Computer-Assisted Instruction for Introductory Genetics[1]

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ABSTRACT

Computer-assisted instruction (CAI) offers a valuable supplemental teaching aid for courses that require repetitious drill to develop problem-solving skills. Computer assisted genetics instructor (CAGI) help students and teacher identify weaknesses and misconceptions, provides interactive drill to encourage students to master problem-solving, and reduces the need for continuing teacher tutorial time. CAGI contains multiple-choice questions developed by the course instructor and immediately acknowledges correct responses. The performance of students using CAGI was evaluated in an introductory genetics course comprised of students from several majors. Students utilizing CAGI scored an average of between 6 and 10 points higher on hour exams than students in the same class who did not use CAGI. More than 96% of CAGI users received a grade of B (88 percentage points) or better; 67% of the nonusers received B or better. CAGI helps students focus on the key aspects of biological processes, diagnose misconceptions, and provides drill accompanied by immediate feedback.

COMPUTER-ASSISTED INSTRUCTION (CAI) enhances both student motivation and learning and is valuable in teaching subjects such as genetics, which require development of problem-solving skills. Educators in genetics agree that the emphasis must remain on mastery of principles and effective application of those principles to the solution of both theoretical and practical problems (Klug and Cummings, 1991; Nickla, 1991). Experience shows that development of problem-solving skills based on the application of basic concepts requires repetitious drill. Streibel et al. (1987) reviewed the educational basis of CAI and specifically addressed the applications in teaching genetics. They confirmed the benefits of computer instruction in assisting students to master problem-solving exercises in genetics.

Educators and some employers view with increasing concern the level of student mastery of complex subject matter. The Office of Technology Assessment estimated that the emphasis on standardized test performance has led teachers to be satisfied when 30 to 50% of their students have mastered 80% of the needed subject matter (Kelly, 1991). In theory, this would yield a maximum class average of 40%.

Our introductory genetics course serves students with diverse academic backgrounds and career orientations. Computer-assisted instruction examines knowledge and develops problem-solving skills. Some students use CAI to verify their mastery of subject matter; others use it as a learning tool. In this way, CAI can compensate for a diverse student population. Although the course stresses individualized instruction, the size (80 or more each semester) limits the amount of individual tutoring that is practical. The principle-based, problem-solving orientation of this course makes it ideally suited for supplementation with CAI.

Computer-assisted learning is not a panacea for all teaching problems. Appropriate materials enhance learning and may make teaching more efficient, but they do not reduce faculty work load (Hartig, 1984). However, as Waldal (1991) notes, appropriate use of computer and video-technologies increases instructional efficiency by addressing common misconceptions.

COMPUTER-ASSISTED GENETICS INSTRUCTOR

Computer-assisted genetics instructor (CAGI) is a database program, created using dBASE IV (Borland Int., Scotts Valley, CA), and compiled to an executable file using Clipper 5.0 (Computer Assoc. Int., Islandia, NY). The chapter questions are entered, edited, or deleted from within dBASE IV. Such changes require no alteration of the CAGI program itself. CAGI questions are copied to floppy disks for use in IBM-compatible personal computers. In addition, CAGI is on the computer network at Clemson University and can be accessed via remote terminals at several campus locations. The goal is to make CAGI use as convenient as possible.

The course instructor (senior author) wrote the questions, which are designed to be consistent with the terminology in our current text (Klug and Cummings, 1991). Many of the questions address common student misconceptions and mistakes. Wrong responses are clarified in the answer explanation. CAGI questions are written independently of exam questions.

When CAGI is executed, the first screen shows a logo and asks for the student's name. The second screen allows the student to choose from a directory of 20 chapters corresponding to major lecture topics. Chapters contain up to 40 questions from which the computer presents 10 randomly selected questions at a time.

A question with choices (Fig. 1) appears on the monitor and remains on the screen until the student moves to the next question. After completing 10 questions, the student chooses to restart the program or prints the results of this CAGI session. Printouts are given to the course instructor. They show the CAGI chapter number, the number of correct responses, the student's name, number of each question asked (as entered in the database), and the response for each question. This information identifies frequently missed questions. Instructors can

[1] Disk available upon request. Send a blank floppy disk (3.5 inch) to N.H. Ferguson, Dep. of Agronomy and Soils, Clemson Univ., Clemson, SC 29634-0359.

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Abbreviations: CAI, computer-assisted instruction; CAGI, computer-assisted genetics instructor.

