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AUTHOR Skavaril, Russell V.; And Others
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ABSTRACT

This paper describes an application of Computer Assisted Instruction named 'genpbs' consisting of five modules of preliminary instruction and 19 modules of problems for students in an introductory genetics course. Each problem module consists of an average of 14 problems arranged in increasing level of difficulty. The program also contains a report module designed for use by the course instructor to obtain an on-line summary of student performance in the problem modules. The program was tested by a group of 135 students in a formal course, and student performance data on the problem modules are reported. An evaluation of the program by the students indicated a highly favorable student reaction and an overwhelming preference for the computer problems as compared to problems and solutions placed on library reserve. A slight, positive correlation was found between time spent by the students on the computer and the course numerical grade. The mean course numerical grade for students using the computer was found to be slightly higher than the corresponding mean from a previous quarter when the computer was not used, but the difference was not statistically significant. (Author)

THE USE OF CAI TO PROVIDE PROBLEMS FOR STUDENTS IN INTRODUCTORY GENETICS

by

Russell V. Skavaril
C. William Birky, Jr.
Richard E. Duhrkopf
Jeffrey A. Knight

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THE USE OF CAI TO PROVIDE PROBLEMS FOR STUDENTS IN INTRODUCTORY GENETICS[1]

Russell V. Skavaril[2], C. William Birky, Jr.[3],
Richard E. Duhrkopf[4], and Jeffrey A. Knight[5]
The Ohio State University

This paper describes an application of Computer Assisted Instruction named 'genpbs' consisting of 5 modules of preliminary instruction and 19 modules of problems for students in an introductory genetics course. Each problem module consists of an average of 24 problems arranged in increasing level of difficulty. The program also contains a report module designed for use by the course instructor to obtain an on-line summary of student performance in the problem modules. The program was tested by a group of 135 students in a formal course, and student performance data on the problem modules are reported. An evaluation of the program by the students indicated a highly favorable student reaction and an overwhelming preference for the computer problems as compared to problems and solutions placed on library reserve. A slight, positive correlation was found between time spent by the students on the computer and the course numerical grade. The mean course numerical grade for students using the computer was found to be slightly higher than the corresponding mean from a previous quarter when the computer was not used, but the difference was not statistically significant.

It is generally agreed that, in a course in genetics, a student's ability to work problems correctly is essential to a mastery of the subject material. Virtually all texts in genetics include problems; see, for example, Burns (1972) and Strickburger (1968) which are used in Genetics 140 and Genetics 500 at The Ohio State University, Srb, *et al.* (1965), Goodenough and Levine (1974), Crow (1966), and Singleton (1967).

Problems are valuable teaching aids because teaching genetics involves, essentially, the presentation of a body of facts; and mastery of the body of facts is achieved by the student being able to *use* the facts in real life problem solving. Students learn genetics by working problems. Unfortunately, most texts do not include the solutions to all problems; when solutions are included, there is no attempt to lead the student to the correct answer by identifying a mistake, reminding the student of a principle which he has forgotten, etc.

Instructors of genetics traditionally prepare fully annotated problems and solutions. Copies of these materials may then be distributed to the class, but this becomes time-consuming and expensive for a large class. Alternatively, sets of problems and solutions are put on reserve in a library. Library problem sets are, however, difficult to maintain and preserve in the numbers needed for effective use by students, particularly for large enrollment courses. Even if such technical problems can be overcome, library problem sets cannot provide immediate feedback to a student who is laboring under a misconception of some genetic principle, nor can such problem sets avoid presenting remedial material to a student who does not need it.

CAI problems, on the other hand, can obviate most of these difficulties. The materials are easy to maintain, preserve, and update. The number of computer terminals available to students at our institution exceeds the number of library reserve problem sets which can reasonably be provided. CAI can provide immediate guidance to a student who is making a minor error or who has overlooked a fundamental principle. This capability is the principle advantage of CAI.

In addition, CAI provides individualized instruction in that each student may proceed through the material at a pace that is consistent with his abilities and time commitments. Each student may spend as much time as he likes on difficult material and proceed quickly over material which he finds easy or familiar.

The purpose of this paper is to describe a CAI application consisting of problems for students in a

[1]Requests for reprints should be sent to Dr. Skavaril or Dr. Birky.

[2] [3]Dr. Russell V. Skavaril and Dr. C. William Birky, Jr. are Professors, Department of Genetics, The Ohio State University, 484 West 12th Avenue, Columbus, Ohio 43210.

