program. The first of these has to do with the extraordinary demands placed on our students by requiring them to complete the entire program, including the six co-op blocks, in four years. There is currently discussion on campus about how to give students an option of studying for a fifth year under some form of reduced tuition. The second area has to do with finding better general and systematic methods of integrating the co-op and classroom experiences.

REPRESENTATIVE CURRENT CO-OP JOBS

U. S. Department of Energy, Pennsylvania & West Virginia

Applications invited from students second year and above interested in this fossil energy program. Appropriate majors are geology, physics, health sciences, chemistry, computer science, and accounting. Six months preferred and the openings are competitive with students from other colleges.

Cray Research, Mendota Heights, MN

Occasional openings in computer research for students with a background in Fortran, Pascal, C, and UNIX. A recent co-op helped in the development of compilers and supporting software products for Cray supercomputer.

Field Museum of Natural History, Chicago, IL

For upperclass students. Possible openings in natural history museum in the areas of anthropology, botany, paleontology, zoology, and science library. Only students with completed degree plans in relevant fields, and at least two previous co-ops with written evaluations will be considered.

Interferon Sciences, New Brunswick, NJ

Occasional openings in this biotechnology company for advanced science students to work on cloning, gene manipulations, and library screening. Previous off campus lab experience plus courses such as organic chemistry, microbiology will make the applicant attractive.

National Park Service, Fort Collins, CO

Spring and summer openings for a student interested in studying the effects of acid rain in the national parks. Work will involve sampling water, precipitation, and snow. Applicants must have cross country ski equipment and winter gear.

Yellow Springs Instrument Co., Yellow Springs, OH

Openings for one student per quarter in one of several phases of this business that manufactures scientific instruments for both medical and scientific research. Students are encouraged to describe their special hope for their work experience as there is no set job that needs to be filled. Assignments may be in administration, research and development, testing or others.

Xerox Corporation, Rochester, NY

Opportunity for students with strong backgrounds in physics, organic or physical chemistry and a willingness to spend six months (not necessarily at one time). Students work in close association with senior staff on projects concerning synthetic organic chemistry, physical organic chemistry, photochemistry, and instrumental analysis. Early application is necessary.

Oregon Health Sciences University, Portland, OR

Well qualified upperclass students are frequently needed in the cardiology research laboratory and in the obstetrics and gynecology department.

REPRESENTATIVE CO-OP PROGRMS OF RECENT GRADUATES

Student A; Major field: Environmental Science/Geology; a 1987 graduate, is currently employed as a professional geologist with Technos, Inc. while he ponders what he wishes to do in graduate school.

Intern Teacher Catlin-Gabel School Portland, OR	Crew Member Archaic Oshara Project Albuquerque, NM
Research Assistant Savannah River Ecology Lab Aiken, SC	Scientific Assistant (2 blocks) Field Museum of Natural History Chicago, IL
Field Assistant Mass. Dept. of Environmental Quality Engineering Boston, MA	Researcher Division of Water Quality Testing Yellow Springs Instrument Company Yellow Springs, OH

Student B; Major Field: Physics, a 1986 graduate, is currently on leave from the graduate program in Philosophy of Science at Tufts University, with the Peace Corps in Cameroon.

Mechanic A.B.J. Foreign Auto Repair Somerville, MA	Technician IBM Corporation Yorktown Heights, NY
Travel (2 blocks) Mexico and Alaska	Research Assistant (2 blocks) Xerox Corporation Rochester, NY

Student C; Major Field: Mathematics/Computer Science; a 1987 graduate, is currently a regular employee of Apple Computer, Inc.

Cashier/Asst. Manager Century 23 Theatre San Jose, CA	Photo-Journalist "The Japanese Summer Festival" Amori & Hirosake, Japan
Personal Secy/Apt. Maint. Project SEED Berkeley, CA	Software Intern Cray Research, Inc. Bloomington, MN
Software Test & Engineering (2 blocks) Apple Computer, Inc. Cuprtino, CA	

Student D; Major Field: Chemistry; a 1986 graduate, is currently a graduate student in Chemistry at the University of California, Berkeley.

Boat Shop Apprentice (2 blocks) Chesapeake Bay Maritime Museum St. Michaels, MD	Research Assistant (2 blocks) Yale University, Dept. of Molecular Biophysics & Biochemistry New Haven, CT

Lab Technician (2 blocks)
Yellow Springs Instrument Co.
Yellow Springs, OH

Student E; Major Field; Chemistry/Biology; a 1985 graduate, is currently a medical student at The Ohio State University.

