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ABSTRACT

The objectives of the SUMIT project was to develop, evaluate, and disseminate 20 course modules (microcomputer programs) for instruction in general biology and ecology. To encourage broad utilization, the programs were designed for the Apple II microcomputer and written in Applesoft Basic with a user-adaptable format. Each package focused on a key concept in biology, with specific educational objectives. User's guides documented programs, provided theoretical background, and offered suggestions for modification. Formative evaluation was conducted by project staff, other faculty, and graduate students. In most cases this evaluation was accomplished by pre- and post-testing, using computer administered multiple-choice examinations. For three modules, classes were split and students using computer modules were compared to students using lecture or text-reading instructional formats. In essentially all cases, students filled out a subjective evaluation form dealing with aspects of student preference. Significant short-term learning was found for all modules. The final stage of evaluation was carried out by professional reviewers working under contract with CONDUIT. Although some dissemination of programs occurred during the project, the primary plan for dissemination involves release of the programs to CONDUIT for their review, modification, publication, and marketing. (Author/JN)

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User-Adaptable Microcomputer Graphics Software
for Life Science Instruction

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FINAL PROJECT REPORT

1982

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Part III - TECHNICAL INFORMATION

A. Abstracts of Theses

The following three Master of Science reports were developed in part as a result of this project:

1. Evaluation of three microcomputer teaching modules. A report submitted in partial fulfillment of the requirements for the Master of Science degree in Biological Science by Theodore Soldan. The project employed pre- and post-testing to evaluate the short-term learning effectiveness of three microcomputer modules developed on population growth, predator-prey dynamics, and mitosis/meiosis. The results supported the hypothesis that significant short-term learning is achieved by the use of computer-aided learning techniques.

2. Development and evaluation of a microcomputer module entitled 'Predator Functional Response'. A report submitted in partial fulfillment of the requirements for the Master of Science degree in Biological Sciences by Mark B. Shaltz. A class of 30 students was randomly divided into two groups of 15. One group examined a microcomputer module dealing with the subject of Predator Functional Response. The second group received a graphics based lecture on the same subject. Both groups were given the same multiple choice exam immediately after their learning experience. No significant difference was found between groups based on analysis of covariance and item analysis. The results indicate that microcomputer modules are at least as effective as the classical lecture approach.

3. Development and evaluation of the microcomputer module entitled Photophosphorylation. A report submitted in partial fulfillment of the requirements for the Master of Science degree in Biological Science by Catherine Leece. A class of 102 general biology students was randomly divided into two groups during regularly scheduled laboratory periods. One group was assigned to examine a microcomputer module on the subject of photophosphorylation (light reactions of photosynthesis) and the other group was assigned to read textual material concerning the same subject. At the end of the lab, both groups took a 20 question multiple choice exam on photophosphorylation. The microcomputer group performed significantly better on the exam than the text group. Ten of the 20 questions were found to be good discriminators based on item analysis. Five of these questions showed significant differences between computer and textual material groups. Analysis of these responses supported the contention that microcomputer-aided instruction is particularly valuable for subjects which can be enhanced by animation and visual cueing of diagrammatic materials. Intermittant questions

emphasizing key subject matter were also thought to contribute to the higher achievement of the computer-aided learning group.

B. Publication Citations.

Spain, J.D. 1981. Teaching Simulation Techniques with Microcomputers. Proc. Nat. Educational Computing Conf. 3: 255-227.

Spain, J.D. 1981. SUMIT Courseware Development Project (Abstract). Proc. Nat. Educational Computing Conf. 3: 113.

Spain, J.D. 1982. The SUMIT Courseware Development Project (Abstract). Proc. Nat. Educational Computing Conf. 4: 233.

Spain, J.D. 1982. BAEFLES: A New Deductive Game. Proc. Nat. Educational Computing Conf. 4: 91-94

Spain, J.D. 1982. "Basic Microcomputer Models in Biology". Addison-Wesley Publishing Company, Reading. p. 354.

C. Data on Scientific Collaborators

James D. Spain, Principle Investigator, Professor of Biological Science.

Kenneth Kramm, Co-investigator, Professor of Biological Science.

Catherine Leech, Graduate Research Assistant.

Mark Shaltz, Graduate Research Assistant.

Theodore Soldan, Graduate Research Assistant.

Brian Winkel, Visiting faculty (Rose Hulman Inst. Terre Haute, IN)

James Horton, Visiting faculty (California State Univ., Bakersfield, CA)

D. Information on Inventions

No inventions resulted from this project.

E. Technical Summary of Activities Accomplished
Under the SUMIT Project (SED-7919051)

1. General Overview of the Project

The objective of the SUMIT project was to develop, evaluate, and disseminate 20 courseware modules (microcomputer programs) for instruction of General Biology and Ecology.

In order to encourage broad utilization, the programs were designed for the Apple II microcomputer, and written in BASIC with a user-adaptable format. Each package was focused on a key concept in biology with clearly defined educational objectives. User's guides were written to document the program, provide theoretical background and offer suggestions for program modification.

Each module went through several stages of evaluation. During the early stages of development, members of the SUMIT staff, other faculty and graduate students assisted in the formative evaluation of individual modules. Summative evaluation was carried out with the assistance of students in regularly scheduled classes at Michigan Tech. In most cases, this evaluation was accomplished by pre- and post-testing, using computer administered multiple choice examinations. For three of the modules, the classes were split, and the students using the computer modules were compared with students which had been exposed only to a lecture or text-reading mode of instruction. In essentially all cases, students filled out a subjective evaluation form that focused on questions dealing with the most interesting and least interesting features of the module, suggestions for improvement, and other aspects of student preference. Several programs were evaluated by faculty from other schools who were participating in workshops at Michigan Tech. The final stage of evaluation was carried out by professional reviewers, working under contract with CONDUIT.

Some dissemination of product programs occurred during the development stages of the project as a result of the faculty workshops at Michigan Tech, national conventions, and personal correspondence. However, the primary plan for dissemination involves release of the programs to CONDUIT for their review, modification, publication and marketing. As of August 15, 1982, 14 instructional modules have been submitted to CONDUIT, and eight have been accepted for publication, subject to minor modification. The remaining modules will require significant changes before final acceptance is obtained.

