Computer Center

Computer Simulation In Bioeducation

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Whenever computers in education are mentioned, two general uses come to mind most frequently: drill and practice, and tutorials; and simulations. Both can be excellent uses of limited educomputing resources and available time, but for somewhat different reasons. Drill and practice, and tutorials accomplish what could be done without computers. But computer-based drills and tutorials can make more effective use of both the educator's and students' time. Computer-based review gives us more time to educate at higher cognitive levels. And at the same time, *intelligent* computer-based drill and practice sessions can be customized to each student. In contrast, computer-based simulations permit us to accomplish what otherwise could not be done easily. It may be because the real activity is too costly, too complicated, too dangerous, or too time-consuming.

At present too few biology educators use simulations; some simply are not familiar with the method and thus a bit afraid to reveal their ignorance. (Such vanity is inefficient in teachers; who says we are supposed to know everything about everything?) Still others dismiss simulation as mere electronic animation. This second view is unfortunate, because the most valuable approach is to consider simulation as a logical extension of the scientific method. It can be used to carry out experiments related to biological phenomena. But because they are simulated experiments, an extra step is essential: verification that the computer model of the biological system is valid. Usually we do this by comparing the results of computer experiments with some experimental results with the real biological material.

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For use in The Computer Center, Ted welcomes suggestions on what subjects should and should not be treated, summaries of educational computing centers, innovative uses of computers, and information about relevant books and events.

Once a computer simulation program has been created and verified, it certainly can be used as a demonstration for students. But as already suggested, real educational dividends occur when the program becomes the basis of the scientific method. Yes, I mean the implementation of steps like the formal statement of a hypothesis; the design of a series of computer simulations that vary one or more factors affecting a response variable (like population size); carrying out the analyses; and evaluation of the results to see if they support the hypothesis. Computer models of biological phenomena do not have to be complex to have pedagogic value. For example, students learn much from evaluation of simple population growth or Mendelian genetics models. While programs for such simulations are commercially available, if possible have students work in teams of two to four and create their own! They not only will feel more challenged but also should learn more, since they now have to teach the computer about populations, genetics, etc. And as all of us know, we really only learn something when we have to teach it!

Where can bioeducators learn more about the methods of computer simulation? One source is the 1982 book by James D. Spain called *BASIC Microcomputer Models In Biology* (Addison-Wesley Publishing Company, Reading, MA 01867). It is oriented toward research, but the principles are the same for education. While suitable as a textbook for a course on computer simulation, parts can be read profitably by educators interested in private study, or better yet by a group of three to four people who want to learn together. Parts of the book require some knowledge of calculus, but these are not necessary to understand simulation concepts. Let's overview the book, concentrating on important aspects of simulation.

Spain's introduction includes the basic concepts of system, models, and the relation of modeling and simulation to the research process (i.e., the scientific method). His full-page diagram summarizing this process in itself would be a valuable aid in discussing the scientific method in the computer age. The book is divided into three parts: Simple Model Equations; Multicomponent System Equations; and Probabilistic Modeling.

The Simple Model Equations section investigates models based on differential equations, e.g., exponential growth, diffusion across a boundary of unit area, a stream drift model. Equilibrium models are introduced with examples like the effect of pH on enzyme activity, the Michaelis-Menten model of enzyme saturation, and selection within the Hardy-Weinberg model of genetic equilibrium. The rest of this section of the book introduces specific techniques useful in simulations: fitting model equations to experimental data; flow-charting; and the numerical solution of rate equations.

Part II, Multicomponent Models, constitutes about half of the book's 350 pages. Multicomponent models are those that involve the interaction of several equations to provide a more realistic simulation of a biological system. Topics covered include biochemical reaction kinetics; predator prey models; age class and life tables; populations genetics; photosynthesis; effects of temperature on biological activity; energy flow in ecosystems; microbial growth; physiological control systems; and nutrient limitation models. Some of the models described are difficult, especially for bioeducators who do not regularly read quantitative papers. But this should not deter you since other examples can be readily understood. In addition, if you teach any of the abovementioned topics it is revealing to see a presentation of them in a way different from the normal college or high-school textbook. A valuable asset of the book is that for many examples the author provides both flowcharts and actual BASIC programs.

Probabilistic Modeling forms the last part of the book. After an introduction to random number generators and tests of randomness, methods of probabilistic simulation are described. Biological examples include Monte Carlo models of mono- and dihybrid crosses; mark and recapture; spatial distribution of organisms; population growth; simulation of an epidemic; and simulation of wolf-moose interactions. Some readers, especially those less familiar with calculus, may find it profitable in the beginning to concentrate on this section of the text.

After a bibliography, the book ends with an introduction to BASIC programming and listings of several utility programs written in BASIC. These are also available from the publisher on a diskette. Spain has written a solid introduction to simulation for biologists, and you should become acquainted with it.

As responsible educators, it is our obligation to explore the use of computer simulation in our biology courses. Even if we choose never to use it, I contend that the exploration will still have been valuable in providing us with another view of the topics we now teach and of the logical extension of the scientific method in the computer age. In addition, you will be in a better position to evaluate the opening sentence of the introduction of Spain's book: "Future life scientists may be characterized more by their ability to use the computer for data analysis and simulation than by their ability to use the traditional microscope." You don't have to agree with this statement to benefit from his book!