Personal Research Project
Granada Hills, CA

Assistant to Nurse/Midwife
Independent Baptist Mission
Creve, Haiti, West Indies

Laboratory Aide
Yale Medical School
New Haven, CT

Laboratory Aide
National Inst. of Neurological &
Communicative Disorders & Stroke
Bethesda, MD

Dancer/Choreographer
Dancing with East
Yellow Springs, OH

Oakland Feminist Women's Health
Collective
Healthworker
Oakland, CA

Bunk Counselor
Camp Rainbow
Croton-on-Hudson, NY

An anecdote about student E will again illustrate the power of the co-op program. She had applied to the Medical School at The Ohio State University and was invited for an interview on a day when many applicants were being interviewed. The faculty had a heavy load that day with numerous twenty minute interviews. She had her last interview late in the day. Her interviewer, who had her file in front of him, started asking her the usual questions. After a few minutes of this student E said, "I am very happy to continue answering these questions. However, most of that information is in the file in front of you. I thought that perhaps it would be more useful to you if I told you about my three months working with a nurse/midwife in a rural Haitian health clinic." The interviewer talked with her for an hour, and her letter of admission arrived the next week.

SOME COMMENTS

A number of years ago, one of us was a panelist at a national American Chemical Society meeting on co-op programs. We explained the Antioch program and its virtues, but there was very little interest. Most of the educators and representatives from industry were interested in how to set up and run an efficient co-op program as an employment agency, while we stress the virtue of a wide variety of co-op experiences. One of the employers at this meeting (and he was by no means alone in this opinion) stated that once a student started a co-op job with his company, that student was expected to continue with that company and seek employment there after graduation. If there were a number of students from the same school who did not meet these expectations, the company would stop taking co-op students from the school. We are not job-brokers - we are offering our students opportunities.

We encourage our students to take jobs all over the country, all over the world. A number of educators at this meeting were concerned about finding co-op jobs close to the school so that the student would not have to deal with a dislocating travel experience. It is true that this kind of co-op program is a powerful way for students to find employment. Our students, however are trained in self-sufficiency, resourcefulness, and sophistication, qualities in great demand in the work-place. When they graduate our students find jobs and the co-op program has given them the world.

Chapter 16

The Nature Of Innovation In College Science Teaching

by

John E. Penick
John A. Dunkhase
Robert D. Allen
Linda W. Crow

"If you want to see bad teaching, look to a college science class." How often have we heard these words? Unfortunately, they seem well-justified as we look at National Assessment data from 1977 and later which indicate that the more science a person takes the less likely they are to find it useful or interesting. The same National Assessment, in asking young adults aged 22-35 about the utility of science, found that they were even more pessimistic than were our younger citizens. Obviously, attitude toward science is in a decline.

At the same time as these declines, we find that college science courses are becoming more mathematical and rigorous, excluding general interest students from participation. Rarely do such science courses include applications or a focus on societal issues. Many universities are even eliminating laboratories for freshman science courses and are trying to make the courses more abstract. Looking at such courses, one might be led to believe that they are designed to produce professional scientists, not scientifically literate citizens. And, equally unfortunate, it is still true that most science courses can be completed successfully by someone who merely memorizes well even though they may not understand.

Looking at the sequence of events in many college science courses, one might easily come to the conclusion that the developers and the instructors of these courses feel that all students need to gain theory before they can apply knowledge. We would find that only a few college science courses are seriously trying to affect student attitude and that, in fact, professors assume that most students wish to become scientists and that science courses eliminate those not fit to such a profession.

While we all know these stereotypes and can find instances where they fit, we know equally well that they are not true of all. Unfortunately, like bad news, the negative examples are the ones which gain the most publicity and are best remembered. But, we are pleased to say, the fifteen programs described in this monograph do not fit that negative description. Excellence is alive and well in college science teaching. In all of these programs we find instructors striving to have courses which reflect the nature of science and allow students many opportunities for decision making. We find courses where theory comes after application; where students come to learn science and appreciate it by doing something with it rather than merely memorizing. We also find that many of the courses are designed for special populations, most of whom will not be professional scientists.

Sampling fifteen college science programs out of the multitude available can hardly be considered rigorous and quantitative research. As a result, our analysis of these fifteen programs is definitely neither rigorous nor quantitative. Rather, we look to provide some generalizations about the nature of excellence in college science teaching as reflected in this sample. With these generalizations, we think you will be able to look at your own teaching and curriculum, making some decisions about how these generalizations fit with what you are doing or what you may wish to do. Our goal is a broad use of generalizations for we feel strongly about their existence, can cite evidence as to their impact, and are quite delighted that we have fifteen outstanding college science programs to describe. We hope that you agree with us.