2. Program Development

Three graduate research assistants were appointed for a two year period to assist in the writing and evaluation of the courseware. These individuals were selected on the basis of previous experience with computer programming and strong recommendations by faculty who had attended workshops at Michigan Tech. The mean grade point average for the students was 3.63. Although the graduate students had a primary responsibility for writing the courseware, the two principal investigators were also actively involved in the programming phase as well as directing the students. The 1980 summer faculty workshop served as a vehicle for orientation of the newly-formed SUMIT staff. During the final stages of program development and formative evaluation, a team approach was very successfully employed. See the accompanying table describing staff programming responsibilities during the project.

Each program was written for the Apple II microcomputer, using Applesoft Basic. Some programs, such as Osmotic Pressure and Molecular Motion, were compiled into machine language in order to speed up the animations involved. In these cases, the BASIC versions of the program were also provided so that user modification is still possible. Each program has been documented both internally and in the user's guide to facilitate user-adaptability. User's guides typically contain program run instructions, program objectives, theoretical background, mathematical basis (if any), suggested exercises, list of major program sections, and a description of program variables. The accompanying table describes the instructional programs that were developed for the SUMIT project.

3. Summative Evaluation of the Instructional Modules.

a. Written Evaluations. All the modules were evaluated in regularly scheduled courses at Michigan Tech. The general approach was to have the students examine the module, carry out the associated quizzes, and complete a written evaluation form. Sample forms are presented in Appendix A. These forms asked questions about the most interesting and least interesting aspects of the module, annoying aspects, and suggestions for improvement. About 1000 evaluations of this type were obtained and reviewed as part of the SUMIT project. Summaries of comments for each module are presented in Appendix B. In general, the students were very positive about the SUMIT modules. Clearly, they liked certain programs better than others. It was also evident that students in a given class became more discriminating after reviewing several programs. Differences also resulted from the different programming styles of the five different authors involved, and the range of difficulty represented. The student comments

INSTRUCTIONAL PROGRAMS UNDER DEVELOPMENT

ECOLOGY PROGRAMS

Population Age Structure.

This program explains the use of age class models and provides a means of manipulating real data using the Leslie Matrix.

Mark and Recapture.

This program examines the Lincoln-Peterson index and other techniques for estimating population size. A utility program permits analysis to real data.

Island Biogeography.

This program examines models for describing the effects of immigration and extinction on isolated populations.

Population Growth.

This program describes simple growth curves, geometric growth, logistic growth, and doubling time for populations of organisms.

Competition.

This program examines the use of the Gause or Lotka-Volterra competition equations for modeling interspecific action.

Predator-Prey Dynamics.

This program explores the interaction of predator and prey populations using the Lotka-Volterra predation equations.

Predation Models.

This program explores some of the more advanced models of predation and compares them with the simple Lotka-Volterra model.

Predator Functional Response.

This program explores the interactions that occur between the predator functional response model and the prey recruitment model.

Forest Succession.

This program examines two models for describing the last stages of secondary succession in northern hardwood forests.

Energy Flow in the Ecosystem.

This program looks at food chains, food webs, energy pyramids, and block diagrams. The dynamics of energy transport is stressed.

Carbon Cycling and the Greenhouse Effect.

This program describes the greenhouse effect, the light absorbing characteristics of carbon dioxide, and the cycling of carbon in the ecosystem.

GENERAL BIOLOGY PROGRAMS

Molecular Motion.

This program uses animation to demonstrate the kinetic theory of gases and allow the user to explore the nature of the diffusion process by simulation.

Osmotic Pressure.

This program explores the molecular events that result in osmosis and osmotic pressure, and then allows the user to carry out simulated experiments to explore the effect of solute concentration, and solute type on osmotic pressure.

Photosynthesis Pathways.

This program employs animation to describe the light and dark reactions of photosynthesis and their interaction.

Cell Structure.

This drill and practice program employs graphics to present information about the structure of cells.

Gene Code.

This program uses animation to illustrate the transfer of information from a DNA base sequence, to RNA base sequence, to an amino acid peptide sequence. The program also demonstrates the effect of point mutations and frame-shift mutations on the amino acid sequence.

Lac Operon.

This program employs both animation and simulation to demonstrate the effect of lactose on the induction of "lactase" enzyme synthesis by bacteria.

Quiz Master.

This is system of three programs and two data files which may be employed to generate multiple choice quizzes, administer them to students, and record their responses and associated statistics.

Baffles.

This is a computer game which encourages the use of the scientific method to ascertain the locations of hidden reflective baffles by the use of laser probes.

Taxonomic Key.

This is an adaptation of the ANIMAL game program that allows the user to develop dichotomous keys for any collection of objects.

Life Expectancy.

This program asks questions of the user and from the answers estimates how old the individual will be when he/she dies. The program is based on an article that appeared in Time magazine.

GENERAL BIOLOGY PROGRAMS (CONT.)

Enzyme Activity.

This program explores the effect of temperature, pH, substrate concentration, enzyme concentration, and coenzyme concentration on the rate of enzyme catalyzed reactions. The user is encouraged to make many of the same decisions that one would make in the biochemistry laboratory.

Mitosis/Meiosis.

This is a program that uses animation to show the distinguishing features of both mitosis and meiosis.

Widgels (Mendelian Genetics).

This is a program that allows the student to observe the genetic effects of mating mythical creatures called "widgels". Based on a TRS-80 program written by Norman Kerr, Univ. Minn.