[4] [5] Mr. Richard E. Duhrkopf and Mr. Jeffrey A. Knight are Graduate Teaching and Research Associates, respectively, Department of Genetics, The Ohio State University, 484 West 12th Avenue, Columbus, Ohio 43210.

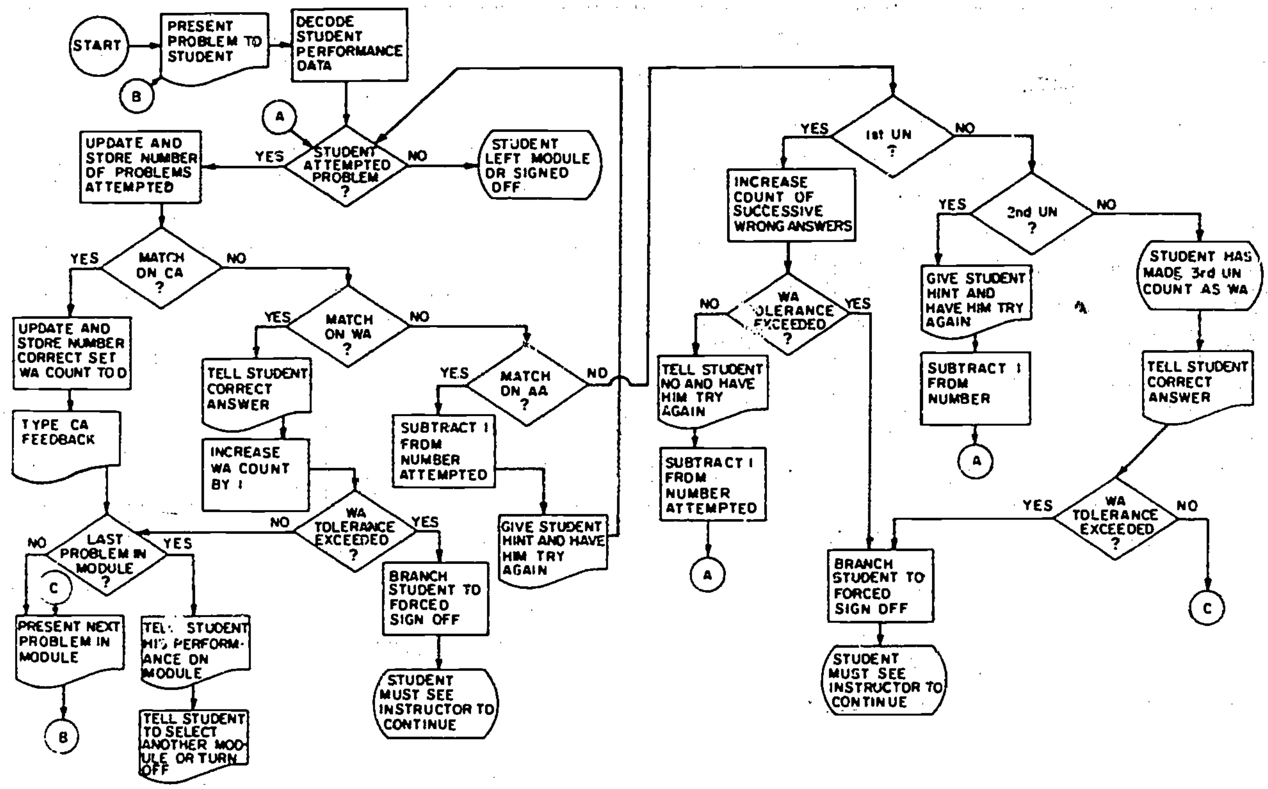
genetics course and to report an evaluation of student performance on the modules.

COMPUTER SYSTEM AND FACILITIES

CAI at The Ohio State University is run on the IBM 370/158 central computer of the University Systems Computer Center (USCC). There are over 100 remote CAI terminals distributed across the campus, the majority of which are IBM 2741 Communication Terminals. Approximately half of the terminals are restricted, and the remaining are public terminals. Members of the university community use the terminals and the central computer of USCC under a time sharing environment (multi-programming with a fixed number of tasks).