SOME GENERALIZATIONS

Predictably, this collection of fifteen exemplary college science programs present many commonalities. Most are small, private colleges without graduate programs. Several have a religious affiliation and some are community colleges. All, however, have programatic aspects which should be of interest and could be transported to another institution.

The programs are locally developed, designed for the needs and interests of a particular group of students.

Many of these curriculum developers expressed the same frustration; trying to create a meaningful curriculum for their students from commercial materials. While all use a variety of textbooks and many commercially available materials, none found a single commercial program that exactly met their needs. Now, most rely on a multiple-reference format with many readings and activities which are locally designed and developed.

Programs are often built around a professor's outside interest and activities.

In designing curriculum, professors turn to the most likely source; themselves. As Kay Elsen (Chapter One) put it I wanted the "same opportunities and excitement for my students as for myself." Elsen drew on her own with research on the feeding patterns of infant lowland gorillas at the Milwaukee Zoo. Now, her zoo biology course for non-majors finds students heavily involved in long term projects. These projects have an instructional component and are almost always interdisciplinary with their majors.

James Bugh (Chapter Ten) assigns students land use and planning projects which are a "direct outcome of my professional experiences." His students have evaluated sanitary land fills, housing developments, a highway relocation, and a proposed mine. In the process, they have had to apply their geology as well as their land use and planning expertise. Drannar Hamby (Chapter Nine) takes advantage of his own special knowledge and interesta through a physical science class which meets outdoors in winter. Camping in the mountains allows many opportunities for him to develop and enhance his own outdoor survival skills while passing on his knowledge to other students. At the same time, students are studying many aspects of the physical sciences in a somewhat more severe environment and more meaningful conditions that they would find in the typical classroom. As a result, these students come to not only appreciate the science but the difficulty of obtaining data under real conditions.

Fourteen of the programs are clearly built around a general theme of **Problem Solving In The Real World.** While some emphasize the processes of science and some are more concerned with applications of science, all involve the students in doing, in making decisions, and in critical thinking. In the process, students are quite active in doing and using their science, have to make decisions at critical points, and actively communicate what is happening to them.

Students identify and make clear statements of a scientific problem.

In general, these innovative programs have moved away from standard laboratory activity format toward true scientific investigations. And, most of this involves students following their own hunches and ideas in identifying, resolving, and communicating scientific problems. Thomas Alford (Chapter Four) has developed his general biology course around **Science As A Way Of Knowing**, based on a paper by that name in the Journal of College Science Teaching. In Alford's laboratory, students learn that science is a way of knowing and that "observation and hypothesis testing is a process common to human thought and not a special technique employed by scientists." His students investigate scientific issues of the real world, often found in the press of popular magazines. Then, they research issues back to the professional literature for critical evaluation.

Donald Ferruzzi (Chapter Six) developed Project INHALE where students become both subjects and experimenters in research. Documenting the effects of progressive effects of cardio pulmonary exercise, "the course strategy directly involves students in appropriately designed experiments to learn.... an appreciation of a systematic processes of inquiry...critical thinking, and a higher level of intellectual freedom." Again, many of the ideas for research come from sources such as the New York Times, Science, and Scientific American. Once again, students search back to the source, trying to find truth.

In Applied Chemistry for the Non-Scientist, Judith Kelley and Barbara Smith (Chapter Seven) built an introductory chemistry course around "thinking scientifically while learning the basic principles of chemistry." They have done this by focusing on the "process by which knowledge is developed in science and relationships between chemistry concepts and their many applications in our lives." We see considerable evidence of this in the popular literature where many issues are related to chemistry. Students explore several major and minor library research projects and student exams center around an analysis of issues based on the issues of the students' knowledge of chemistry. Kelley and Smith feel that a format of seeking a clear statement of scientific problems helps students to become knowledgeable about finding a variety of technical information and evaluating sources of biases. As they put it, "this is clearly an advantage for fulfilling their roles as informed citizens."

In Oglala Lakota College in South Dakota, Debra Dunn (Chapter Fourteen) designed a course to meet the needs of adult Indian students on the reservation. Her course focuses "solely on the problems of the reservation and how they differ from other rural regions of the country." Her students often believe that "science is strictly a part of the dominant culture...and a threat to their land," an attitude not easily changed by reading and lecture.

Oriented heavily toward a student perspective and the reservation, she has made the course quite practical and encourages students to examine critically perceived problems. When they are finished, students "know how to do a complete scientific evaluation of environmental problems."

Students complete long term science projects.