SUMIT Staff Programming Responsibilities and Status
December 15, 1982

James Spain - Principal Investigator

OSMOTIC PRESSURE - Accepted by CONDUIT, Sept 1982
PREDATION MODELS - Accepted by CONDUIT, Sept 1982
ENZYME ACTIVITY - Submitted to CONDUIT, Sept 1982
BAPFLES - Accepted by CONDUIT, Dec 1982
COMPETITION - Submitted to CONDUIT, Nov 1982
MOLECULAR MOTION - Internal evaluation completed
TAXONOMIC KEYS - Internal evaluation completed
QUIZ MASTER - Submitted to CONDUIT, Dec 1982

Kenneth Kramm - Co-Investigator

ISLAND BIOGEOGRAPHY - Acc. by CONDUIT, subject to mod.
MARK and RECAPTURE - Accepted by CONDUIT, Dec 1982

Catherine Leece - Graduate Research Assistant

AGE STRUCTURE - Accepted by CONDUIT, subject to mod.
LESLIE MATRIX - Accepted by CONDUIT, subject to mod.
FOREST SUCCESSION - Submitted to CONDUIT, rejected.
PHOTOSYNTHESIS - Submitted to CONDUIT, Sept 1982
CELL STRUCTURE - Internal evaluation completed
MENDELLIAN GENETICS - Internal evaluation completed

Mark Shultz - Graduate Research Assistant

PREDATOR FUNCTIONAL RESPONSE - Acc. CONDUIT, sub. mod.
ENERGY FLOW in ECOSYSTEMS - Submitted to CONDUIT,
rejected
SAMPLING - Incomplete
DIVERSITY - Incomplete
CARBON CYCLE - Incomplete

Theodore Soldan - Graduate Research Assistant

PREDATOR-PREY DYN. - Accepted by CONDUIT, Sept. 1982
POPULATION GROWTH - Submitted to CONDUIT, Oct 1982
MITOSIS/MEIOSIS - Submitted to CONDUIT, Nov 1982

Summary Status of Programs on December 15, 1982

5 programs are in final stages of publication by CONDUIT
5 programs are accepted by CONDUIT, subject to
modification
2 programs rejected by CONDUIT in their present form
5 programs are still being reviewed by CONDUIT
5 programs have received internal evaluation only
3 programs are incomplete and unevaluated

obtained on the written evaluations proved to be very valuable in making the final changes in the programs.

b. Pre-test and Post-test evaluations. About half of the programs were evaluated by the technique of giving an 8 to 10 question multiple choice exam just prior to the use of a module and the same 8 to 10 question exam again immediately following the exposure to the module. The questions were based upon the performance objectives that had been established for the module being evaluated. The exams were formulated by the Quiz Maker program in such a way as to be stored as a question file on the same disk as the program being evaluated. The pre-test and post-test question files would be called up and administered by a second program called Quiz Master. At the completion of each quiz, the results were stored on the disk in the form of a record file that could be subsequently accessed by using a Quiz Record program. Thus, the entire process of administering the pre-test and post-test to the student could be done on an individual basis by the same computer that was presenting the instructional module. /

When evaluating an instructional module, the student would first be presented with a short introduction describing the objectives of the SUMIT project, and the student's role in the evaluation process. Then, the student's name and recitation number were taken, so that quiz records could be properly assigned. This also encouraged the student to adopt a serious attitude toward the evaluation process. The computer would then call up the Quiz Master program and administer the pre-test. At the end of this short quiz, the computer would add the results to the quiz record file, and automatically call up the instructional program for evaluation. The student would then follow through the program performing whatever tasks were involved. At the end of the program, the computer would return to the Quiz Master program which would now call up the post-test question file. At the end of the exam, the results would be added to the post-test record file. The technique had the advantage of automatically providing pre-test and post-test quizzes to individual students immediately before and after examining a given module. Since the quizzes were not being taken for a credit, we were not particularly concerned that students would pass along information about the quiz to other students.

After all the students had completed the evaluation, the pre-test and post-test scores were analyzed using the paired t-test. All modules were found to demonstrate a significant short-term learning of the concepts that were covered in the exam. A summary of the pre-test and post-test results are provided in the accompanying table.

SUMMARY OF RESULTS-ON MODULE EVALUATION

MODULE	COURSE	WRITTEN EVALUATION		PRETEST/POSTTEST			
		NUMBER	RESPONSE	DIFFERENCE	T-VALUE	N	SIG.
Competition	Ecology	20	Moderate	28.4	6.98	25	< .01
Mark and Recap.	Ecology	21	Good	24.5	4.76	30	< .01
Population Growth	Ecology	21	Good	17.2	3.90	29	< .01
Pred. Prey Dyn.	Ecology	24	Good	33.0	5.70	15	< .01
Energy Flow	Ecology	23	Good	17.5	4.34	16	< .01
Life Tables	Ecology	31	Good	17.0	5.5	26	< .01
Succession	Ecology	Special	Evaluation	Special Evaluation	→ → → → → → → → →		
Island Biogeogr.	Ecology	21	Good	No pretest/posttest	→ → → → → → → → →		
Pred. Func. Resp.	Ecology	Special	Evaluation	Special Evaluation	→ → → → → → → → →		
Predation Models	Ecology	Formative	Only	No pretest/posttest	→ → → → → → → → →		
Cell Structure	Gen. Bio.	90	Good	No pretest/posttest	→ → → → → → → → →		
Population Growth	Gen. Bio.	54	Good	25.7	6.50	48	< .01
Osmotic Pressure	Gen. Bio.	48	Good	No pretest/posttest	→ → → → → → → → →		
Molecular Motion	Gen. Bio.	35	Good	No pretest/posttest	→ → → → → → → → →		
Taxonomic Key	Gen. Bio.	15	Good	No pretest/posttest	→ → → → → → → → →		
Mitosis/Meiosis	Gen. Bio.	55	Excellent	13.9	4.12	24	< .01
Photosynthesis	Gen. Bio.	Special	Evaluation	Special Evaluation	→ → → → → → → → →		
Baffles Game	Gen. Bio.	34	Excellent	6.8	2.96	81	< .01
Enzyme Activity	Gen. Bio.	35	Moderate	No pretest/posttest	→ → → → → → → → →		
Life Expectancy	Gen. Bio.	45	Good	No pretest/posttest	→ → → → → → → → →		
Widgels (Genetics)	Gen. Bio.	50	Good	No pretest/posttest	→ → → → → → → → →		
Amino Acids	Biochem.	108	Good	No pretest/posttest	→ → → → → → → → →		
Enzyme Activity	Biochem.	104	Good	No pretest/posttest	→ → → → → → → → →		
Photosynthesis	Biochem.	105	Excellent	No pretest/posttest	→ → → → → → → → →		
Gene Code	Biochem.	105	Good	No pretest/posttest	→ → → → → → → → →		
Lac Operon	Biochem.	102	Good	No pretest/posttest	→ → → → → → → → →		