Table 1. Computer Assisted Instruction Problem Modules in 'genpbs'

Name	Number of Problems Available	Brief Description	Estimated Time Required
mendl1	28	MENDL I -- Law of segregation; one-factor crosses and pedigrees; probability.	60
mendl2	23	MENDL II -- Law of independent assortment; crosses with two or more factors, all unlinked.	60
stat	15	STATISTICS -- Chi-square.	40
quant	26	QUANTITATIVE -- Quantitative and multiple-factor inheritance.	60
link	43	LINKAGE -- In higher organisms: sex linkage, mapping, assigning genes to chromosomes.	60
genenv	17	GENE/ENVIRONMENT -- Dominance, epistasis, modifiers, background genome, other interactions between genes; lethality, penetrance, expressivity, other interactions between gene and environment; twin studies.	60
chmthy	26	CHROMOSOME THEORY -- Mitosis; meiosis; and relationship to Mendel's laws.	30
tetanl	21	TETRADS -- Tetrad analysis, other aspects of eucaryotic microbial transmission genetics.	30
chmno	23	CHROMOSOME NUMBER -- Variations in number; ploidy.	30
chmstr	26	CHROMOSOME STRUCTURE -- Variations: deletions, duplications, inversions, translocations.	40
prokar	35	PROKARYOTES -- Reproduction and transmission genetics of prokaryotes and viruses.	60
bchemg	21	BIOCHEMICAL GENETICS -- One gene-one enzyme theory; pathways; auxotropic mutants.	45
dna1	20	DNA I -- DNA structure, replication, mutation, repair, recombination.	30
dna2	25	DNA II -- Coding; gene fine structure.	45
prosyn	22	PROTEIN SYNTHESIS -- Protein synthesis.	30
devgen	17	DEVELOPMENT GENETICS -- Development genetics; cell differentiation: control of gene action (transcription).	30
nchmg	20	NON-CHROMOSOMAL GENETICS -- Genetics of genes in chloroplasts, mitochondria, symbionts.	40
popgn1	24	POPULATION GENETICS I -- Gene pools and frequencies; Hardy-Weinberg law.	30
popgn2	25	POPULATION GENETICS II -- Evolution in gene and genotype frequency.	45



Abbreviations: CA = Correct Answer; WA = Wrong Answer, AA = Anticipated Answer; UN = Unanticipated Answer.

Figure 1. Problem module logic as used in 'genpbs'.

Description of CAI Modules

A CAI course named 'genpbs'[6] has been designed and implemented during 1975. The course was written in Coursewriter III, Version 3 (IBM, 1971, 1973a, 1973b) and consists of 5 modules of preliminary instruction, 19 modules of genetic problems, a report module, and a question skeleton generating macro.

The five modules of preliminary instruction deal with such CAI system features as the completion of registration of students on the course, the signal for student response or sign off, the use of the '*go to*' command, the use of the '*calc*' function, and how a student may send comments to authors while working on the course.

Table 1 gives the module names, the number of problems available, a brief description of the type of problem, and an estimate of the time in minutes required to complete the module. The categories correspond to blocks of lectures given in *Genetics 500* (General Genetics) at The Ohio State University, but are applicable to virtually any introductory course in genetics. Typically, students in Genetics 500 are distributed, relative to rank, as follows: 40% Juniors, 30% Seniors, 10% Sophomores, 10% Graduate Students, and 10% Continuing Education and other categories. Approximately 80% of the students are from departments within the College of Biological Sciences, as follows: 32% Zoology, 17% Biology, 17% Microbiology, 5% Botany, 6% Genetics, 4% Biochemistry, and 1% Biophysics.

Figure 1 is the flowchart using standard flowchart symbols for the logic which is used within each problem module of 'genpbs'. After a student has completed the preliminary instruction modules, he uses the '*go to*' command to take him to the beginning of the problem module (the block labelled "START" in Figure 1), at which point the student is provided with a brief description of the nature of the problems in the module and asked whether or not he wishes to work the problems in the module. If the student enters a negative response, he is asked to use the '*go to*' command

[6]Arrangements can be made to supply the course to members of the educational community. Individuals interested in acquiring 'genpbs' should contact Dr. Skavaril.

to take him to the module on which he wishes to work or to sign off the course. If the student responds that he does wish to work problems within the module, then the first problem is presented to the student and the performance data for that module are decoded and prepared to be updated in the event that the student decides to answer the question. We have attempted to write and design each problem so that the computer will help the student who is making an error to achieve the correct answer to the problem. This is done by reminding the student of a fundamental principle after the student has entered a wrong answer and asking the student to attempt the problem again, etc. In addition, the problems within a module are presented to the student in approximate order of increasing difficulty so that the student has the opportunity, when working in a difficult problem, to utilize what he has learned by working the preceding, relatively simpler problems.