Many of these projects focus on more traditional scientific research projects and techniques Angela Sauro's (Chapter One) students determine which microorganism is affecting reptiles at the Milwaukee Zoo and make recommendations as to the drug of choice. In doing so, they are using their skills in a very applied way, seeing real world results, and providing a needed service to the zoo. In The Unity of Life, a core course for biology majors, Grayson Davis and Robert Hanson (Chapter Three) "hope to expand the organized facts and concepts of science to include a mechanism of inquiring and re-examining facts...including an experimental component." Each student designs and carries out an independent research project, including a research proposal that is defended to the professor in a formal scientific paper as a culminating project. At Antioch College (Chapter Fifteen) Stanley Bernstein and Robert Parker involve all students in a senior research project. They need this "as a culminating educational experience in which the student focuses knowledge and analytical skills on specific scientific problems." Most of these research projects involve

considerable library research as well. Some of the courses describe in these fifteen chapters, such as Applied Chemistry for the Non-Scientists (Chapter Seven) and the introductory biology course at Orange County Community College (Chapter Four) focus more on library research. But, clearly students are identifying and formulating the problems, persuing those problems in the literature, and drawing conclusions.

While some are not doing research as it is traditionally thought of, five of these programs are involving students in significant long term projects. At the Milwaukee Zoo, Kay Elsen (Chapter One) has students from a variety of majors working on projects to enhance their own learning and the effectiveness of the zoo. Her students might, for example, design an exhibit and instructional materials for a particular part of the zoo. Or, they might make recommendations about a change in habitat for an animal or make recommendations to educate the public about a particular exhibit. Her students have prepared pamphlets, signs, and other management and instructional aspects of the zoo. Each of them was able to bring their own major expertise to the zoo in some way.

At Trinity College in Connecticut, David Henderson (Chapter Eight) designed an upper level analytical chemistry course where the major departure is "structuring the curriculum around a major project similar to that which the student might encounter as a professional chemist." Just like a chemist, his students identify real life analytical problems, research the relevant literature, and conduct analytical procedures to gather data. Ultimately, they report the results of their findings.

James Bugh (Chapter Ten) sees a culmination to his course when students conduct an evaluation of a proposed land use, prepare text and graphics, and complete a report as if presenting it at a local planning board.

Rebecca Halyard, Clayton State College in Georgia (Chapter Thirteen) "replaces a more classical study of unknowns in microbiology with problems in a simulated or actual clinical situation." Her students' projects are quite similar to what they would be expected to complete in actual job settings.

Debra Dunn (Chapter Fourteen) has her "students choose a project that they believe to be a problem on the reservation...and gather information available to the public and other interested groups." In the process, her students learn science is not just something of a white culture and that they do have control over both their land use and their thinking.

Students present the results of their research projects.

While almost all of the project oriented programs involve some types of communication, some go so far as to write a formal scientific paper. The students at Valparaiso University (Chapter Three) even have to defend a research proposal to the professor before conducting their project. The formal scientific paper is critiqued just like any other paper would be. Students at Mount Mary College in Milwaukee (Chapter Two) report results of their studies both to the zoo officials and as they dissiminate data at conventions and through science journals. As in most of these programs, these students are learning that the work they are doing in school is not a mere academic exercise; it's meaningful, interesting to others, and worthy of dissemination and communication.

All of these program developers attempt to bring real and relevant problems into the educational process. Sometimes they do this by taking the students outside the classroom and sometimes by bringing resources into the classroom. But, in all instances, the students are actively involved in science as well as their learning and are often performing the same type of functions as professionals in the field might. In doing so, the students are not only learning their science but a variety of career opportunities as well. And, many community members see students in a new light and with a fresh appreciation for their usefulness.

Several programs provide internships for students.

Sister Buettner at Molloy College in New York (Chapter Five) offers her students an extensive summer internship program where "students come to value practical experience in research, hospitals, and private and county laboratories. They often reorient their thinking and crystalize their aspirations." Now, her students are a viable and visible portion of the community performing internships in a dozen community agencies, laboratories, and public works

The cooperative education program at Antioch College (Chapter Fifteen) makes internships a requirement for the whole college to "balance scholarship with life experience." At Antioch, every student participates in a plan of alternating work and study quarters. There, students in science have completed internships in dance, industry, laboratories, and public service agencies. Just reading about a number of places students have worked makes one rather excited the students and the program. Though these two internship program descriptions, the reader quickly gains an image of students who have many opportunities to apply knowledge and a different perspective on both the world of learning and the world of work.

Outside activities of the professor often provide a focus for the course.