c. Special split-section evaluations. Three modules were evaluated by the technique of splitting a class randomly into two groups and exposing only one group to the computer program while the control group received another form of instruction. In one case, the control group was given a lecture over the same material that was discussed in the computer module. In the other two cases, the control group was given written material covering the same subject matter that was presented in the computer module. In all three cases, the combined groups were given an examination over the material that had been covered, and the two groups were compared by standard statistical methods. The results showed that the computer was significantly better than simple written material in imparting information, but was not significantly different from a good lecture on the same subject. A complete discussion of these experiments may be obtained from the three bound reports that accompany this summary report.

d. Evaluation by Workshop Participants. A total of 34 college biology faculty from various parts of the U.S. attended workshops at Michigan Tech during the summers of 1980 and 1981. A list of participants is presented in Appendix C. Most of the modules received a formative evaluation by this group of individuals. Some of the modules were sufficiently complete to receive a summative evaluation during the 1981 workshop. A majority of the modules examined were rated as good to excellent by this group. The comments obtained were quite useful in final stages of development.

e. Evaluation by CONDUIT. The final stage of evaluation is being carried out by CONDUIT, using a well established reviewing process that involves both internal and external reviewers. At present, 14 programs have been submitted for review and eight programs have been accepted for publication, subject to minor modifications. Other programs will require more extensive modification before final acceptance is assured. Seven additional programs are to be submitted to CONDUIT for review in the near future. The status of each program is shown on the table describing staff responsibilities. (Section E.2. above)

4. Dissemination of Courseware.

Considerable dissemination of courseware has occurred as a result of the 58 participants who have attended the three microcomputer workshops that have taken place since the project was initiated. In addition, about 20 people have written for copies of one or more programs as a result of presentations at national meetings or other contacts with the project director.

The major plan for dissemination is to have all of the materials eventually published and marketed by CONDUIT. As stated in the previous section, about half of the material appears to be acceptable to CONDUIT with only minor modifications. the remainder will apparently require significant modifications to make it acceptable. the project director plans to continue working on these programs during the next year. Thus, it is expected that the goal of producing and disseminating 20 high quality programs to the academic community will be achieved sometime during 1983.

Presentations and Workshops where SUMIT Courseware was Demonstrated

MTU High School Science Teachers Workshop, July 1980 (20)

MTU College Biology Faculty Workshop, August 1980 (20)

Edgewood College Faculty Workshop, January 1981 (15)

National Educational Computing Conference, June 1981 (75)

MTU High School Science Teachers Workshop, July 1981 (30)

MTU College Biology Faculty Workshop, August 1981 (18)

American Institute of Biological Sciences, Symposium on Microcomputers, August 1981 (50)

National Educational Computing Conference, June 1982 (50)

MTU High School Science Teachers Workshop, July 1982 (20)

MTU College Biology Faculty Workshop, August 1982 (24)

Bemidji State Univ Faculty Workshop, September 1982 (15)

National Association of Biology Teachers, Microcomputer Workshop, Oct. 1982 (50)

University of San Francisco, SUMIT Demonstration, Oct. 1982 (10)

University of San Francisco Faculty Workshops, Nov. 1982 (10)

San Francisco State University, Demonstration, Nov. 1982 (15)

University of British Columbia, Zoology Dept. (scheduled, Jan 1983)

University of British Columbia, Inst. Animal Ecology (scheduled, Feb. 1983)

American Society of Microbiology, Microcomputer Symposium (scheduled March 1983)

California State University, Sacramento, Faculty Workshop (scheduled April 1983)

Table of Equipment Purchased Under SED7919051

EQUIPMENT ITEM	REQUESTED			PURCHASED		
	NO.	UNIT PRICE	TOTAL	NO.	UNIT PRICE	TOTAL
Apple II Plus Microcomputer, 48 K Bytes	4	\$1495	\$5980	10	1132	11320
Apple II Plus Microcomputer, 32 K Bytes	6	1350	8100	0		
Disk Drives with Controllers, Apple	10	595	5950	10	472	4716
Disk Drives Without Controllers, Apple				2	383	766
Disk Conversion Kits DOS 3.2 → DOS 3.3				14	44	626
Video Monitors (B&W)	10	240	2400	3	149	447
T.V. Color, Sharp Linytron				3	332	994
T.V. (B&W) Monitors				2	N.C.	N.C.
Printers, Centronics, Micro	6	400	2400	1	473	473
Printer, Centronics - 700	1	1545	1545			
Printer, Qume Daisy Wheel				1	3099	3099
Printers, Silentype				5	469	2347
Cassette Recorder-Tape Deck	1	50	50	1	26	26
Disk Drive-TRS-80 Model I.				1	450	450
Interface-TRS-80				1	178	178
Lower Case/Graphics				1	113	113
Lower Case Conversion Kit				1	79	79
EQUIPMENT TOTAL			\$26,425			\$25,624
SUPPLIES						
Diskettes	80		380	100		464
Cassettes	20		40			
Printer Paper	20		80			229
Manuals			100			N.C.
Printer Ribbons (Qume)						125
Mics.						75
Computer Software			600			449
TOTALS			1200			1342

APPENDIX A

Sample Forms used in the Subjective Evaluation of Modules
in Animal Ecology and General Biology.

ANIMAL ECOLOGY..INSTRUCTIONAL PROGRAM EVALUATION

Name of Program:.....

Your opinions concernning the educational value of this instructional program will be very helpful to the SUMIT project. Please express yourself as honestly and candidly as possible. Thank you for your assistance.