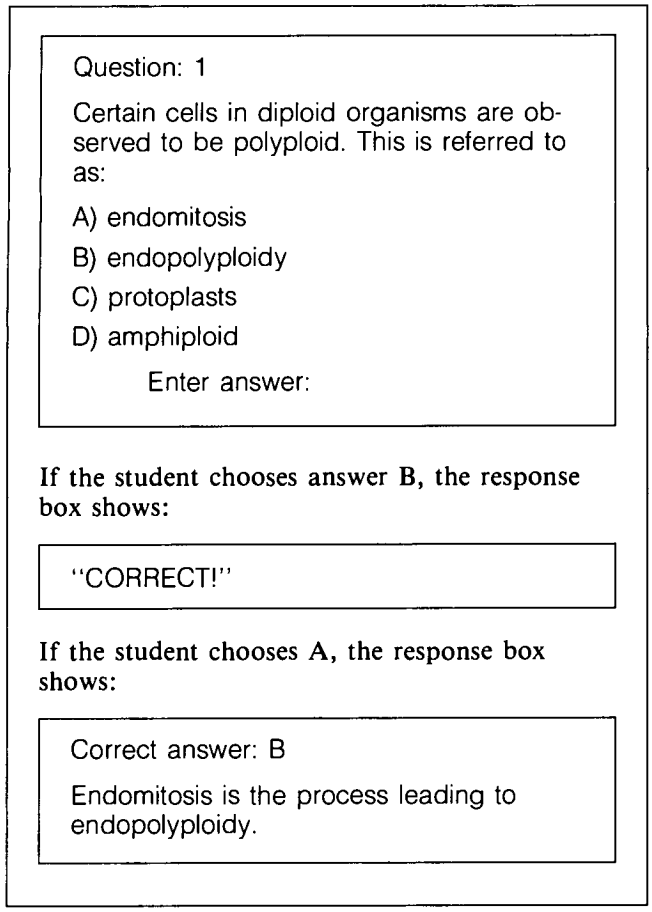

Fig. 1. Format of a computer-assisted genetics instructor question as shown on computer monitor.

evaluate these questions to determine if the question is not clear or if it relates to specific problem areas where students do not understand subject matter.

The CAGI helps resolve three problems in genetics teaching. It helps students and teacher identify misconceptions, provides interactive drill to assist students in problem-solving skills, and reduces the need for extensive teacher tutorial time. An advantage of CAGI to students is that it immediately acknowledges correct responses to the multiple-chioice questions. If the incorrect response is selected, CAGI indicates the correct response plus an explanation.

Used as a diagnostic tool, CAGI helps students and instructor identify problem areas and employ other strategies to facilitate learning before the student is tested on a major exam. If students are satisfied with their performance on a single trial for a specified block of subject matter, then they need not repeat CAGI in that area. CAGI use is superior for learning and grade improvement to students' studying old exams. Even with old exams, unless keys are provided, students have no feedback on incorrect answers. Furthermore, CAGI can expose students to more questions, thereby broadening understanding and application.

The CAGI exercises parallel the subject matter chapter-by-chapter in the text and formal lectures. Students identify difficult subject areas and determine the need for repetition. Most units in CAGI contain a series of questions from which 10 are randomly chosen by the computer for each session; students may choose to repeat exercises in a given subject block until they are satisfied and confident about their performance. In addition, CAGI stresses key concepts, and this helps students avoid spending a significant amount of time on areas of minimal importance. Since CAGI is intended to be a user-friendly program and most of our students are familiar with computer technology, CAGI provides a comfortable learning experience.

Table 1. Subject areas tested on exams in introductory genetics.

Exam	Subject area on exam	No. of CAGI questions	No of lectures
1	Mitosis, meiosis, Mendalian inheritance, linkage	97	9
2	DNA structure and replication, protein synthesis, chromosomal aberrations	113	7
3.	Mutation, bacterial and viral genetics, prokaryotic regulation	98	7
4	Eukaryotic regulation, population genetics	79	12

Student Selection for CAGI

In the 1992 spring semester, more than 100 students enrolled in Introductory Genetics. The class included 56% biological science, 37% agricultural science, and 7% science education majors. At random, half of the students from each of the major fields were assigned to participate in CAGI with the understanding that participation did not earn specific credit. In addition, no students were forbidden access to CAGI. All students were requested to turn in their printouts if they used CAGI.

Student Performance Reflects the Benefit of CAGI Use

Four exams (Table 1) provided an opportunity to evaluate the effect of CAGI on student performance in several subject areas of genetics. Students utilizing CAGI scored an average of between 6 and 10 points higher on hour exams than students in the same class who did not use CAGI (Table 2). Analysis of variance showed statistical differences between CAGI-users and nonusers on each exam. Final averages of students using CAGI for at least two exams were 8 percentage points higher than averages of students who did not use CAGI. This improvement suggests that these exercises reinforce and enhance their understanding of the material in each section of the course.