We have designed a successive wrong answer tolerance parameter which we initially set to six. While the student is working on 'genpbs', the computer keeps a count of the number of successive wrong answers entered by the student. If this count should exceed the successive wrong answer tolerance, the student is immediately informed that he has incorrectly answered that many questions in a row and is forced off the course. He is informed that the computer will not allow him further use of the course until after his instructor has authorized additional use. This successive wrong answer tolerance has been incorporated as a feature of 'genpbs' so as to encourage students to be serious when they work the problems and to force students to obtain help from the instructor and teaching associates when their difficulties exceed the computer's instructional capabilities. The count of each student's number of successive wrong answers is set to zero each time the student enters a correct response. The instructor of the course and the graduate teaching associates have been trained in the on-line procedures necessary to allow a student who has been forced off the course to resume use of 'genpbs'[7] and, if necessary, to change the successive wrong answer tolerance for a particular student.

Students who have been forced off the course are identified in a monitor's student status listing. Students who have attempted to sign on the course without proper reauthorization are also identified in such listings.

If the student's answer to a question is correct, the student's performance record is updated and stored. The student is told that his answer is correct, the number of successive wrong answers is set to zero, and the next problem in the module is presented. If the student's answer was one of the specific wrong answers anticipated for the problem, the student is told that his answer was incorrect and is given the correct answer to the problem. The number of successive wrong answers is increased by one, and the student is either sent on to the next problem in the module or forced off the course.

If the student's response is one of the specific anticipated responses (neither a correct nor incorrect answer to the problem), the student receives an appropriate feedback from the computer and is asked to answer the question again. The student's number of successive wrong answers is not changed. For example, a student might be asked the question "Can you tell me how many different gametes could be produced by an individual whose genotype is AaBbCc?" The student responds "yes". We consider such a response neither correct nor incorrect, and the computer would respond with something such as "O.K., how many? Enter a number, please, to answer the question." In general, however, we have attempted to avoid ambiguous questions, such as the one in this example, by phrasing such questions as follows: "How many different gametes would be produced by an individual whose genotype is AaBbCc?"

Each problem allows for three unanticipated answers. The first unanticipated answer is considered to be incorrect. If the number of successive wrong answers is less than the wrong answer tolerance, the student is asked to try again; otherwise, he is forced off the course. The second unanticipated answer is not counted as being incorrect; however, the student is given a hint to the solution to the problem and asked to attempt the problem again. The third unanticipated answer is counted as being incorrect, and the student is told the correct answer to the problem, following which the number of successive wrong answers is checked to determine whether the student is sent on to the next problem in the module.

After the student has completed the last problem in the module, he is told how many problems he attempted in the module together with the number

[7]Reauthorization for use of 'genpbs' for a student who has been forced off the course is achieved by the instructor performing an on-line author load of 0 into parameter nine of the student's record. If a student who has been forced off the course attempts to sign on without the parameter being changed, the computer will tell the student that, according to the computer's record, further use of 'genpbs' has not been reauthorized; and the computer will sign such a student off the course again.

answered correctly. The student is then asked to sign off or to use the *'go to'* command to take him to the next module on which he wishes to work. A student may repeat a module as often as he wishes.

The following is an example of the output which would be produced at a terminal by a student working on one of the problems in the module labelled 'mendl1".

```
One of the seven characters Mendel studied in peas
concerned the shape of the pods — either full or
constricted. The gene for full pods (F) was found to
be dominant over that for constricted pods (f). When
homozygous FF plants were crossed to homozygous ff
plants, the resulting F1 all had full pods. When the
F1 progeny were selfed (F1 x F1), the F2 generation
contained plants with either full or constricted pods.


If Mendel scored 148 plants, how many plants would
you expect to be phenotypically F?

***** 48

No.
Please try again.
***** 75

No. Here's a hint.

The genotypic ratio is 1:2:1.
Please try again.
***** calc .75*148

     111.
***** 111

That's right, Michael!


Of these 148 plants in the F2 generation, how many
would you expect to have the genotype FF?

***** sign off

LINE IS SIGNED OFF, TURN OFF TERMINAL.
```

In the example, the responses of the student are preceeded by * * * * * . This helps the student distinguish his typing from that produced by the computer. In the example, the student's first and second answers are incorrect. The student receives a hint after his second incorrect answer and is asked to try again. At this point, the student uses the *'calc'* function to arrive at the correct answer. He enters 111 as his response and is told that he is correct.