Did you learn any new concepts from this program?.....

Did you think the program was generally interesting?.....

What part of the program was the most interesting?

.....

What part of the program did you find the least interesting?

.....

Is there anything about the program that really annoyed you?

.....

Which of the following modes of instruction would be most effective for presenting the material covered by this program?

- a. Lecture b. Lab experiment c. Textbook
d. Educational T.V. e. Computer program

.....

In the following space, please give any suggestions you have for improving the educational value of this program.

Thank you very much for your help in evaluating this program.....SUMIT Project staff

GENERAL BIOLOGYINSTRUCTIONAL PROGRAM EVALUATION

Name of Program.....

Name of Evaluator.....Sec.No.....

What part of the program did you find most interesting?

What part of the program did you find least interesting?

Is there anything about the program that really annoyed you?

Is there anything presented in the program that you did not understand? What?

Is there anything about the program that did not work, such as data input, response, etc.?

What suggestions do you have for improving the program?

Thank you for helping us improve this program.

APPENDIX B

Summaries of Comments made during the Subjective Portion of the Summative Evaluation of Modules in Animal Ecology, General Biology and Cell Biochemistry.

Also included is a list of un-solicited comments made on Cell Biochemistry course evaluation forms.

Summary of Comments on the Competition Module
Based on 20 Ecology Evaluations

Did You Learn New Concepts? 18 yes; 2 no

Was Program Interesting: 13 yes; 7 no

Most Interesting Part: different ways of graphing; graphs; explanation of phase plots; comparison of plots; phase plots; feedback to questions.

Least Interesting Part: vague explanations; long explanations; too many equations; introduction; all of it; none of it; time plots; math too heavy; part that printed data.

Anything Annoying: equations hard to understand; many flaws; grammatical errors; the model was off(?); program does not respond correctly to some inputs; none; has closed loop error.

Suggestions: put phase plot and time plot on screen at some time; make it so color plots visible on B & W monitor; explain more about how populations behave around isoclines; need "Press return" in phase plot section.

Summary of Comments on the Mark and Recapture Module
Based on 21 Ecology Evaluations

Did You Learn New Concepts: 20 yes; 1 maybe

Was Program Interesting: 21 yes, 0 no

Most Interesting Part: plots; comparison of techniques; most of it; calculate population.

Least Interesting Part: waiting for sampling; numbers used; repetitious; exit; confusing.

Anything Annoying: nothing; inability to go back to previous frame; equations; lack of instructions; fuzzy picture.

Suggestions: jazz it up with more graphics; make easier; clarify section 4; use better summation signs.

Summary of Comments on the Population Growth Module
Based on 21 Ecology Evaluations

Did You Learn New Concepts: 16 yes; 5 no (covered in lecture)

Was Program Interesting: 19 yes; 0 no; 2 so-so

Most Interesting Part: the sounds; geometric growth; calculator subroutine; graphs; lice problem; excellent graphs; working with equations; hypothetical problems; manipulating equations; sound effects; calculator subroutine.

Least Interesting Part: menu; not personal enough; all good - all rather interesting; explanation of equations; explanations; none.

Anything Annoying: didn't prompt for r value; slow printing of text; use of menu; audio effects; no challenge to problems; too slow; noise on graph.

Suggestions: great review; good balance between graphics and text; have student set up problem; good program; provide workbook.

Summary of Comments on the Predator - Prey Dynamics Module
Based on 24 Ecology Evaluations

Did You Learn New Concepts: 22 yes; 2 no

Was Program Interesting: 22 yes; 2 no

Most Interesting Part: graphs; phase plot diagrams; changing model parameters; relating time plot to phase plot; phase plots; isoclines; how phase plots work; many; good explanation; printing text slowly; varying parameters; the beginning; color interesting.

Least Interesting Part: none; reading explanations; waiting for graphs to develop; general information.

Anything annoying: none; needs more pazazz; too long; too slow; more faster, writes too slowly; too simplistic; won't accept all values for variables; written for 5th grade.

Suggestions: none; the best program yet; good program; come up with different style; put whole paragraph on ~~average~~.

Summary of Comments on the Energy Flow Module
Based on 23 Ecology Evaluations

Did You Learn New Concepts: 19 yes; 4 no

Was Program Interesting: 20 yes; 3 no

Most Interesting Part: how diagrams change; box diagrams; energy pyramid; diagrams; time lag in energy transfer; changing energy pyramid; fine graphics; block diagram and energy pyramid; food webs; answering questions during program.

Least Interesting Part: it was all interesting; most of it; food chains and food webs; it was too fundamental; repetition; menu; changing flow numbers.

Annoying Part: none; make more interesting; too many "press returns to continue"; inputs did not add up to outputs and change (?); no; not being able to slow down or stop the pyramid; too redundant; little user control; sitting through all the months.

Suggestions: Section 3 well written; menu does not give enough information; have a graph that plots the energy content of various trophic levels for each month; its too hard to follow the numbers.

Summary of Comments on the Life Tables Module
Based on 31 Ecology Evaluations

Did You Learn New Concepts: 31 yes

Was Program Interesting: 28 yes, 3 no

Most Interesting Part: all of it; quizzes, highlighting; birth/death rate; the use of round; going through it step by step; comparing calculations with computer; all at good interest level; applications; explanation of table; adjusting for 1000 charts; all of it; data; not much; when user was asked to make calculations; graphs.

Least Interesting Part: none; waiting; quiz; explaining correct answers; explanation of variables; the use of equations; dull introduction; generally dull, reading; calculations dull; classifying coyotes as pest species.

Anything Annoying: none; not really; the cursor; need shorter introduction; it tends to be smug; went too fast; didn't have calculation.

Suggestions: good job; give out written version of program; correct calculation of lx; it is too easy to skim over without understanding it; all user to input values to table.