Kay Elsen (Chapter One) had no difficulty using her outside professional activities on lowland gorillas at the Milwaukee Zoo to lead into opportunities to use the zoo for the further education of her students. Even though her students are general education students, she felt strongly that working on real projects with professionals would add to their store of knowledge. At the same time, she is broadening her own experience in working with the zoo, giving her more contacts with people in various departments.

Drannan Hamby (Chapter Nine) has attended a number of workshops with outward bound and the National Outdoor Leadership School. So, it was quite natural that he should take his interest in outdoor experiences, survival training, and outdoor leadership to his students. What better way to do science than in the out of doors? In doing so, he feels strongly that students are not only learning science but developing personal skills and awareness both useful to the total life experience. And, after two weeks of camping in the snow and the mountains, we have no doubt that they also have a number of stories to tell to their grandchildren.

James Bugh (Chapter Ten) requires that his students work on on-going projects, many of which are direct outcomes of his professional experience. In doing so, he takes advantage of his contacts, his personal knowledge, and his interests. This probably means that he has more interest in what the students are doing than the more traditional situation where students merely choose a topic, project, or assignment. Also, since it involves areas where he has working professionally, he is able to provide considerable input, advice, and leadership.

Local community resources are critical components.

The Milwaukee Zoo (Chapters One and Two) offers 185 acres and a number of highly specialized functions which provide a delightful interdisciplinary campus for students at Mount Mary College. The internships at Malloy College (Chapter Five) and at Antioch College (Chapter Fifteen) use a large number of community service agencies, laboratories, and industries, all community resources. Many of the programs use local newspapers as well as more traditional national publications resources in introducing societal issues to their classes. These resources are readily available, are quite meaningful to students, and, in many of the programs, provide a lead in to new ideas and topics. The programs at Linfield College in Oregon and Cortland College in New York (Chapters Nine and Ten) use a mountainous area and a college owned field outdoor laboratory respectively. Often, such areas are rarely used and readily accessible to the college instructor and students.

Stephen Stropes, of Columbia State Community College in Tennessee (Chapter Twelve), uses video tape made in real hospital and clinical situations. From these, he produces highly technical interactive videos which demonstrate the applications of biology concepts to the practice of nursing. Columbia State College has a Center of Emphasis project specifically created to produce interactive videos. Students of Oglala Lakota College in South Dakota (Chapter Fourteen) analyze real environmental problems on their reservations. Thus, these students are learning to identify and resolve very personal problems from both practical and cultural standpoints.

Many programs stress the interdisciplinary nature of learning and science.

The Mentors in Science program at Brown University (Chapter Eleven) offers science mentor groups as an additional aid to students in science classes. Mentors are involved in a variety of different courses targeted to both science majors and non-majors. Mentors in Peter Heywood's program provide extra help and enrichment and help get science avoiders to enroll in more science courses. Sometimes science mentors provide demonstrations, discussions, field trips, or even a reiteration of a lecture. The programs at the Milwaukee Zoo (Chapters One and Two) as well as the internships at Antioch and Malloy Colleges (Chapters Fifteen and Five) have students performing in a variety of work related, interdisciplinary settings.

Included in the interdisciplinary nature of many courses is a focus on societal issues such as that found in Applied Chemistry for the Non-Scientist (Chapter Seven) or the analytical program at Trinity College (Chapter Eight). Here, the students are actively identifying societal issues and seeking resolution for them. These courses are, by definition, interdisciplinary since the resolution of such societal issues involves looking at the problem from a variety of aspects and with as much information as can possibly be gathered.

Innovative professors continue to innovate.

The developers and instructors for these courses have much in common. Quite experienced, averaging almost sixteen years of college teaching experience, they continually express their concern for innovation, evolution, and the futures of their programs. They speak quite directly of the need for continual change and a fear of the status quo and resulting complacency. Most describe themselves as teaching at small, liberal arts schools known for their teaching rather than their research. Words like "friendly openness of concerned faculty," "small classes," and "professors teach the labs" abound in their descriptions.

We also sense these instructors to be more than average as we look at their lists of publications, presentations, and awards such as the NSTA Ohaus Award. Quite a number have extensive field work in their profession in areas as diverse as anthropology, geology, nursing, and chemistry. Many describe their volunteer work at museums, zoos, and even the Peace Corps. It appears that they bring themselves and their professional lives into their science classrooms much to the benefit of their students.

SOME CONCERNS

While all of these are exemplary programs, evolving in their own directions, they are not yet at their peak. We would like to see more emphasis on societal issues in all programs so that students have a better understanding of current events in relationship to the science they are studying. While several of the science for non-science majors courses do use a number of societal issues, several of the major courses do not indicate that this is a priority. The National Academy of Science and many writers have stressed the need for science literacy and a basic understanding of the relationship between science and society.

