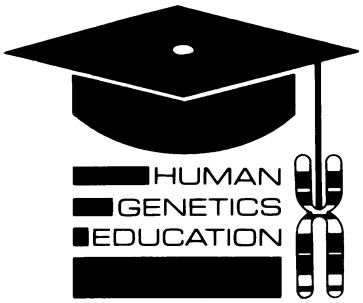
Am. J. Hum. Genet. 45:176–181, 1989

INNOVATIONS IN HUMAN GENETICS EDUCATION

The Design and Development of Computer-assisted Instruction for Integration into the Medical Genetics Curriculum



Terry Reed,* Susan Buriak,‡ Judy Z. Miller,*,† Nyla A. Heerema,* and Beverly E. Hill‡

Departments of *Medical Genetics and †Medicine and ‡the Medical Educational Resources Program, Indiana University School of Medicine, Indianapolis

Introduction

Childs (1982) and Riccardi and Schmickel (1988) have highlighted problems of course directors in teaching human genetics in medical schools. Two of these problems, which are beyond the control of course organizers, are the varied background of the students and the placement of the course in the same quarter as other classes with more contact hours (for instance, pharmacology and pathology for the medical students in Indianapolis). The latter are perceived by the students as more important, in part because of the sections on part I of the examination of the National Board of Medical Examiners.

At the Indiana University School of Medicine, these problems need to be dealt with in the context of what Davidson and Childs (1987) would classify as a variation of the "traditional" approach, i.e., a relatively rigid curriculum. In addition to teaching medical genetics to approximately 130–140 sophomores at the main campus of the medical school in Indianapolis, the Department of Medical Genetics also provides up to one-third of the instructional hours for the other half of the class, who receive their preclinical training at each of the satellite medical education centers in Bloomington, Evansville, Gary, Lafayette, Muncie, South Bend, and Terre Haute.

Received February 8, 1989; revision received March 7, 1989.

Address for correspondence: Dr. Terry Reed, Department of Medical Genetics, Indiana University School of Medicine, 702 Barnhill Drive, Indianapolis, IN 46202.

0002-9297/89/4501-0025$02.00

This article presents application of computer-assisted instruction as a tool to deal with these problems in our particular settings, but it may also have broad application to enhance the level of knowledge and understanding of course material in medical genetics elsewhere. Because the program is more likely to be utilized in conjunction with preparation for class examinations, the students have greater motivation to use it.

Computer-assisted Instruction

Computer-assisted instruction modules, or *courseware*, are special purpose software that can be designed for a variety of educational outcomes. Use of computer-assisted instruction involves the learner interactively with a computer that has a programmed study plan. These plans in the medical school setting generally fall into three main instructional categories—tutorials, drill and practice (question-bank programs), and clinical simulations. Use of computer-assisted instruction has been shown to increase learning and understanding of material (Tsai and Pohl 1978; Kulik et al. 1980; Bracy 1982; Dalton 1986), to increase instructional efficiency, i.e., time on task (Bitzer and Alpert 1970; Dence 1980), and to affect student motivation and attitudes in a positive fashion (Fisher 1983; Seymour et al. 1987).

Computer-assisted instruction was first offered as a resource to the faculty of the Indiana University School of Medicine in 1984 through the Medical Educational Resources Program. To establish this additional educational service, a position was established for an instructional designer specializing in computer-assisted instruction with financial support for computer programming

and computer graphic capability. All courseware packages are available for use at the Learning Resource Center on the medical center campus. The Medical Genetics Question Bank module, to be described, is designed to run on IBM machines or compatibles with a minimum of 256k RAM memory. A color monitor is required to accomodate the color graphics employed, and the program can be run from either a fixed disk or a two-floppy-disk drive system. The program is written in version 4.0 of PILOT authoring language. Statistical packages were written in Turbo Pascal version 3.1, and graphics include a combination of HALO graphics, PC Paintbrush, and PC Storyboard.