Summary of Comments on Island Biogeography Module
Based on 21 Ecology Evaluations

Did You Learn New Concepts: 20 yes; 1 no

Was Program Interesting: 19 yes; 2 no

Most Interesting Part: simulation of wildlife refuge; graphs; not much; changeable graphs; all of it was interesting; how features of an island affect species number; opening up of an island to immigration; immigration and extinction; being able to change parameters and see results; use of multiple values on the graph; use of color.

Least Interesting Part: explaining how equations work; none.

Anything Annoying: none; too long; was confusing; program bombed; too slow; I didn't have a color monitor; too much waiting; sick of computer programs.

Suggestions: explain why equilibrium level goes below the colonizing species level; could be done as effectively as a lecture; more user control; make it clear that the long island referred to not the one in New York!

Summary of Comments on the Cell Structure Module
Based on 90 General Biology Evaluations

Most Interesting Part: drawing cell and organelles; very personal; finding out why somethings were or weren't correct; information following questions; very helpful; speed; all of it; graphics good naming all parts; liked questions, answers and comments; showed what I needed to study more; very informative; sense of humor; communicating with computer; enjoyed comments.

Least Interesting Part: multiple choice a bit long; reading instructions; long explanations; definitions; none.

Annoying Aspects: nothing; comment to wrong answer; slow moving cursor; use of color on a non-color monitor; don't like computer addressing me personally; letters irritating on eyes; diagram not very clear; I wasn't fast enough in responding to computer; did not explain how to get back to beginning of program; sarcastic answers.

Anything Not Understood: syntax error; no problems; didn't know how to back up and erase mistakes; all very clear; liked when it talked to me personally.

Anything Not Work: No; graphics could be better; worked fine.

Suggestions: be able to move on if you know the answer; make more challenging; be able to skip definitions; speed up response; speed up printing; leave response to wrong answer on the screen longer; excellent for review; make sure letters are white on a color T.V.; make it longer.

Summary of Comments on the Population Growth Module
Based on 54 General Biology Evaluations

Most Interesting Part: doubling time; demonstrations with graphs; noises with graphs; using - and being able to vary - graphs; the problems made you pay attention; none of it; the geometry of the curves.

Least Interesting: program was irrelevant to lab & lecture; some of the explanations; the amount of reading involved; the geometric growth; logistical analysis; I didn't understand much of it.

Anything Annoying: no; the silly noises; doubling time graphics were screwed up; the moving cursor having writ moves on.

Anything Not Understood: Some of the equations; no; some formulas were hard to read; needed more time; the graphs; the math involved.

Anything Not Work: equilibrium was spelled wrong; no; skipped ahead before I was through reading once; numbers were printed in wrong spot once; bunch of stuff went up on screen and was removed before I could understand it.

Suggestions: could use some more introductory explanations; explain origins of formulas better; none; jazz it up a little; make it apply more to lab & lecture; get shades for windows so the glare is cut down on the screen.

Summary of Comments on Diffusion & Osmosis Module
Based on 48 General Biology Evaluations

Most Interesting: osmotic pressure reaches equilibrium; diffusion of particles; interaction with the program; everything; none; the graphics; introduction to osmosis; determining molecular weights; seeing the gas law applied to biological processes.

Least Interesting: reading was too difficult; osmotic pressure simulations; it was all worth-while; none; figuring molecular weights; diffusion was too slow; reading everything that was a review; waiting for discs to load.

Anything Annoying: have to switch between return and space keys all the time; nothing; wasn't very interesting.

Anything Not Understood: how to calculate molecular weights; none; terminology wasn't very clear, at beginning.

Anything Not Work: No; the end; worked fine; wouldn't run first time; part 3 say to press "reset" to get to menu but have to press space bar instead.

Suggestions for Improvement: make osmosis clearer; make it less game like; make it more personal like asking and using your name; use either return or space not both; it was practically perfect, no.

Summary of Comments About the Molecular Motion Module
Based on 35 General Biology Evaluations

New Ideas: that diffusion is a random process; none; never reach an exact equilibrium; diffusion is a function of density; diffusion depends on area (volume).

Most Interesting Part: ability to change window size, particle numbers, etc.; the graphics; random movements; seeing the results graphed out.

Least Interesting Part: none (predominant comment); tended to be too long; did not understand time intervals; changing window size.

Annoying Parts: none (predominant); the rate at which 199 particles move given 100 time intervals; having to reset the program; the inability to reach a perfect equilibrium; there should be more explanation of data input, changes related to results; no chance to see final outcome before text came on screen.

Anything Not Work: after hitting button should have explanation as to how to get back into program; should have option for varying number of molecules while keeping compartment and window size the same; none.

Summary of Comments on Taxonomic Keys Module
Based on 15 General Biology Evaluations

Most Interesting: classifying animals; all of it; classifying objects; adding questions that could be used later.

Least Interesting: none; trying to think of new questions; how to get from one key to another; the cars; seeing the menu all the time.

Anything Annoying: you can't erase a question; no; program was confusing because it didn't tell you what to do.

Anything Not Understood: no; how the key worked at first, some directions on menu was not clear; how to get to different parts of the program.

Anything Not Work: sometimes it would not work i.e. get stuck or jump around; on one disc it would not get past the menu.

Suggestions: try to make it more error proof; program was very relaxing and fun; should have more stored data to work with; improve the instructions.

Summary of Comments on the Mitosis & Meiosis Module
Based on 55 General Biology Evaluations

Most Interesting Part: the diagrams; the whole thing (predominant comment); excellent graphics; very informative; good animation; different phases; excellent program; everything; chromosomes moving; cleared up confusion; quizzes.

Least Interesting Part: first part not as interesting as second part; none (predominant comment); some parts had too much information without questions; slow drawing process; was boring; best module yet; introduction; too much information.

Annoying Parts: none; took a long time for cell to appear; waiting for drawing of cell parts; the words are hard to read on screen.

Anything Not Understood: no; the number of chromosomes got confusing; some words were confusing; could use some definitions.

Anything That Didn't Work: pictures were not too clear; no.

Suggestions: could compare both processes at same time on screen; some words difficult to read; graphs and pictures helped a lot; is it possible to go back to previous frame for review; maybe show difference in plant and animal cells; more definitions; list phases of mitosis and meiosis side by side for comparison.

