CALIFORNIA COMMUNITY COLLEGES
AND
KERN
COMMUNITY COLLEGE DISTRICT

#92-0011
This proposal is a grant request. This proposal suggests that problems in general-biology education may be corrected by focusing on two major efforts: (1) a deliberate move to active from passive learning and (2) the design and implementation of learning experiences that stress critical-thinking and problem-solving skills.

We propose to reorganize the biology-majors sequence around the concept of science as a process. This reorganization permits students to become active participants in their education. After introducing fundamental critical-thinking and problem-solving skills, students will be required to continuously apply those skills as they practice science as a process. Students will become responsible for collecting information and putting the information into an appropriate context. Students then critically examine the evidence obtained, propose hypotheses to account for the evidence, and conduct experiments to test their hypotheses.
Introductory Biology Curriculum Reform

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Content will not be sacrificed to process; however, presentation of content will not be the sole function of lectures. Instead instructors will focus on developing deep understanding of key concepts. There will be a reduction of the terminology load to the minimum necessary to prepare students for upper division work, to communicate effectively, and to think critically about concepts.
1. Specific Educational Program Being Addressed

Targeted Educational Programs and Services

The proposed project is to revise the introductory sequence for biology majors at Bakersfield College. The sequence serves our transfer program. Approximately 125 students begin the sequence each year but fewer than 20 currently progress beyond the first semester. Relevant successful instructional strategies developed through this work will be applicable to general education biology classes (serving approximately 650 students per year).

The project has three primary goals that address the funding priorities delineated in the RFP for the Fund for Instructional Improvement. The most important goal is to improve our traditional instructional program for biology majors. Goal two is to increase our retention rates and provide educational services that better serve non-traditional students including women, older students, and ethnic minority students. Goal three is the improvement of our faculty and staff. We believe that all these goals can be achieved combining traditional and nontraditional forms of instruction as described in the Proposal Objectives section.

How we intend to address each of these areas is described in the following two sections.
2. Specific Problems Being Addressed

Educational Problems

Most general biology courses employ traditional didactic pedagogy. These traditional methods tend to foster and reinforce a number of pedagogical problems identified and discussed in depth by AAAS (1990) including:

* science is presented as a body of factual information to be absorbed uncritically;
* traditional teaching methodology suppresses students’ natural curiosity;
* traditional methodology leaves many students with the mistaken impression that they are incapable of understanding science;
* women and ethnic minority students are the first to opt out of courses emphasizing traditional pedagogy;
* students often leave science courses unable to apply the principles they learned to real-world problems; and
* students develop few salable skills to help them obtain a job in biology.

Specifically, courses based on the traditional lecture format convey science as a body of factual information to be memorized uncritically (AAAS 1990, Paul 1990). Students are not asked to consider the evidence that supports scientific principles or how this information came to be accepted by the scientific community. Students are not asked to learn the theoretical/hypothetical basis for modern technology (e.g., how gas-chromatographs and electron microscopes work). Students are asked to learn staggering numbers of mind numbing facts that could be looked up in any reference book. Students should be asked to examine why they believe what they believe. This will require building slowly, with ample discussion. It also means that laboratories should be exercises in experimentation and knowledge acquisition, not an exercise in following recipes (NRC 1990).

Traditional didactic pedagogy suppresses students’ inherent curiosity and leaves many with the mistaken impression that they are incapable of understanding science. This approach leads to high attrition rates and students who do persist are able to describe processes in intricate detail but are unable to relate the processes they study in the classroom to real-world situations. For example, students may be able to successfully answer questions regarding meiotic cell division on an examination but they cannot describe the significance of the process for developing better varieties of cotton for Kern County farmers.

Traditional pedagogy fails to develop in students the kinds of active engagement with the natural world and social interaction found among practicing scientists. Students fail to understand and share scientific standards for the kinds of evidence that are admissible in scientific debates and for the ways in which that evidence is interpreted. Most students erroneously believe that theories are guesses and that evolution and special creation are equally useful scientific theories.
The Specific Case of Bakersfield College

The introductory sequence for biology majors at Bakersfield College suffers from the same problems and from a myriad of additional problems that have grown more apparent over the years. The approach chosen by our predecessors was a two-semester introductory sequence of Botany (4 units) and Zoology (4 units). As more discoveries were made at the cellular and subcellular levels, a third course (Cell Biology also 4 units) was added. Only minor curriculum revision has occurred following the introduction of the Cell Biology course.