Medical Genetics Question Bank

Previously, the medical genetics course director supplied copies of past years' tests on reserve at the library, so that potentially each medical student had the same opportunity to examine old exams at an accessible location. Among the disadvantages of this approach were that students received answers to the questions without any explanation as to why the correct choice was correct and that there was no indication of questions later discarded because of ambiguity or syntax problems. Thus, a question bank using computer-assisted instruction based on the better questions from past examinations was developed. Questions were selected based on student performance criteria and were divided into the following eight topic sections: (1) Mendelian genetics, (2) population genetics, (3) molecular genetics/DNA, (4) cytogenetics, (5) quantitative genetics, (6) birth defects, (7) metabolic defects, and (8) clinical genetics and other related topics, such as ethics.

The initial question bank consisted of under 80 items and was offered to the fall 1987 class in Indianapolis on an interim basis. Prior to their midterm and final examinations, the students answered 5,561 questions in 616 individual sessions. Table 1 shows the results of voluntary evaluations completed by 52 students (approximately 40% of the class) from the pilot study. The 15 items were ranked on a scale from 1 (strongly favorable) to 5 (strongly disfavorable) and included the following three areas: content, presentation and design, and overall attitude (like/dislike). The three items with the least favorable rating (higher means) all related to an insufficient number of questions. With approximately 10 questions per topic in the pilot courseware, it was not unusual for a student to exhaust the questions in that area. As a result of the pilot study, we expanded the question bank to its current size of 178 questions covering a 4-year period of examinations.

Table 1

Average Evaluation Ratings, Fall 1987 Class (52 responses)

Item	Mean
Lesson well suited for computer	1.63
Program facilitates comprehension	1.79
Prompts are clear	1.83
Program motivates me	1.87
Graphic art enhances learning	1.87
Directions are clear	1.92
Screens are interesting	1.96
Program forgives input errors	1.98
Lesson is esthetically pleasing	2.02
Content is relevant	2.02
Content is accurate	2.04
Objectives are clearly stated	2.42
Length of program is appropriate	2.46
Content is sufficient to meet goals	2.63
Units are appropriate length	2.63

Program Modes

Questions are in simple or complex multiple-choice formats or in complex true/false formats designed to reflect the style later encountered on the medical board exams. Samples are presented in figures 1 and 2. The latter demonstrates the enhancements of the screen with the use of color graphics, symbols, and text highlighting for emphasis and retention. The program operation includes two modes. In the quiz mode, the student

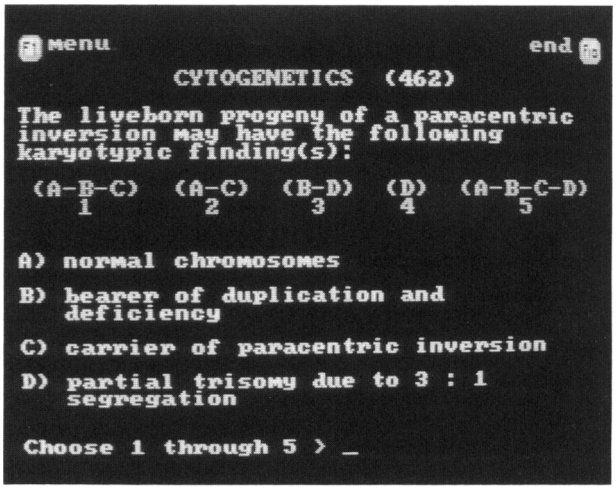


Figure 1 Sample question from the cytogenetics section. This screen is from the program in the quiz mode.