Summary of Comments on BAFFLES Educational Computer Game
Based on 34 Evaluation Forms

- 1) How interesting compared to other computer games?

more interesting
16

less interesting
4

same
12

- 2) How difficult for student use?

too difficult
2

too easy
1

about right
29

- 3) Relevance to science instruction:

relevant
28

slightly educational
3

no relevance
1

- 4) Attributes of sci. method -

none; hypothesis testing; thinking; deductive reasoning; ability to reason; methodology; analysis; insight; cause and effect.

- 5) How many games played?

one
3

two
10

three
12

> three
7

- 6) Would you like to play game again?

yes
28

no
4

- 7) Objectives clearly defined?

yes
29

no
3

- 8) Problems running program -

some; syntax error; none; rather not enter coordinates of baffles; bad subscript error; game quite challenging - I liked it; no problems; add noises.

Summary of Comments on the Enzyme Activity Module
Based on 35 General Biology Evaluations

Most Interesting Part: graphing of output; when it showed how each variable affects enzyme; effect of factors was awesome; none; visual aids (graphs); changing variables; regraphing on a new scale; nothing - too confusing.

Least Interesting Part: whole thing rather dull; none; good program; none; everything - couldn't understand it; waiting for graphs to be drawn.

Annoying Part: none; need to be able to abort a run and start over; not understanding it; could not understand information under graphs.

Anything Not Understood: clear on second run; not in the end; a lot was presented; don't understand it all; all of it; hard to understand what graphs meant; why does it take 10-60 minutes when product molecules produced at 100,000/minute?; concentration of enzymes and coenzymes.

Anything That Didn't Work: worked fine; division by zero errors in 4010; changing time constant can cause it to plot off scale; subscript error in line 162; undefined statement error in 915.

Suggestions: make it more fun; provide hard copy; should be preceded by lecture on enzymes; should be a limiting time factor; should study subject before using module; explain what the 5 enzymes actually do; add graphic animation of how an enzyme works; error traps to prevent division by zero; provide HELP; provide summary; add a lower level exploration program for beginners.

Summary comments on the Wiggels module, Based on
50 general biology evaluations

Most Interesting: Wiggels looked like cows; the several crosses we made; entire program was helpful; the quiz at the end; explanations were good.

Least Interesting: Wiggels got dull after awhile; filling in of squares; none; the breeding of the wiggels; almost too easy; reading the text; the basics that we already covered.

Annoying Parts: lasted too long; none; everything made sense; was hard to keep track of stuff; should be able to go back and review what you are doing more often; was too long of a program; those little animals.

Anything Not Understood: the back cross; nothing; some of the definitions.

Anything Not Working: none.

Suggestions: explain back crosses more clearly (predominant); a little too long; program was fine; have summary available as a reference; helped me understand genetics better; after a question there should be an explanation of answers.

Summary of Comments on the Life Expectancy Module
Based on 45 General Biology Evaluations

Most Interesting Part: smoking = 8 years of life; computations; all of it; general loss of life due to overweight, smoking, etc.; didn't take a lot of concentration; seeing how long I could live; which questions were asked.

Least interesting: none; program was sore of trite; dumb questions (\$50,000/yr); no real high points; questions that didn't apply.

Annoying Parts: silly questions (\$50,000/yr); none; the fact that 3 years were lost due to maleness; should have totalled loss after all questions were asked; save answer until end; should ask about drugs; should explain how years to add or subtract were figured.

Anything in Program Which You Did Not Understand: no; are questions realistic; how were figures arrived at; why liquor only took off 1 year; why living alone takes years off your life; why they ask what age you are now; none of my grandparents are dead and all are under 80 - so what do you answer for those questions?

Anything About Program Which Did Not Work: no.

Suggestions: more questions for more accuracy; state reasoning behind questions; it was fun; questions should include diet, drug intake, exercise, physical problems, etc.; be a little more easy going; don't tell user how old he is going to be after every question - save it until the end and explain figure; good program; love it; have questions cover past history.

Summary of Comments - The Amino Acid Ionization Module
Based on 108 Cell Biochemistry Evaluations

Most Interesting Part: entire program; showing stepwise ionization of lysine; titration curves; pH curves; good graphics; good review.

Least Interesting: titration of various amino acids; introduction; waiting for pH to reach 14.

Anything annoying: no; graphs have no accompanying explanations; program ran too slowly; the flashing cursor; for titration curves other than lysine there was no way to tell which hydrogen ions were coming off.

Anything Not Understood: the final graphs of concentration vs. pH; concentration curves; still unsure of ionization curves; didn't have enough directions for running computer; didn't understand protic species.

Anything Not Work: no; I didn't know how to sign off; program 5 did not come on; without color I could not tell different lines on titration curves.

Suggestions: explanation of titration curves would have been helpful; program in general was informative; could label different parts of titration curves; including a post-test would help; more explanations would help; take a small protein and show ionization as in part 2.

Summary of Comments for the Enzyme Activity Module
Based on 104 Cell Biochemistry Evaluations

Learn New Concepts: temp. effect on activity; effect of pH & conc. on activity; good reinforcement of previous knowledge; materials used for experiments; effect of coenzymes; better understanding of K_m , V_{max} , V & S ; how to evaluate enzyme activity; none.

Most Interesting Portion: post quiz; level 2; effect of coenzyme; graphs; entire program; doing lab experiment; titration curves for buffers; interaction with computer.

Least Interesting Portion: waiting for re-plots; none; time-product curves; picking values over and over again.

Anything Not Understood: no; first part of second section was a little complicated; some applications concerning buffers - never given the optimum ranges for the enzyme; how to choose buffer; coenzyme vs. product plot; in arginase, why isn't liver homog. a good choice when its enzyme activity is highest.

Anything Not Work: no; points from graph went off screen; bad subscript error line 117; in graph of product formation vs. coenzyme concentration it did not print the coenzyme conc. value.