Now a plethora of problems are apparent including: a failure to incorporate important modern concepts in portions of the sequence (e.g., animal behavior, and the mechanisms of immunity, muscle contraction, and nerve-impulse propagation), low retention rates, poor advice (based on course titles rather than course content) being given to our students, and failure to emphasize the hypothetico-deductive method. All these problems require attention. In our view, the issues that demand immediate attention are: inadequate attention to the methods of science, a lack of emphasis on critical-thinking and problem-solving skills, and a high attrition rate.

Too Little Emphasis on the Methods Of Science. The sequence relies heavily upon taxonomy and description. These topics develop important skills (such as careful observation, record keeping, and biological illustration). The approach also acquaints students with biological diversity and classification. However, these skills are inadequate for modern biologists.

Biology has become a quantitative and predictive science during the past 20 years. For example, ecologists can now predict, with high precision and accuracy, the periods of activity of organisms in their natural habitats (Nobel 1983, Gates 1980, Porter et al. 1973), where organisms will be found in space (Woodward 1987, MacArthur 1972), how many species will occupy a given habitat (MacArthur and Wilson 1967), and even the quantity of tequila that can be harvested from wild Agaves in Mexico given rudimentary weather statistics (Nobel 1988).

These exciting new discoveries of modern biology were made using hypothetico-deductive (scientific) methods. The vast majority of new jobs in biology require biologists competent in hypothetico-deductive methods. Proficiency with these methods requires that they be practiced repeatedly. Unfortunately, the traditional descriptive-taxonomic approach offers few opportunities to develop these skills.

Critical-Thinking and Problem-Solving Skills. Most new jobs in biology require use of hypothetico-deductive methods, critical thinking, and problem-solving skills that are not fostered by the descriptive approach. The approach in Botany and Zoology is primarily taxonomic with emphasis on memorization and following instructions. Students receive almost no writing, critical thinking, or problem-solving instruction, nor are they asked to practice the methods used by scientists to obtain the facts they are expected to learn. The primary skills students are expected to demonstrate in laboratory are dissection and description skills. These exercises should be replaced with genuine investigations, designed and tested to
enable students to achieve the conceptual changes necessary for intellectual development and understanding (NRC 1990).

Attrition rate. Science pervades all aspects of modern life yet many Americans, even those who are otherwise well educated, have little understanding of science or how science affects their lives and standard of living (Miller 1982, 1988). There have been more than 300 reports recounting this and other deficiencies in the knowledge and intellectual skills of American students since the publication of A Nation at Risk (NCEE 1983). These social problems cannot be rectified if most students drop-out of biology courses.

Attrition rates in our general biology sequence are shocking. The attrition rate in zoology typically ranges from 40 - 60%. The attrition rate in Botany, an alternate first course in biology, ranges between 15 and 20%. The attrition rate in Cell Biology averages 8%.

More shocking is the number of students that choose NOT to continue their study of biology after completing our Zoology course. Fewer than 20% of students entering the sequence in Zoology enroll in another life science course at Bakersfield College. Less than 8% of students entering the sequence in Zoology choose to take the Botany course. Clearly these attrition-rates are unacceptable.

Additional problems. The existing sequence fails to prepare our students adequately for the job market of the twenty-first century. The vast majority of professional positions in the Life Sciences are (and are likely to remain) in genetics, molecular biology, cellular biology, ecology, and physiology. Traditional pedagogy does not provide instruction focused on the central concepts of these areas of modern biology nor does it provide instruction in the intellectual skills required of modern biologists. Alternative instructional techniques (described in the Proposal Objectives section) exist which reduce the barriers between school and work, link academic knowledge and learning outside the classroom, improve problem-solving abilities, and place greater responsibility with the student. These techniques have been found to better serve the needs of nontraditional students including the poor, reentering women, and underrepresented ethnic minorities (AAAS 1990).