We have attempted to personalize the instruction by addressing each student by his name. The example ends with the student signing off 'genpbs' before he answers the next question. When he next signs on the course, the computer will resume his use of the course at the point where he signed off by repeating the second question in the example.

A Coursewriter macro was written and used to generate the skeleton of a problem within a module. The skeleton, once generated at the appropriate position in the course, was then modified to insert the text of the problem, the specific wrong and anticipated answers, and the feedback which the student receives. The macro is designed to permit teaching assistants and instructors not thoroughly familiar with the programming procedures of Coursewriter to construct problems for 'genpbs' or to add new problems in the future with greater ease and dispatch.

We have also written a report module, a module to which only the instructor and his teaching associates have access. The report module allows the instructor to obtain an on-line summary of student performance on the problem modules. The report, which can be produced for one or a group of students registered on 'genpbs', will give the name of the student, his 'genpbs' registration number, the time spent on the course, the number of times a student has been forced off the computer for having exceeded the successive wrong answer tolerance, and, for each problem module, the number of problems attempted in the module and the number of problems answered correctly. In the report, the problem modules have been numbered 1 through 19 corresponding to the sequence of the modules as listed in Table 1. For example, the performance of a student on the problems in the module labelled "mendl1" will be found in the report under module number 1; the performance of the student on the problems in the module labelled "link" will be found in the report under module number 4, etc. Figure 2 shows an example of the report produced for one student.

The example of the report indicates that the student named John Smith, student number 1105, has spent a total of 848 minutes on the course. In module 6, the module labelled "genenv", for example, this student has attempted 18 problems and answered 15

Today's Date Is 01/23/76

Name (c30)	Number	Module Attempted Correct Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
John Smith	1105	00848	53	23	16	26	53	18	26	15	0	5	8	21	20	23	22	18	20	27	30
00003			40	21	12	23	43	15	20	14	0	5	5	17	15	15	13	11	18	20	21

Figure 2. Instructor's report on an individual student

correctly. The 3 below the student's name is the number of times he has been forced off the course for having exceeded the successive wrong answer tolerance.

A few miscellaneous features have been incorporated into 'genpbs'. A routine supplied by Central Computer Assisted Instruction has been used to create a portion of the course to which students do not have access, but which will allow the instructor to obtain an on-line summary of student use of 'genpbs' at that moment. A second section to which students do not have access allows an erronous student record to be corrected. The latter module would be important if student performance data were used to contribute to a student's course grade.

STUDENT USE AND EVALUATION

The CAI course 'genpbs' was first used by students enrolled in *Genetics 500* at The Ohio State University Autumn Quarter 1975. In previous years this course utilized practice problems in the text book. Copies of the correct answers, with explanation, were put on reserve in the Biology Library. The course was taught by one instructor and two graduate teaching associates. There were 135 students who completed the course.

Early in the quarter, a graduate teaching associate gave a brief, preliminary lecture to the students concerning the facilities available for their use (locations of the terminals, hours CAI available, how to sign on 'genpbs', etc.). At this time, the students were given a handout similar to Table 1 and informed that they could begin work on the problems in the first module. The students were informed that the problems were available for their use on a strictly optional basis. The students were not required to work the problems, and student performance on the problems did not contribute numerically to course grade. It was initially planned that a second lecture, devoted to questions and difficulties which the students encountered during their initial sessions with 'genpbs', would be needed. However, due to there being no such difficulties, the second lecture was cancelled. Throughout the quarter, as the instructor proceeded through the presentation of the lecture material, he would inform the students as to which modules in 'genpbs' contained relevant problems.

Six of the 135 students who completed *Genetics 500* elected not to use 'genpbs'. The performance data for those students who used 'genpbs' are given in Table 2. In general, the mean number of problems attempted within each module is close to or exceeds the number of available problems. Students, therefore, repeated some problems, perhaps as a review effort. In any event, the data do indicate that students made considerable use of the problems. The percent correct data for some modules falls at or slightly below 60 percent. The problems in these modules are perhaps too difficult for the students at the introductory level. Students spent an average of 15 hours working on 'genpbs' throughout the quarter.