Suggestions: put instructions on how to operate machine on machine itself; discuss how to choose buffer; put more than one graph on screen to help in comparisons; quiz was really helpful.

Summary of Comments for the Photosynthesis Module
Based on 105 Cell Biochemistry Evaluations

New Concepts Learned: learned what happens in cyclic-non-cyclic phosph.; most of program material was new; learned how pathways of photosyn. interact; no, but was good review; explained pigment systems well.

Most Interesting Part: graphs of cyclic & non-cyclic phosphorylation; representations of electron transfers; animated graphs; liked interaction with computer; all of it.

Least Interesting Part: facts about photosyn. I already knew; none; dark reactions seemed to be anticlimax; dark reaction explanation seemed a bit brief.

Anything Not Understood: no; exactly where does carbon from CO_2 end up; can cyclic and non-cyclic run simultaneously; if so, how many ATP are produced?

Anything Not Work: no

Suggestions: great program; could use more material on dark reactions; rework dark-part so it is similar to light-part; descriptions may be wordy; quiz and questions were good; keep this program; could use quiz after dark reactions; very informative; some pathways move too quickly; expand menu into subsections so you don't have to review entire sections.

Summary of comments on the Gene Code Module
Based on 105 Cell Biochemistry Evaluations

New Concepts Learned: none; good review; effect of shifting bases in a point mutation; learned about frame shift mutation; learned more from book.

Most Interesting Part: gene mutation; effect of mutation; RNA sequencing along template chain; computer interaction.

Least Interesting Part: complementary base pairing simulation; none; sequencing; whole program was very "plug & chug".

Anything Not Understood: no; why was AUG chosen as a starting point - is this standardized; is the template chain generated by random numbers to determine the base sequence after 1st codon; why is UAA a terminator codon; is a terminator the last codon in the chain.

Anything Not Work: error statement "Next without for in 1210" during mutagen program; incompleted "shif" instead of "shift" in simulation of the two types of mutation; one too many A's for the chain of mRNA showing transcription; kept repeating point mutation portion; for point mutation portion it said the mutagen concentration was too low - press [RETURN] - and got "next without for error 1210".

Suggestions: it was very short - can't review first section without starting all over again; could give examples of disease caused by mutation and show type of mutation involved; more explanations could be given; could use a post quiz; might give student a chance to figure out amino acid code using a genetic code dictionary; could be a little more complex; further discussion of tRNA and mRNA would be helpful; allow student to do some of the coding work; possibly could simulate ribosomes at work; make the program more interactive; slow things down; include a model or explanation of codons.

Summary of comments for the Lac Operon Module
Based on 102 Cell Biochemistry Evaluations

Learn New Concepts: It was all new; how the lac operon works; helped explain gene regulation and repressor protein action; good reinforcement of lecture material; where and how lactose binds with regulator protein to prevent it from inhibiting the operator; when lactose is absent then the mRNA is inhibited.

Most Interesting Part: graphical presentations; the simulations; finding concentrations in the cell; the experimental part; what happens when you add lactose and a lactose enzyme to a system.

Least Interesting Part: simulations; none; explanations at beginning of program; discussion of regulator gene action; program was boring.

Anything Not Understood: difficult concept but finally got it; the last simulation; exactly why the concentrations of the enzyme varies with time - there didn't seem to be a pattern; some of the numerical data was unclear, involvement of the "operator" in the system was unclear.

Anything Not Work: no; getting out of the lactose diagram explanation; how to end the program; if data was entered out of range the program was terminated, - should give a re-enter statement instead.

Suggestions: slow down speed of screen for simulations; on graph it is hard to tell the difference between the enzyme curve and the mRNA curve; try simulations with other bacteria as well as E. coli; concentration numbers could be flashed a little slower; interesting program; give more visuals in introduction; could use a post quiz, perhaps a longer or/and slower program would be in order - went through this one 4 times; could illustrate the lactose - reg. protein complex and mRNA - re. protein systems; the statement "repressed genes do not synthesize mRNA hence do not lend to the formation of proteins" should be clarified as to what genes are being referred to - structural or regulatory genes; could use an ending.

UNSOLICITED COMMENTS ABOUT COMPUTER MODULES

Five computer modules were used to augment the instruction of cell biochemistry during the spring quarter of 1982. Students examined the programs on an ad lib basis and received 10 points (equivalent to one recitation quiz) for reviewing all five modules. The following un-solicited remarks were volunteered by the 125 students who filled out the course evaluation sheets. It is significant that there were no negative comments.

"The computer modules were very helpful in the reinforcement of concepts."

"Computer simulations made some points interesting."

"The computer modules emphasized some of the more difficult concepts."

"The Biosimulations were also an added help in clarifying certain subject matters."

"Computer simulations were great help in understanding the material."

"I especially liked the computer simulations. There can't be too many of those in this course. They force student interaction with no real intimidation or pressure as in a classroom situation. They can't replace lectures, but on difficult subjects, they do help a lot."

"I really liked the phosphorylation computer module!!"

"The SUMIT project was very helpful."

"The computer modules were very helpful-I only wish there had been more of them."

"The computer simulations helped quite a bit. They helped in visualizing quite a bit of the misunderstood material."

"The use of computer simulations was an interesting way to learn Bio-Chem."

"The computer simulations were also helpful, although the first two seemed awfully basic."

"Computer simulations: helped when it came to difficult material- use more of them!"

"I liked the computer modules- more of them!"

"Computer-simulations were instructive and clearly a big plus.

"Computer modules were a good idea, I liked the one about enzyme activity best because it allowed me to simulate actual experiments and make decisions an experimenter would make.

"The simulations were a great aid in understanding material.

"I liked the simulations, they helped to clear up some misunderstandings that I didn't realize were there.

"The computer labs helped a great deal in understanding material."

Eight people also commented that the computer modules were very helpful.

APPENDIX C

A List of Workshop Attendees who Participated in the
Formative Evaluation of SUMIT Modules during the summers of
1980 and 1981.

MICROCOMPUTERS AND MODELING IN UNDERGRADUATE LIFE SCIENCE INSTRUCTION
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