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AUTHOR	Spain, J. D.
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ABSTRACT

The programable calculator has great potential for the development of simulations which provide new dimensions to instruction in the biological sciences. Basic principles of both biology and simulation itself can be presented. An introductory course on digital computer simulation in biology is now taught at Michigan Technological University; the Olivetti Programma 101 is employed because of its simple programing language and convenient size. The course provides two quarter hours of credit and gives the students direct experience with the development and testing of a variety of biological simulations. Typically, student program and test about 15 models or simulations, and work with 5 additional prepared simulations. They prepare flow charts and write, test, and employ programs to generate data. Both students and instructors find the course gratifying. It effectively teaches the concepts and techniques of simulation, demonstrates the mathematical basis of biology, and indicates that the programable calculator will soon become an integral part of undergraduate science courses, for simulation and computer modeling as well as for data compilation and statistical analysis. (PB)

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TEACHING BASIC BIOLOGICAL SIMULATION TECHNIQUES WITH THE PROGRAMMABLE CALCULATOR

J.D. Spain
Department of Biological Sciences
Michigan Technological University
Houghton, Michigan 49931

INTRODUCTION

At the Conference on Computers in the Undergraduate Curricula held in June 1970 at the University of Iowa, a technique of employing the Olivetti Programma 101 programmable calculator for simulation of biological processes was described and some examples of typical simulations were presented (8). Additional techniques for simulation with this desk top "computer" have been described elsewhere (9, 10). As a result of this work, it has become evident that the programmable calculator shows great potential for development of simulations which can provide a whole new dimension to instruction in the field of biological sciences. So far about 40 programmed simulations have been developed, and it appears that the range of applications is limited only by the ingenuity of the programmer.

In the early work with simulations it became apparent that although computer programmed simulations offered tremendous possibilities for teaching basic principles of biology, perhaps an even more valuable use of the programmable calculator is to instruct students on the basic principles of simulation itself. The advantage of the programmable calculator for such a use is that it allows the instructor to place the primary emphasis of a simulation course on basic concepts and techniques rather than on the problems of programming.

An introductory course on digital computer simulation in biology based on this approach has been developed during the past two years at Michigan Tech. The Olivetti Programma 101 was employed, because of the simplicity of the program language, and the ease with which the machine is moved between classrooms, labs and offices. It is also felt that the unimposing nature of the machine encourages greater student interaction than do most large computer systems. In our experience, there seems to be little the student can do to damage the machine; in fact, the only maintenance required after 650 hours use by students during two years of operation was lubrication of the tape drive and replacement of a fuse. The present paper describes the nature of the simulation techniques course which has been offered by the Biological Sciences Department at Michigan Tech.

GENERAL DESCRIPTION OF THE SIMULATION COURSE

The course as presently set up provides the student with two quarter hours of credit. This amounts to about 66 hours of total work, 20 hours of which are spent in lecture or recitation, the remainder is left for individual study, development of programs, working with the computer, and consultation with the instructor. By allowing the students free access to the computer, the two machines available were found to be more than adequate for the 18 students enrolled. The course is taught at the senior level, and more than half of the students were undergraduates.

The basic objective of the course was to give the student direct experience with the development and testing of a wide variety of biological simulations employing each of the three basic approaches (2, 10). Typically a student was capable of programming and testing about 15 models or simulations during the course. In addition he worked with about 5 prepared simulations dealing with systems which were considered too complicated for him to do on his own. In these cases the student prepared computer flow charts for the simulation, and employed program to generate some representative data for submission to the instructor. In the laboratory the student was left largely on his own to write up programs and test them on the machine, although the instructor was available for questions dealing either with programming or computer operation. The outline provided below is based on that employed during the fall of 1971. An instruction manual (11) developed by the author was used throughout. A list of additional source materials applicable to the course is included in the bibliography.

COURSE OUTLINE

Week 1 Basic programming techniques for the P-101. Arithmetic operations, program storage and data storage. (Laboratory emphasizes the programming of simple algebraic equations.)

Week 2 Programming conditional jumps, counting, histogramming and special storage techniques. (In laboratory students prepare programs involving conditional jumps, and gain experience with flow diagrams.)

Week 3 Use of mathematical subroutines, logs, exponents, trig functions. (Students program equations involving subroutines and develop first models employing subroutines.)

Week 4 Three basic approaches to simulation is presented. Equation solving, deterministic, and stochastic simulations. (Students work with prepared simulations of radioactive decay based on the three basic approaches.)

Week 5 The equation solving approach. Equations based on theory and empirically derived equations. (Students write programs for models based on both theoretically and empirically derived equations with special emphasis on the polynomial equation.)

Week 6 The deterministic approach. Simple techniques for numerical integration of differential equations are presented. (Students program simulations involving integration of simple differential equations dealing with population growth and diffusion. The Hardy-Weinberg mathematics is also introduced.)

Week 7 Simulations in population dynamics and ecology. Environmental factors, life cycles, and the empirical approach. (Laboratory emphasizes a prepared simulation on predator-prey interaction. Students prepare simulations dealing with competition, and another dealing with an epidemic.)

Week 8 Simulation of physiological systems. The compartment model, simple mechanical systems (aortic pressure), and feed back control mechanisms. (Lab introduces prepared simulations of temperature control, and enzyme kinetics. Students prepare simulation of extra-cellular fluid space measurement, and simple feedback control.)

Week 9 Pseudo-random number generators. Tests for randomness in generated numbers. (Students generate a series of random numbers and evaluate their randomness by chi square and poisson distribution tests.)

Week 10 The stochastic approach. Use of random number generators for Monte Carlo simulations. Stochastic transformations from uniform distribution of random numbers to normal distribution. (Laboratory involves simulation of coin flipping, dice throwing, random walk, and monohybrid genetic cross.)

STUDENT EVALUATION

Students seemed to get more satisfaction from developing models of their own than working with prepared models, although they conceded that the prepared models did help them to understand more fully the nature of simulation. They also indicated that some time should be devoted to discussion of models which they had themselves programmed. Many students remarked that the course had given them a whole new insight into certain aspects of biology. All students found the course to be a valuable and stimulating experience, and no student complained that it was beyond his mathematical capability. However, it should be acknowledged that this was an elective course, and presumably students with a weak mathematical background did not enroll.

INSTRUCTOR'S EVALUATION

I found this to be a very gratifying course from the instructor's standpoint. Students learned to use the computer quite rapidly, and were enthusiastic about their ability to write programs and work with the machine. There was no difficulty in stimulating class discussion as there were always questions and comments arising from their laboratory experience. In fact several students brought forth programming suggestions which had not occurred to me.

CONCLUSION

The programmable calculator offers tremendous potential for instruction of undergraduate science majors on the concept and techniques of simulation. It has also been our experience that it can be used to demonstrate a mathematical basis of biology and related sciences that cannot be fully appreciated in any other way. It is not difficult to visualize a time in the future when the programmable calculator will be recognized as a necessary piece of apparatus for many undergraduate science laboratories not only for compilation of data and statistical analysis (for which it is already a recognized necessity), but for simulation and computer modeling, a field which has only begun to achieve its full potential.

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