A greater concern is instruction. Though instructors are highly energetic, concerned, and quite interested in their students, these program descriptions still indicate a relatively teacher-centered curriculum where the professor is making most of the critical decisions. Considerable evidence now exists to suggest that students learn best in an atmosphere where they are making decisions related to their learning style, problems to be identified and resolved, and their level of performance. Although several of these problems do have students identify their

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own problem, none seem to indicate self-evaluation and most offer students few choices in terms of the actual activity they will pursue.

The exact nature of instruction in these programs is somewhat unclear. But, enough reference is made to traditional words such as lecture, laboratory, and assignment to make us believe that many of these courses are relatively traditional in format and scheduling. While we recognize the problems inherent in teaching in a college as well as in scheduling students, we feel strongly that more innovation could take place in this arena. We hope the next generation will extend student decision making further, making it a key ingredient.

Instructors in these programs speak of encouraging students, guiding and assisting, but none clearly describe how they undertake these. The assumption is made that instruction, motivation, and encouragement merely happen. Yet, we know that some people believe that encouragement comes from pushing and coercing while others believe it comes from guidance. Still others believe encouragement comes from paying attention to basic needs. We would like to see college instructors think more specifically of the behaviors they exhibit in the classroom and the impact these might have on the students.

Evaluation is another weak point in all of these programs. Typically, evaluation focuses on finding out what students have learned as opposed to discovering the worth of the program itself. Again, although this is quite difficult for most instructors, would like to see both program and instructor evaluation have a higher priori.

SOME FINAL THOUGHTS

From conception to production we have found this to be an exhilarating project. Each days' mail brought descriptions of new and innovative programs unlike most of the ones with which we were familiar. In the process, we have had the opportunity to correspond with many members of the Society for College Science Teachers, coming to know several of them quite well. We look forward to seeing all of them in the future and meeting more college science teachers with an eye for innovation and excellence.

We hope you find these programs as inspiring as we have and see ways to incorporate these ideas into your own teaching and curriculum. When you do, we hope you will write us and others in an attempt to publicize your efforts and the efforts of good teachers everywhere.

ABOUT THE AUTHORS

Thomas Alford received his bachelors degree in botany from Ohio University, Athens, in 1961 and his masters degree in plant cytogenetics from Indiana University, Bloomington, in 1963. He came directly to the Biology Department at Orange County Community College in the fall of 1963 where he teaches courses in biology, botany, and genetics.

Robert D. Allen, Dean of Instruction at Inver Hills Community College, received a Ph.D. in Biophysics at UCLA. After working with Sam Postlewaithe at Purdue, he was on the biology faculty of West Virginia for twelve years. President of the Society for College Science Teachers in 1986-87, he now conducts many workshops for developing critical thinking skills.

Stanley Bernstein received his Ph.D. in Chemistry from the University of Michigan. After two years of post-doctoral work at The Ohio State University he joined the faculty of Wright State University in Dayton, Ohio. In 1970 he became Assistant Professor of Chemistry at Antioch College. Since 1979 he has been Chairperson of the Chemistry Department and, since 1984, Professor of Chemistry. Early in his Antioch career he chaired the committee that brought the co-op syllabus up-to-date and detailed the requirements for the co-op project.

Sister Janice Buettner, O.P., Professor of Biology, earned a B.A. from St. John's University, an M.S. from New York University, and her Ph.D. in Biology from St. John's University in 1971. Sister Janice taught for 15 years with the Science Department of Bishop McDonnell Memorial High School, Brooklyn, and has been a member of the Biology and Physics Departments of Molloy College for 30 years. At present, she teaches courses in biology for majors and non-majors, conducts a course for Gerontology majors in "Biology for Aging", and prepares student nurses in physiology. She also directs the Field Experience program in Biology and coordinates a new B. S. Degree program in Cardio-Respiratory Sciences.

James E. Bugh studied geology at Capital University, Bowling Green State University, and received the Ph.D. from Case-Western Reserve University in 1968. His field work has ranged from the mountains of New Mexico to alpine glaciers of Alaska, and, in more recent years, centered on geology applied to land-use problems in New York State. Following a semester as an exchange faculty at the Beijing Teachers' College, China, he was appointed Chairman of the College Task Force on International Education and acting International Student Advisor. The State University College at Cortland has the most extensive study abroad program in the State University system.