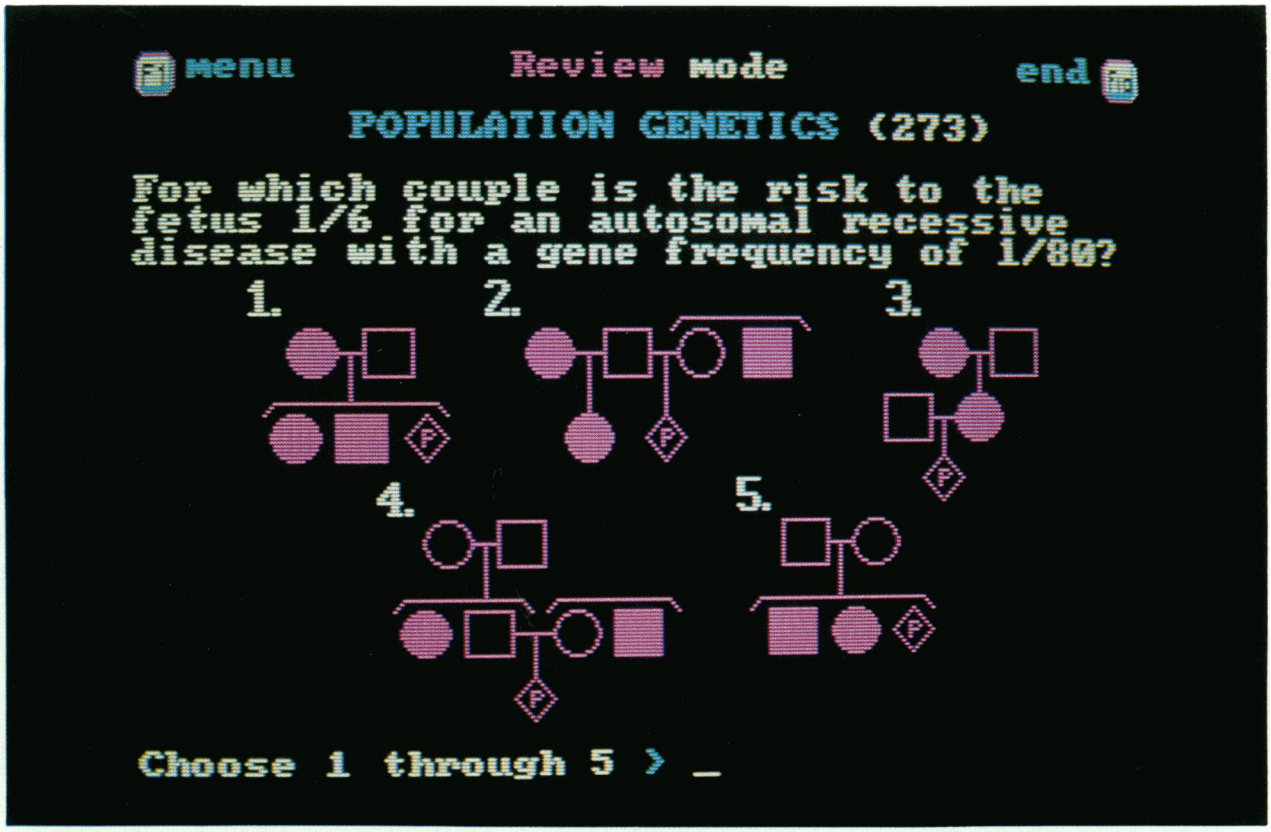


Figure 2 Sample question from the population genetics section in the review mode of the program. In pedigree problems, the students are instructed to assume that all other family members are phenotypically normal, unless otherwise indicated.

can cycle through the questions in a time-efficient manner. After answering a question, the student is informed whether his or her response was correct. After three incorrect trials, the student is shown which choice was the best correct answer.

In the review mode, there is a feedback screen tailored for each response to each question. Sample feedback scree are given in figures 3 and 4. Figure 3 represents the corresponding correct response screen to the question in figure 1. Cues are imbedded in the feedback screens of incorrect choices to guide the student toward the correct response. As with the quiz mode, the student is allowed three attempts to answer the question. Where possible, feedback screens reinforce concepts presented in class or provide additional information which may not have been directly covered in lectures but is present in the textbook. Both quiz and review modes inform the user as to how many minutes were taken to answer each question. In either mode, the student may select, as an option, presentation of questions randomly from the different topic sections.