Most working biologists routinely use computers. Bakersfield College has a multimillion dollar investment in computer technology for student use. However, the existing sequence fails to prepare students to use computers as laboratory equipment. We should ask our majors to use this facility and develop proficiency with computers.
3. Population To Be Served

Populations to be Served

The proposed changes will directly serve biology majors in the transfer program of Bakersfield College. However, community colleges across the state face the same pedagogical problems. The project will foster the graduation requirement in critical thinking established by the system in 1983 and expand application of critical thinking into the life sciences. Consequently, if our project is successful, it can serve as a model for revision for the rest of the system.

Most of the instructors teaching in the transfer program at Bakersfield College also teach in the general education program. The most effective strategies developed through the implementation of this proposal will also be incorporated in the general education program.

We also seek to increase the service we provide to nontraditional students including: women, ethnic minorities, and older students. "The need for greater participation of minorities and women in science and math careers, coupled with the fact that nearly half of all minority college students attend a community college underscores the importance of establishing two-year college programs for the recruitment and retention of talented minority and women students in math and science disciplines" (Quimbita 1991). The proposed changes have been found to be successful at retaining women, ethnic minority students, and older students in science programs (AAAS 1990). Therefore, in the short term we expect to retain more diversity in our student body and prepare our students to be more effective learners at senior institutions. In the long term we expect to significantly increase the number of students remaining in the science pipeline and to better prepare these students for the jobs which will be available in the twenty-first century.
4. Objectives

Proposal Objectives

Task 1. Devise critical thinking exercises in reading, writing, listening, and speaking within the framework of general biology. At least one significant exercise in reading, writing, listening, and speaking is planned for each lecture. Performance objective - 100 exercise sets completed by June 1, 1993.

Task 2. Select samples of historical development of biological concepts for presentation to students in lecture and for which students will perform critical evaluation. Performance objective - 10 exercise sets completed by June 1, 1993.

Task 3. Design laboratory experiences that emphasize science as a process. These exercises are to require students to perform all the steps in the hypothetico-deductive methods of science. Performance objective - 20 exercise sets requiring students to complete all steps in the scientific method and 50 exercise sets requiring significant critical-thinking but not necessarily requiring all steps in the scientific method completed by June 1, 1993.

Task 4. Acquire data sets from the primary literature for student evaluation. These data sets should be from classic experiments that led to major break-throughs in biology. Performance objective - 10 exercise sets completed by June 1, 1993.

Task 5. Design problem sets emphasizing data analysis and problem solving. These exercises should be as close to multifactorial real-world problems as possible. They should not be the typical artificial exercise concocted for student drill-and-practice. Performance objective 25 exercise sets completed by June 1, 1993.


5. Workplan Narrative

Proposal Strategy

This proposal suggests that the problems noted previously may be addressed by focussing on two major efforts: a deliberate move to active from passive learning imposed by didactic instruction, and the design and implementation of learning experiences that stress critical-thinking and problem-solving skills.

Traditional lecture-based instruction reaches large numbers of students at one time but does not actively engage the learners in acquiring knowledge. Laboratory classes are improvements over lecture-only courses, because the students have to collect and process their own data. Unfortunately, laboratory emphasis is often placed on data collection, not on data analysis. In reading lab reports, it is often evident that students have difficulty making a mental connection between information given in lecture and the lab exercises performed. They frequently do not understand the point of an exercise.

The problem of passive learning is solved by actively involving students in learning. The instructor designs and guides the learning experiences, providing encouragement and assistance when needed, rather than "professing" all the time. The students are responsible for collecting information and putting the information into context. Making students active learners is the focus of recent reforms in science education (Carter et al. 1990, Lawson, Rissing and Faeth 1990, Peterson and Jungck 1988, Levine 1991, Wheeler 1989), collaborative (cooperative) learning (Cuseo 1990, Newell 1990, Jackson 1989), critical thinking (Paul 1990), and problem-solving (Glock 1987, Woods 1989, Crow 1989, Perkins 1985).

We propose to implement these changes by reorganizing the majors sequence around the concept of science as a process. Focus will shift from taxonomic description to the nature of scientific enterprise, concepts, principles, and theories that model the natural world. Taxonomy will remain a substantial portion of the course; however, it will assume a secondary role in course organization.