Linda W. Crow, an instructor of Earth Science in the Houston (TX) Community College System, earned her Ph.D. at the University of Houston in 1978. Active in the Society for College Science Teachers, NSTA, and the National Association for Research in Science Teaching, she has published widely and is currently editing the research column for the Journal of College Science Teaching, directing a Minority Institution Science Education Program grant, and coordinating local arrangements for the NSTA 1991 national convention in Houston.

Grayson S. Davis received his B. S. in zoology from George Washington University, Washington, D. C., and his Ph.D. in developmental biology from the University of Virginia. In 1981 he joined Valparaiso University. He is one of two lecturers and three laboratory instructors in the introductory course for biology majors and also teaches comparative vertebrate anatomy and developmental biology. His primary research interest is amphibian gastrulation. Fishing for steelhead trout, particularly in the company of his colleague Robert J. Hanson, is a favorite relaxation.

John A. Dunkhase is currently on the faculty at the University of Iowa in both the Geology Department and the Science Education Center. He has a BS in Geology and a Ph.D. in geochemistry from the Colorado School of Mines. Before coming to Iowa, Dunkhase spent fifteen years in the mineral exploration industry and before that three years teaching junior high science in the New York public schools. He maintains an active interest in several mining operations.

Deborah Jean Dunn has been an instructor at Oglala Lakota College since 1981. While there she has been involved in the expansion of the science curriculum and the development of two science courses for non-majors: People and the Environment and Human Biology. She also teaches biology courses for the nursing program and general science courses for elementary education majors. Prior to coming to OLC, she served for two years with the Smithsonian/Peace Corps as a Park Botanist mapping out the tropical forest for a new national park in the Caribbean and taught high school biology for three years in Ralston, Nebraska. Dr. Dunn has a Doctorate of Arts in Biology from the University of Idaho, a B. A. in Biology Education and a Masters of Science in Botany from the University of Northern Colorado.

Kay M. Elsen, Professor of chemistry at Mount Mary College, has been teaching at the college level since 1965. Even though most of her graduate work is in chemistry and education her undergraduate work included biology, still a special interest. In 1976 Dr. Elsen joined the Milwaukee County Zoological Society and Zoo Pride, the volunteer organization of the Society. Her major contributions to the Pride organization have been concentrated in the education committees. Various activities have been outgrowths of her interest in animals and her involvement at the zoo. During the summer, she leads safaris to

Africa and later lectures on her travels. Papers related to her educational endeavors have been given at national meetings and conventions.

Donald Ferruzzi is Chairman of the Department of Natural Sciences at Suffolk Community College's Western Campus where he is also a Professor of Biology. He has taught human anatomy and physiology at the College since 1974. Among his publications are A Laboratory Manual of Human Anatomy and Physiology, Volume I and II, The BioLab Book: Laboratory Studies in Life (co-editor) and Sex-Sense & Nonsense: A Workbook for Human Sexuality (co-editor). Professor Ferruzzi lives with his wife and two children in Setauket, Long Island, New York.

Rebecca A. Halyard received her bachelors and masters degrees in biology from Emory University. She received her Ed.D. in Science Education from the University of Georgia in 1976. She has been on the biology faculty at Clayton State College (formerly Clayton Junior College) in Morrow, Georgia since 1969 and has held the title of Professor of Biology since 1983. She teaches the microbiology as well as the anatomy and physiology sequences for health science students. She has a particular interest in studying how students use basic science knowledge in clinical areas and has reported several such studies. She is a charter member of the Society for College Science Teachers and currently serves as a Counselor-at-Large in that organization.

Drannan Hamby graduated from Linfield College with a major in chemistry in 1955. After a year in Germany as a Fulbright Scholar he returneed to Oregon as a chemist for Linfield Research Institute. His Ph.D. is from Oregon State University with a major in physical chemistry and a minor in physics. Since 1962 he has taught at least part-time in the Departments of Chemistry and Physics at Linfield College. His research interests have concentrated in the field of electrochemistry and he has published in the areas of high and ambient temperature batteries and basic properties of high temperature salt mixtures. Since 1972 he has been involved in outdoor education, complementing an interest in hiking, skiing, and climbing. He has completed numerous classes as a student with both Outward Bound and the National Outdoor Leadership School (NOLS) and, for several summers, has worked as an instructor for NOLS. He is an active member of the Mt. Hood Ski Patrol and the Electrochemical Society and has been active in local civic affairs.

Robert J. Hanson earned his B. S. at Valparaiso University, Valparaiso, in 1948. He achieved the M. S. in 1949 and the Ph.D. in 1955 at the University of Illinois where he subsequently taught in both the medical and dental schools. Viral antigens were his primary research interest. Since returning to Valparaiso University in 1962, he has participated in many courses, most recently the introductory course for biology majors, bacteriology, molecular biology and environmenal biology. He has long been an environmental activist and an avid outdoorsman with admirable skills in hunting, fishing and gardening. He became Professor Emeritus in 1987.