Statistical Package

Tied to the instructional modules is an assessment package, or *statpak*, which performs several important functions. It is the computer-managed component of the program, serving both the development team and the user through the collection and analysis of data. For the student exiting the program, the statpak displays a summary of the number of questions answered and the percentage of correct (on first-attempt) responses with the accumulated time on task for the session. For the instructor, the statpak provides the frequency distribution of responses answered by the students for each question. For the designer, an item analysis report allows for assessment of question discrimination (too easy or too difficult) or for identification of nonfunctioning individual distractors (i.e., rarely

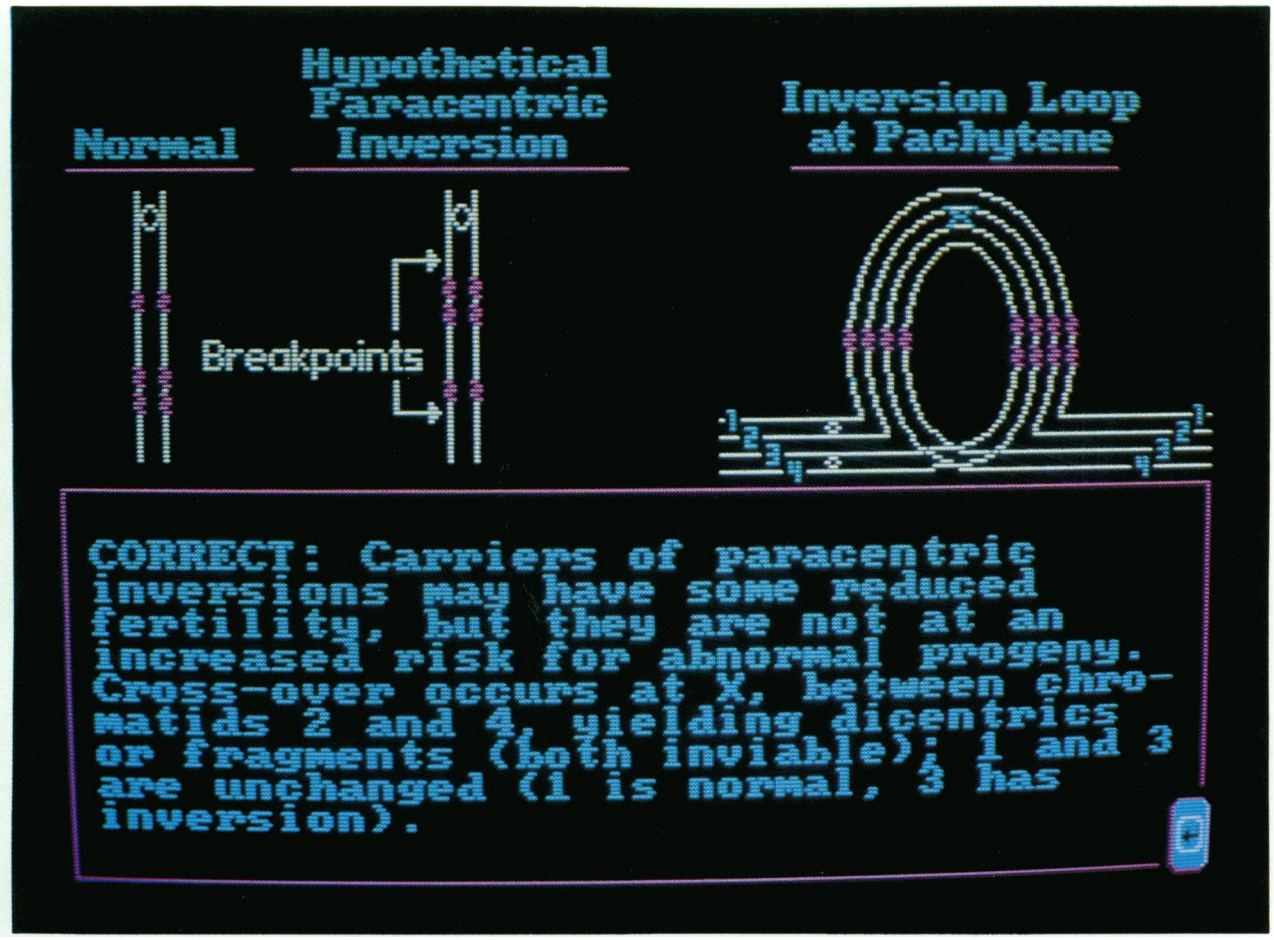


Figure 3 Feedback screen for the correct answer from the question in fig. 1 if the question is asked in the review mode.