We propose to shift emphasis away from authoritarian presentations of scientific information to instruction that is more consistent with the methods and values of practicing scientists. In addition to presenting content, instructors will present observations to the class during each lecture period. Students will experience the processes of examining the evidence provided, proposing hypotheses to account for the evidence, and designing experiments to test their hypotheses. This practice will begin within small groups (2-6 students) formed spontaneously in lectures. After a brief period of group discussion, the instructor will lead a general discussion using Socratic questioning (Paul and Binker 1990). When the class reaches consensus on an hypothesis and an experimental protocol to test the hypothesis, the instructor
will provide additional feedback (whenever possible) by informing the class of the outcome of the experiment they designed.

Content will not be sacrificed to process; however, presentation of content will not be the sole function of lectures. Instead instructors will focus on developing deep understanding of key concepts. Instructors will demonstrate the reasoning skills required and will provide students with the opportunity to practice those skills during lecture periods. During the practice periods, instructors will guide students through appropriate thought processes using Socratic questioning. Once students acquire deep understanding, they will be able to reconstruct much of the content using reasoning skills (Paul 1990).

There will be a reduction of the terminology load. Students will not be expected to memorize as many anatomical and morphological terms as they are currently expected to master. Instead, terminology will be reduced to the minimum necessary to prepare students for upper division work and to communicate effectively about the concepts. This effort will require close cooperation with upper-division colleges and universities. We have already begun dialogs with CSU Bakersfield and CSU Fresno on this issue. We will continue this dialog during the course of this project.

Recently, the American Association for the Advancement of Science (AAAS) produced a series of recommendations for the improvement of science instruction (AAAS 1990). We propose to adopt a number of the AAAS suggestions including:

- Goal-oriented instruction - teaching science as a process,
- Experiential activities - more activities involving living organisms in the lab and the field,
- Activities to promote independent learning and analysis- described below,
- Group discussion and projects - described below,
- Writing activities - described below,
- Mathematics in biology - described below,
- Cross-disciplinary content - described below.

Development of these skills is usually reserved for graduate study in the sciences. In graduate school, students engage in real scientific study under the direction of a thesis or dissertation advisor. Students participate in laboratory or field work which is aimed at developing new knowledge regarding natural phenomena. Students participate in seminars and informal conversations where skills with the methods of science are honed. Competence is judged, in part, by the quality of their written work and by the ability of the student to defend their line of reasoning, methods, and conclusions. There is no reason to wait for graduate school to develop these skills. These are skills which should be inculcated in undergraduates.

Critical thinking can be defined as "thinking skills that are critical to the accomplishment of something" (Glock 1987). Problem solving refers to application of information to real situations, analysis of new situations (break them apart, identify relationships, and determine how parts are organized), synthesis (put information together in ways not previously encountered) and evaluation (to make a judgment based on defined criteria), what Bloom calls
the intellectual abilities and skills (Bloom 1956). Critical thinking and problem-solving skills can be practiced by performing lab exercises and experiments that emphasize all parts of the scientific method (making the initial observations, forming a hypothesis, testing the hypothesis, examining the data, deciding if the hypothesis is verified) and not just collecting data.

Before each major biological concept is introduced, the students first make observations related to the concept. Defining life provides an excellent example. Instead of simply listing attributes of living organisms, a number of living and nonliving objects are presented to the students. Working in groups of 4-5 individuals, students are asked to "discover" the criteria for defining life. A worksheet with a series of directed questions (or the instructor using Socratic questioning) will help guide the students toward identification of the criteria for deciding whether a thing is alive. After the observational stage is completed, the investigational phase begins. Each group of students will be given some objects. The task of each group is to determine experimentally if the objects are alive. Students must develop hypotheses about life and ways to test the hypotheses. When possible, a few of the experiments will be done. The results will be discussed by the whole class, and the exercise summarized in individually written lab reports.

The proposed changes are similar to those implemented for Biology 100, a one-semester introductory biology course at Arizona State University at Tempe, Arizona (Lawson et al. 1990). In Biology 100, students find answers to biological questions by devising and (at times) conducting their own experiments. The current proposal is expected to enhance active learning by emulating the changes at Arizona State and adding the use of collaborative (small group) learning and concepts maps (Moreira 1979, Cliburn 1990, Novak 1990). Concept maps are word diagrams with arrows and short descriptive phrases that show relationships between different ideas. Building a concept map is actually a way to practice linking new knowledge to previously-learned information. Thus, students can begin to see a "big picture" where information is integrated into a whole, instead of existing as smaller, separate (unconnected) pieces.
6. Expected Outcomes

Expected Outcome of Proposed Project

Several outcomes can be achieved by the proposed shift of emphasis in the course structure.