David E. Henderson is currently Professor of Chemistry at Trinity College and Director of the Interdisicplinary Science Program. He received his Ph.D. in Analytical Chemistry from the University of Massachusetts in 1975. After three years of post-doctoral research at the University of Massachusetts, during which he also taught part time at Mt. Holyoke College, he joined the faculty of Trinity College. In addition to developing the program in Analytical Chemistry at Trinity he also developed a course in Chemistry for non-science students and more recently has lead the development of an honors Interdisciplinary Science Program which provides a broad interdisciplinary approach to the study of science and mathematics. He is also active in development of HPLC separation methods for labile metal complexes and peptides.

Peter Heywood grew up in Manchester, United Kingdom, and received his undergraduate and graduate degrees in Botany at London University. As a cell biologist, he has published more than 40 papers on the ultrastructure of algae, protozoa and mammalian cells. An Associate Professor of Biology at Brown University, he has taught botany, cell biology, histology, and biology for non-majors. As Chair of the Committee on Science and Technology in the Liberal Arts he has been concerned with the development of scientific and technological literacy in non-science majors. He is also very involved in computer-assisted instruction and is collaborating with software experts to teach a cell biology course using a hypermedia system comprising text, micrographs, diagrams and 3-dimensional models. He is a Fellow of the Linnean Society of London and a recipient of a National Science Teachers Association-Ohaus award for innovations in college science teaching.

Judith A. Kelley, a member of the Chemistry Department at the University of Lowell since 1966, has developed courses and materials for Precollege Refresher Chemistry and several freshman chemistry courses. With a colleague she recently designed The Responsible Chemist in which students preparing to be chemists explore their ethics and values within the context of what it means to be a practicing chemist. With area science teachers she has established STARS, a network for the professional development and support of science teachers. Her primary interests are exploring ways to help students develop their reasoning and improving science education at all levels.

Robert L. Parker has been involved in experiential education for over thirty years, first as an Antioch employer, hiring students at an outdoor education site in New Hampshire. He subsequently came to Antioch College where, as director of the college outdoor education center, he was an on-campus employer of co-op students. He later became Associate Director of Cooperative Education at the College and, since 1969, has been Director of the Center for Cooperative Education. He spent a year's leave in the United State Office of Education, Cooperative Education Branch. He is consultant to a number of educational institutions on planning and using cooperative education.

John E. Penick, Professor of Science Education at the University of Iowa, was the first national chair of the NSTA Search for Excellence in Science Education. He edited the Focus On Excellence monograph and has published more than 140 papers in a variety of journals. He is currently on the Board of Directors of NSTA and the International Council of Associations for Science Education, reflecting his interest in international education. The 1989 President of the National Association of Biology Teachers, he is a charter member of the SCST. His research interests usually focus on developing effective teaching practices.

Angela M. Sauro, Chairperson and Professor of Biology, as been teaching undergraduate Biology for 25 years. During this time her interest in effective teaching through unique applications has led to research projects with local community resources -- the Milwaukee County Zoo and Mitchell Park Horticulture Domes. Her work also includes development and evaluation of learning modules for undergraduate non-biology majors on science literacy, technology assessment, and decision-making. Dr. Sauro has also been active in community service serving on the board of directors of the Friends of the Domes and has developed a series of educational modules for grade school children. Her work has led to presenting papers at national and international meetings and scientific and educational publications.

Barbara L. Smith has been a member of the chemistry Department at the University of Lowell since 1966. She has developed innovative materials for several freshman chemistry courses and served as an advocate for providing students with recognition for their achievements. She is currently teaching only part time at the University while she is actively involved in teaching a five and an eight year old about the wonders of science; chemistry in particular. She serves as a science resource person for children in the community, sparking vital interest in science at the grass roots level.

Stephen L. Stropes is currently an Assistant Professor of Biology and Director of the Center of Emphasis in Biology/Nursing at Columbia State Community College. He received a Ph.D. in Zoology from the University of Arizona and taught at several colleges and universities prior to Columbia State. While at Columbia State, Stropes designed a laboratory in human anatomy and physiology which included the use of instructional video programming. He developed these programs with campus production facilities and subsequently co-authored the grant proposal which currently funds the Center of Emphasis. In addition, Stropes is a member of the Tennessee School-College Collaborative Task Force for the College Board's Project E.Q. and was selected as the recipient of the 1985-86 Distinguished Faculty Award at Columbia State.