Micro-Computers in Biology Inquiry

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THREE-FIFTHS of all secondary schools in the United States were already using computers in 1975 (Seidel 1980); but if the way computers are used by schools in our own locale is typical, an enormous potential use is being overlooked—using the computer to enhance the curriculum.

Most secondary schools in our area use computers only to teach minimum programming skills, usually under the aegis of another department, typically mathematics or science. Few schools have their own computer science departments. Few teachers are conversant or comfortable with the use and possibilities offered by these machines. Thus the micro-computer in individual classrooms soon becomes a fascinating noontime toy. But the computer can be used in teaching many subjects, including inquiry biology.

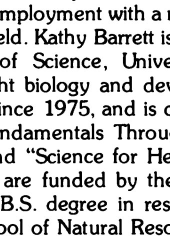
Our challenge was to develop learning units in biology using micro-computers, in this case PET, that would result in a long-term, ongoing, inquiry-directed approach. Because neither of us had a great deal of experience with computers, our first task was to modify existing software to suit our needs. Searching through software libraries, we decided on two models: BISON (1976) and POLLUT (1976) developed by the staff at Lawrence Hall of Science, Berkeley, California.

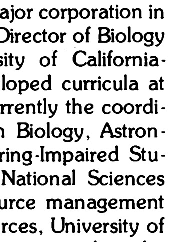
The original BISON is a simulation game designed to let the player manage a herd of animals. The population of the herd is broken into age and sex categories. For each of these groups a certain minimum number is set below which the player cannot go without threatening the herd with extinction. The goal is to maintain a viable population that can be harvested and managed. POLLUT is a simulation that allows the player to observe the impact of various polluting wastes on different water systems, such as a large pond, slow-moving river, fast-moving river, and a large lake. Players may also compare the effects of several treatments on waste entering the water.

BISON

We changed the BISON program to accommodate current population data from four different species indigenous to the Pacific Coast area. Our programmers were high school students, a surprising number of whom have attained good programming skills. Using real numbers, we changed a hypothetical situation to one that is extremely pertinent. For this first attempt we decided to do the research ourselves; this allowed us to discard populations that had too many variables to fit into a single program, or populations with insufficient data.

Initially we picked the California Gray Whale (Storro-Patterson 1980) because it is a rare example of a species brought back from near extinction to a potentially harvestable number. Because of its coastal migration route, it also generates a lot of student interest. It was relatively easy to adapt the model to Gray Whales because these have been intensively studied in the past ten years and





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the sex/age ratios for the population have been established. By manipulating the "harvest" of Gray Whales, students can drive them below critical level, harvest reasonable numbers, or watch the population geometrically explode. The extreme simplicity of this program is its virtue. At the end of the simulation the computer asks, "What things were not considered in this population model?" In brainstorming sessions students developed the questions listed below.

1. Why can the number of adult males go lower than the females?
2. Does the number of calves matter to this population?
3. How can males be distinguished from females?
4. Is there a minimum population below which communication cannot take place? Is there protection in a pack?
5. Are all whales locked into a migratory route? Was this the reason the Grays were saved from extinction?
6. What about parasites and disease factors?
7. How are the young cared for? What will happen if the nursery grounds are contaminated or industrialized?
8. How do they feed? Will pollution be a factor affecting their survival? What about the threat of off-shore oil drilling?
9. Is there intra- or inter-species competition for food or habitat?
10. Is the fast-growing pastime of whale-watching really "harmless" to these animals?

It is immediately obvious that this program not only stimulates inquiry, but also provides a jumping-off place for students to do their own research and programming.

As a comparison problem, our next simulation used the Bowhead Whale (The Whale Center 1980). This posed more of a challenge for our student programmers because of the lack of data. The only firm figure we worked with was an existing population of 2,242 animals. When students request sex/age distribution, mortality and natality rates, and gestation periods, the computer responds "unknown." Any try at harvesting by the player results in the printout "extinction." This leads to all kinds of considerations concerning the acceptable minimal population levels, the cultural and economic needs of the aboriginal Eskimos, and the ethics of human-caused extinction. As they worked on the Bowheads, students were stimulated to raise fundamental questions about how scientists collect data: How do we know the same whale is not being counted twice? How do researchers know the age and sex of counted animals? How long can a female be reproductive? How many offspring does a female produce?

Other programs were developed for a California Bobcat (*Lynx rufus*) and the parasitic California Oakworm (*Dioptidae phryganidia*). With the bobcat students were able to show the differences between an exploited (heavily trapped) population (Modoc County in northeast Calif.), and an unexploited population (San Diego County in the south). The result of this simulation forces them to focus on differences in habitat, in increasing hunting and trapping pressure because of increase in pelt price, in accessibility for trappers, in the differences in types and amounts of food supply, and in the system of classification that labels this particular organism a "varmint." From this point they moved on to how populations are regulated. Should regulation be on a county, state, or federal level? How much does this cost the taxpayer? How effective are the management strategies?

The Oakworm moth was chosen because it is habitat-specific for the California Live Oak indigenous to our area. Because of the exponential figures that resulted, we were able to show why log paper is needed for some graphs. The pros and cons of pesticide use can be discussed by classes as well as the place of the parasite in a local food web. Once again, this program compels students to generate a list of density-dependent factors that affect the moths.

Simulations such as these that bring the problems from a theoretical level to practical consideration allow the students to look at the problem from many different angles. Critical level, harvesting, culling, game management, cost-effectiveness, population determiners, and density-dependent/independent factors suddenly become meaningful terms.

POLLUT

POLLUT was easier to study and program. For a large pond, we used San Francisco Bay (Russell 1980); for a large lake we substituted Clear Lake; for a slow-moving river we used the polluted Petaluma River; and for a fast-moving river, the recreational Russian River. The model allows the students to choose the dumping rate in parts per million (ppm); the temperature of the water; the kind of waste, either sewage or industrial; and the use of either primary or secondary treatments. All of the above figures were programmed according to averages given to us by various government agencies. The amount of information that can be garnered by a few well-placed telephone calls is enormous; once the project was explained, we encountered nothing but cooperation and enthusiasm. As students gathered water information, they were amazed at the bewildering number of agencies involved in the bureaucracy of water administration. Brainstorming sessions based on POLLUT included the following issues:

1. Relationship between oxygen content and temperature.
2. Ethics and practices of illegal dumping.
3. Contents of different kinds of industrial wastes.
4. Thermal pollution and nuclear reactors.
5. Different types of water treatment.

6. Enforcement of existing laws concerning water treatment.
7. Rate of flow ratio to amount that can be dumped.
8. The reasons why different agencies handle different rivers in the same area.
9. What species can handle different water environments?
10. When do fish start to die?

The outstanding feature of this project is its multifaceted disciplinary approach. For the computer science students, it presented a challenge in their field; and along the way, they learned a great deal of biology. For the biology students, it provided an opportunity for individual explorations in creative problem-solving, as well as an understanding of the application of computers in the biological sciences. A computer-literate student will know when the use of computers is appropriate.

Advantages of Using Models

The final benefit to all students is the adaptability of the programs to areas of public concern where biological factors are among the prime elements. Once the basic model has been chosen, diverse kinds of populations or ecological situations can easily be substituted by merely changing the figures. For example, we are currently trying to build a computer file that will contain statistics for every known whale species. The ultimate challenge will be to develop a body of information that relates to biological, social, and even ethical values. Using a simple model, we can show that though no problem is simple, it is never beyond solution.

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