In Table 2, performance data for three modules are absent since access to these modules was not allowed. Practice problems for these modules were handed out in class and answers were placed in the library on reserve, as in previous years, in an attempt to compare student preference for the two types of problems, computer versus library. In the student evaluation of the course questionnaire distributed near the end of the course, 88% of the students indicated that, all things considered, they found the computer problems more useful than the library problems. Ninety-three percent of the students indicated that they found the computer problems helped them understand the course material, while only 24% of the students indicated that they found the library problems helped them to understand the course material.

For the 129 students who used 'genpbs' and completed Genetics 500, the mean and standard error of the number of times students were forced off the course for having exceeded the successive wrong answer tolerance were 1.3 ± 0.1 times. The greatest difficulty

Table 2. Student Performance Data on Problem Modules

Name	Module Number	Number of Available Problems	Number of Students Attempting At Least One Problem	Mean ± Standard Error		
				Number Attempted	Answered Correctly	Percent Correct
mendl1	1	28	132	32.5 ± 0.91	24.5 ± 0.79	74.8 ± 0.89
mendl2	2	23	124	26.2 ± 0.62	21.2 ± 0.52	80.6 ± 1.06
stat	3	15	121	15.9 ± 0.46	11.6 ± 0.40	72.7 ± 1.35
quant	4	26	111	24.5 ± 0.58	20.7 ± 0.56	82.6 ± 1.42
link	5	43	126	42.8 ± 2.09	32.9 ± 1.82	73.6 ± 1.45
geneV	6	17	110	18.4 ± 0.72	14.5 ± 0.65	72.1 ± 2.38
chmthy	7	26	117	28.3 ± 0.69	22.0 ± 0.64	76.9 ± 1.11
tetanl	8	21	101	21.7 ± 0.64	16.5 ± 0.57	75.2 ± 1.25
chmno	9	23	0			
chmstr	10	26	0			
prokar	11	35	0			
bchemg	12	21	77	20.6 ± 0.78	14.7 ± 0.60	71.2 ± 1.49
dna1	13	20	112	24.9 ± 0.91	17.1 ± 0.72	67.6 ± 1.43
dna2	14	25	97	24.9 ± 0.84	15.5 ± 0.71	60.3 ± 1.70
prosyn	15	22	90	22.8 ± 0.76	16.1 ± 0.65	70.0 ± 1.42
devgen	16	17	90	17.4 ± 0.63	10.4 ± 0.49	57.7 ± 2.19
nchmg	17	20	84	19.6 ± 0.76	12.0 ± 0.63	58.0 ± 2.00
popgn1	18	24	74	22.2 ± 1.05	15.6 ± 0.90	69.1 ± 1.92
popgn2	19	25	59	24.3 ± 1.87	16.1 ± 1.45	63.9 ± 2.14

with this feature was that students occasionally were forced off the course on evenings and weekends — times when they did not have access to the course instructor or course assistant in order to have further use of 'genpbs' authorized. In addition, some students reported that other students were using their accounts. Such a student would discover when he attempted to sign on the computer that another individual had exceeded the successive wrong answer tolerance and the student was unable to use his own account. We are considering two alternative plans to attempt to overcome this problem: One plan would be to increase the successive wrong answer tolerance and warn the student when he had reached six successive wrong answers. The second plan under consideration is to leave the successive wrong answer tolerance at six, but to assign non-sequential sign on numbers in order to assure that one student cannot deduce the sign on number of another student.

Student performance in the course was evaluated by two one-hour midterm examinations (100 points each), and a final examination (2 hour, 200 points). The examinations consisted principally of problems similar in kind and difficulty to those in 'genpbs' and short answer essay questions. The course numerical grade of a student is obtained by summing the student's scores on the three examinations. We found a correlation of 0.26 between time spent on 'genpbs' and course numerical grade. The correlation was found to be highly significantly different from zero. There may be a genuine cause and effect between time spent working problems and course numerical grade; however, it is also possible that this observed correlation reflects the tendency of good students to spend more time on optional material and the converse tendancy with respect to poor students.

We compared student performance for Autumn Quarter 1975 with student performance in the preceding Autumn Quarter 1974 at which time 'genpbs' was not used. We found the mean course numerical grade to be slightly higher for Autumn Quarter 1975, 274.4 out of 400 points versus 266.5; however, the difference was not found to be significant. Use of 'genpbs' is valuable to the student and at least as effective as other, traditional methods of providing problems and solutions to students (library problems). We feel the highly favorable student reaction justifies continued use of 'genpbs'.

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