1. Improved critical thinking and problem-solving skills--practicing a scientific method throughout the semester allows students to practice application, analysis, synthesis and evaluation skills.

2. Practice in organizing information and writing--via completed worksheets; written lab reports; construction of concept maps; written quizzes & examinations; written reports of group conclusions; written evaluations of peers and the course.

3. Practice in reading for information--from the course text (the primary reference) and reserved reading assignments from magazines or newspapers.

4. Improved oral communication and social skills--via interaction by students within a small group in order to identify and solve problems, develop consensus opinions; by presenting conclusions or summaries orally to the whole class; via oral quizzes with the instructor (one-to-one). Members of a small group often become a student's peer support group, which can mean the difference between some students' success or failure in a course (Jackson 1989).

5. Improved learning environment to promote greater success of women and minorities.

6. Provide an opportunity to practice or improve learning skills--by gathering information via different ways (personal observation and experimentation; taking notes from chalkboards, overhead projection, videotapes, or written text); reviewing notes, readings or experimental data within one's group; quizzing one another within one's group. The old adage "The best way to learn something is to teach it" could certainly apply here.

7. We expect to increase retention rates in individual courses and for the sequence as a whole.

8. Increased communication and more effective articulation with senior institutions.

9. Revitalization and professional growth for biology faculty.

10. Serve as a model for curriculum reform throughout the California Community College System by expanding application of the critical-thinking approach into the life sciences.
All of the materials produced as part of this project will be made available to our sister institutions for their consideration.

Potential for Continued Support

Bakersfield College is committed to providing the highest quality instruction possible for its students. The college will provide continued support to develop programs of instruction that better serve our students.
7. Evaluation Plan

Evaluation Plan

One significant measure of success will be a significant reduction in the attrition rate for these courses individually and for the sequence as a whole. Evaluating this goal is straightforward and requires only that enrollment figures be analyzed.

Measuring the success of our students once they matriculate at an upper division institution is more difficult but it can be accomplished. The majority of our students transfer to CSU Bakersfield. We will establish a protocol with CSU Bakersfield for following the success of these students.

The effectiveness of the proposed changes will be compared to that of the existing sequence in two different groups of students. One group will follow the revised format, the other group will follow the lecture/lab format currently in place. Comparison of the two groups will be based on four criteria:

1. Performance on written exams, quizzes, reports, 3 or 4 unit exams, 10-15 quizzes or activities, 1 comprehensive final exam, lab reports and 1 writing project (report or paper). The two groups will receive the same exams and quizzes. Evaluation will also include peer evaluation among group members (Newell 1990).

2. Critical thinking/problem-solving skills--if an appropriate standardized test can be found, a before-and-after comparison of these skills could be made on all students by giving the same test at both the beginning and end of the semester. An improved score could be an indicator of better critical thinking or problem-solving skills.

3. Retention in the course--comparing enrollment at the beginning and end of the semester, with respect to examine total numbers of students, female vs. male students, ethnic minorities and the disabled. We believe the establishment of small learning groups will help retain non-traditional students in the course.

4. Student perception of the course--based on written student evaluations gathered at the beginning, middle and end of the course. An alternative approach would be to have the students maintain a journal of their feelings about the course. This information can be used for evaluating students' perceptions about the effectiveness of teaching.
8. Dissemination Plan

Dissemination Plan

Materials and methods developed during this project will be made available to any instructor or institution requesting a copy. An avenue for publication which we wish to explore is distribution on computer diskettes, perhaps on commercial computer bulletin boards (eg. CompuServe). We will submit significant results for publication in peer reviewed journals. A final possibility is to disseminate significant results through Innovation Abstracts (published by The National Institute for Staff and Organizational Development, NISOD), Biobytes (the newsletter of the Association of Biologists in Computing), FACCC (Faculty Association of California Community Colleges) workshop, and networking with peers in sister institutions.
9. Budget Narrative

[NO “BUDGET NARRATIVE” ACCOMPANIES THIS DOCUMENT.]
Literature Cited


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