chosen incorrect responses). We have carefully reviewed questions and individual choices from the pilot study. The questions creating the most difficulty were those which fused more than one concept; the questions that were least difficult included material judged as important but that we expect the majority of the students to know from having already been exposed to the basic concept in previous courses. For example, eukaryotic gene organization is now routinely covered in freshman biochemistry. Breakdown of individual choices revealed some items that were subsequently modified when the pool of questions was expanded to its current length. Such changes included incorrect choices that were rarely selected by the students or rephrasing to avoid potential confusion with the correct answer.

In the current version of the question bank, factor analysis was utilized to reduce from 15 to 10 the number of items in the on-line attitude questionnaire. Information from the questionnaire is invaluable for locating operational difficulties and correcting them, for locating conceptual misunderstandings related to phrasing of questions, and for determining overall opinion toward computer-assisted learning. The fall 1988 class in Indianapolis answered 15,499 questions in 821 individual sessions. This represented a doubling of the average number of questions answered per session compared with the class in the pilot study. Analysis of the mean rankings from 74 students (54% of the class) reinforced the favorable impressions of the program that were expressed by the students. The effect of the increased number of questions was best reflected in an improvement in the average rating, from 2.63 (table 1) to 2.27, regarding whether the lesson units were the appropriate length. The remainder of evaluation items

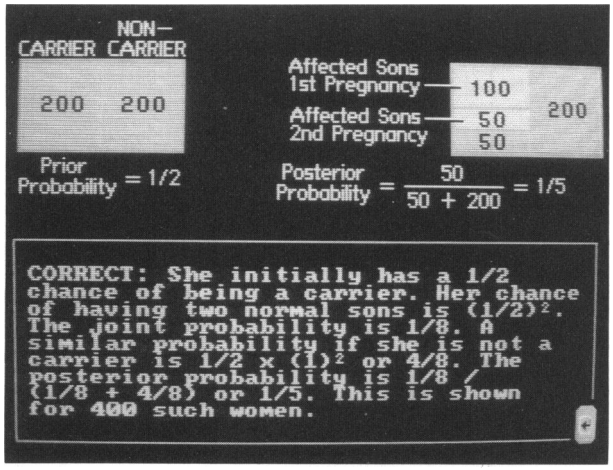


Figure 4 Sample feedback screen from the review mode for the correct answer to a question utilizing Bayesian principles. The question concerns a women whose mother is definitely a carrier for an X-linked recessive disorder. The woman has already had two normal sons; and the students are to determine the probability that she actually carries her mother's abnormal gene.

that were comparable from both the 1987 and 1988 classes had mean averages similar to those in table 1 or were ranked as slightly less favorable by the 1988 class. In addition to monitoring student reaction, the attitude questionnaire also aids in finding potential problems. During field testing, the students are encouraged to find typographical and systematic errors, and they also have the opportunity to give anonymous written comments. Both the questionnaire results and the "open" comments assisted in our revision of existing and prototype questions into the current version of the bank. At the end of each fall term the sophomore students are asked to evaluate all aspects of all of their first-trimester courses. In 1988, there was not a single negative comment about the computer-assisted instruction module in medical genetics.

Other Features

To make the question bank more useful as a teaching tool, particularly at the satellite centers with much smaller class sizes, we have added a provision to allow an instructor to bring to the screen any question desired. After a key code is entered, the program prompts the instructor to select a topic section and then asks for a question number from that section. In this way a problem can be directly incorporated into classroom presentations if that is desired. Alternatively, an instructor can provide the students with the key code in order to allow them to find and recall a question in the review mode if they had trouble with it in the quiz mode.