Final class grades were assigned based on hour exam grades (75%) and laboratory grades (25%). In evaluating final class grades, CAGI users were defined as students using CAGI for at least 2 of 4 hour exams. Since there was no finite reward or absolute requirement for using CAGI, 57% of the students initially assigned CAGI (half the class) were classified as *CAGI-users*. Only two students not initially assigned CAGI chose to use it. On this basis, 28% of the class are considered CAGI-users. Over 96% of CAGI users received a grade of B (88 per-

Table 2. Mean, range, standard deviation, and test of significance of exam scores of CAGI users and nonusers in introductory genetics.†

CAGI	No. of students	Mean	Range	SD	Mean difference
		Exam 1			
Yes	40	76.2	43-98	14.2	7.5*
No	71	68.7	24-98	16.6	
		Exam 2			
Yes	29	90.0	76-100	7.0	7.4**
No	82	82.6	47-100	11.1	
		Exam 3			
Yes	28	84.8	46-100	11.2	5.9*
No	83	78.9	39-100	14.1	
		Exam 4			
Yes	12	85.8	50-100	14.4	10.4**
No	99	75.3	34-98	12.7	
		Exam Avg.			
Yes	31	84.1	67-97	7.2	7.2**
No	80	75.9	41-97	11.0	

*,** Denotes significance at the 0.05 and 0.01 probability levels, respectively.
† CAGI-users defined as students using CAGI for at least two of four exams.

centage points) or better; 67% of the nonusers received B or better. Clearly CAGI use could be confounded with student motivation; however, student success realized through CAGI use may have been a motivating factor.

CAGI Use Benefits Weaker Students More than Strong Students

In previous semesters biological science majors generally performed better in this class than agricultural science majors. Analysis of exam scores by major (Table 3) suggests that performance of agricultural science students generally improved more than that of biological science students when using CAGI, with the exception of Exam 3. Due to the small number of science education students, meaningful conclusions regarding this group are not possible. Agricultural science CAGI-users improved average performance by a letter grade on Exams 1 and 4. A less dramatic but consistent improvement is evident in biological science students. This supports the position that CAGI helps overcome a weak background in genetics.

An optional exam covering material from Exams 1, 2, and 3 was offered at the end of the semester. The optional exam allowed students to improve their performance on the first three exams and their final course grade. Twenty percent of the CAGI users chose to take this exam; 52% of the non-CAGI users took it. This suggests that more CAGI users were satisfied with their performance during the course and did not feel a need to improve. That suggestion is supported by the high proportion of CAGI-users receiving grades of A and B. Therefore, an additional, though less tangible, reward of CAGI is increased student satisfaction with their performance as evidenced by student comments such as "It's like a private help session made fun. It's easier to learn in a fun atmosphere." An increased confidence is suggested by students who say "CAGI helped me learn test material and gave me good test practice," which should decrease anxiety during testing.

Table 3. Mean, range, and standard deviation of introductory genetics exam average of CAGI users and nonusers by major.†

CAGI	No. of students	Mean	Range	SD	Mean difference
		Agricultural science majors			
Yes	11	80.4	67.8-89.5	7.1	9.3
No	32	71.1	41.8-92.0	11.6	
		Biological science majors			
Yes	18	86.0	75.5-97.0	6.7	9.3
No	41	79.5	60.8-97.8	9.8	
		Science education majors			
Yes	2	86.9	81.3-92.5	7.9	10.4
No	7	76.5	66.0-81.5	5.4	

† CAGI-users defined as students using computer-assisted genetics instructor for at least two of four exams.

DISCUSSION

Many students find genetics to be a difficult subject, due to the quantity of material describing biological processes that must be mastered and to the higher-order problem-solving-analytical skills required. CAGI helps students focus on the important features of biological processes and diagnose misconceptions. It provides drills accompanied by immediate feedback in problem-solving exercises. CAGI and other computer-assisted software provide virtual individualized instruction when programs are carefully developed. The questions and explanations developed by the instructor are designed around known problem areas recognized by experience. Students who do not understand material presented in CAGI can be identified, and additional assistance from the instructor can be tailored to individual needs.

CAGI has been demonstrated to improve higher-order learning skills and has the potential to impact the overall educational experience of students majoring in all areas of the life sciences. Students using CAGI can expect to improve their grade by 8 percentage points, which is very close to one letter grade on a 100-point scale with letters assigned at 10-point increments. Computer-assisted instruction increases the proportion of students who master 80% of the subject matter, and the grade average of CAGI-users is much greater than the 40% maximum class average described by Kelly (1991).

Bailey (1990) studied the effects of computers and computers plus interactive video. Bailey (1990) concluded that computers combined with interactive video improved performance on a college-level math achievement test more than computers alone. Future plans include the use of visuals, diagrams, and nested areas within questions to enhance the interactive aspect while maintaining the emphasis and style of the course instructor.

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