Summary and Comments

Student response to the Medical Genetics Question Bank has exceeded our expectations. The best testimony to its usefulness came from the students' comments, which include the following: "Thank you for this program. It has a rather sobering effect, to say the least. I know now what I must concentrate on," "I think I learned more from this program than any of the lectures this term. This program saved me in this course," and "I feel there should be more programs like this . . . in the medical sciences." Students with previous experience in genetics may be more likely to use the quiz mode; those who have either little prior experience or difficulty with the concepts can use the review mode to help in their assimilation of course content. We plan to periodically update the questions in the bank, replace those questions or indivdual choices which appear to no longer be useful from an annual examination of the statpak results, and replace outmoded questions.

An additional motivation for submitting our proposal to create the Medical Genetics Question Bank was to demonstrate to our other faculty the usefulness of a well-done computer-assisted module. Ultimately, we would like faculty responsible for presentation of basic areas of the course, such as transmission genetics, population genetics, and basic cytogenetic concepts, to create computer-assisted tutorials in their respective areas. These are topics where course content changes little from year to year. Such modules may alleviate some of the trips of our faculty to the satellite centers or allow the instructor to pursue more-advanced material during lecture time, and permit a student to review, if necessary, the basic concepts by using the computer. Another potential enhancement to the curriculum would be the development of simulations for commonly encountered evaluation and counseling problems in a clinical setting. An example might be a newborn with ambiguous genitalia. The simulation would take the student through the differential diagnoses depending on the tests ordered and their results, as well as through how the student would handle counseling of the parents during this process.

We want to emphasize the importance of the commitment of the Indiana University School of Medicine and the Medical Educational Resources Program in being able to provide the personnel and financial support

and also the time spent writing and editing the material to be computerized for the creation of our question bank. We haven't by any means solved the problems, highlighted by Childs (1982) and Riccardi and Schmickel (1988), in the teaching of genetics to medical students, but with our question bank we have succeeded in demonstrating to the students that we are exploring ways to improve their experiences in medical genetics. We enourage other educators in medical or human genetics to use or to develop their own computer-assisted instructional programs if there are both the opportunity and appropriate resources to do so. For more information about obtaining program diskettes and accompanying user manual for our Medical Genetics Question Bank, at an introductory rate of $250, contact Beverly E. Hill, Ed.D., Director, Medical Educational Resources Program, Indiana University School of Medicine, 1226 West Michigan Street, Indianapolis IN 46202, USA.

Acknowledgments

The authors wish to thank Charles Shrontz and Mitchell Curry for their work in programming and project updating, Carol Hubbard for computer graphic design, Carol Cutshall for typing and revision, Ron Hanson for photography, and Kathy Cox, manager, MERP publications, for editing and proofing.

References

Bitzer DL, Alpert D (1970) Advances in computer based education. Science 167:1582–1590

Bracy GW (1982) What the research shows. Electron Learning 2:51–54

Childs B (1982) Genetics in the medical curriculum. Am J Med Genet 13:319–324

Dalton DW (1986) The efficacy of computer-assisted video instruction on rule learning and attitudes. J Comput Instruction 13:122–125

Davidson RG, Childs B (1987) Prospectives in the teaching of human genetics. In: Harris H, Hirschhorn K (eds) Advances in human genetics, vol 16. Plenum, New York, pp 75–119.

Dence M (1980) Defining the role of C.A.I.: a review. Educ Technol 20:50–54

Fisher G (1983) When C.A.I. is effective: a summary of the research. Electron Learning 3:82–84

Kuklik J, Kuklik CL, Cohen P (1980) Effectiveness of computer-based college teaching: a meta-analysis of findings. Rev Educ Res 50:525–544

Riccardi VM, Schmickel RD (1988) Human genetics as a component of medical school curricula: a report to The American Society of Human Genetics. Am J Hum Genet 42: 639–643

Seymour S, Sullivan H, Story N, Mosley M (1987) Microcomputers and continuing motivation. Educ Commun Technol J 35:18–23

Tsai S, Pohl NF (1978) Student achievement in computer programming: lecture vs. computer-aided instruction. J Exp Educ 46:66–70