Computer-Aided Personalized System of Instruction for the Virtual Classroom

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Abstract: This paper describes a computer-aided personalized system of instruction (CAPSI) and its implementations with regard to both on-campus and off-campus teaching. Four years of experience with the method have prompted a natural evolution of the system from a single terminal to multiple terminals, with direct and remote links, and electronic mailing and messaging. Local area networks are being considered to extend the system even further to allow stand-alone implementations of CAPSI. In a broad sense, the method is conceptualized as a step toward the goal of involving the computer in the development of educational material and the evaluation of learning in a virtual classroom environment.

INTRODUCTION

In a classic paper, Keller (1968) launched a new approach to teaching at the post-secondary level called *Personalized System of Instruction (PSI).* Based on principles and procedures from the newly emergent field of the experimental analysis of behavior, founded by Keller's friend and colleague, B.F. Skinner (e.g., 1953 and 1954). the approach stressed: a) clear specification of the behavior to be modified; b) frequent and immediate reinforcement of the behavior; c) minimization of punishment: and d) self-pacing by the student. These principles had been incorporated earlier by Skinner (e.g., 1961), in his work on programmed instruction and teaching machines, in which students filled in critical words or phrases that were left blank in a short piece of text. However, Keller applied the principles to larger segments of behavior (See Keller &

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Sherman, 1982). Studies on PSI have shown it to be more effective in teaching specific material than other methods commonly used at the postsecondary level (Kulik, Kulik & Cohen, 1979; Sherman, 1982).

Comparisons between traditional and other techniques of teaching and learning, including PSI, are made in the volume compiled by Sherman, Ruskin, and Semb (1982). A review of modem approaches to a more significant use of machines in design is given by Ehrmann and Balestri (1987). Another example of the extensive use of computer communication systems, and particularly computerized conferencing, in the formation of human community is given by Hiltz and Turoff (1978). A serious attempt to develop an authoring system for the computer-mediated learning environment is represented by NATAL (1981). In a more recent approach, knowledge representation and knowledge engineering are applied to intelligent tutors by Woolf (1987).

The method described in this paper represents a fundamental extension of PSI in which the above modem approaches can be folly applied. The method provides a basis for modelling, parameter estimation, optimization, and the use of knowledge engineering to improve its value to both the teacher and the student. To demonstrate the usefulness of the method, we first describe the principles of PSI, followed by computerization of PSI for on-campus and off-campus education, and an analysis of data obtained using the new method.

PRINCIPLES AND PROCEDURES OF PSI

The major distinguishing characteristics of PSI are as follows:

Clear specification of the behavior. In PSI, the behavior to be learned is specified as answering questions about or solving problems relating to the course material. For each course, a list of study questions or study objectives on the material is drafted, such that a student who can answer a large percentage of the questions or meet a large percentage of the objectives can be said to have mastered the course material. In addition to being given the study questions or study objectives, the student is informed exactly how mastery of the course material will be assessed.

Frequent and immediate reinforcement of the behavior. The course material is broken down into units that are small enough to ensure frequent reinforcement in the form of feedback on unit tests. Immediate feedback on the tests is provided by the instructor, by teaching assistants, and by other students (termed “proctors”) who have mastered the material.

Minimization of punishment. The unit tests are designed to increase in difficulty gradually so as to minimize. the probability of failing a test, which is the most significant form of punishment in educational settings. In addition, the only penalty for not passing a test is that the student must restudy and attempt another test on that unit. Finally, the word “fail” is avoided since it produces conditioned emotional responses in many students.

Self-pacing by the student. For a variety of reasons, different people require different amounts of time to master a given subject matter. PSI takes account of this by

permitting individual students to progress through the course at their own rates within the deadline set by the academic institution for the submission of final grades.

COMPUTERIZATION OF PSI

CAPSI for On-Campus Learning

PSI lends itself well to computerization because it is a highly systematic procedure. Development of a program for computer-aided PSI (CAPSI) has been an ongoing project at the University of Manitoba since 1983. The program has been described in detail elsewhere (Pear & Kinsner, in press). A simplified diagram of the CAPS1 program is shown in Figure 1. The success of the program can be attributed to the finite-state modelling of all the transactions that take place during the course offered.

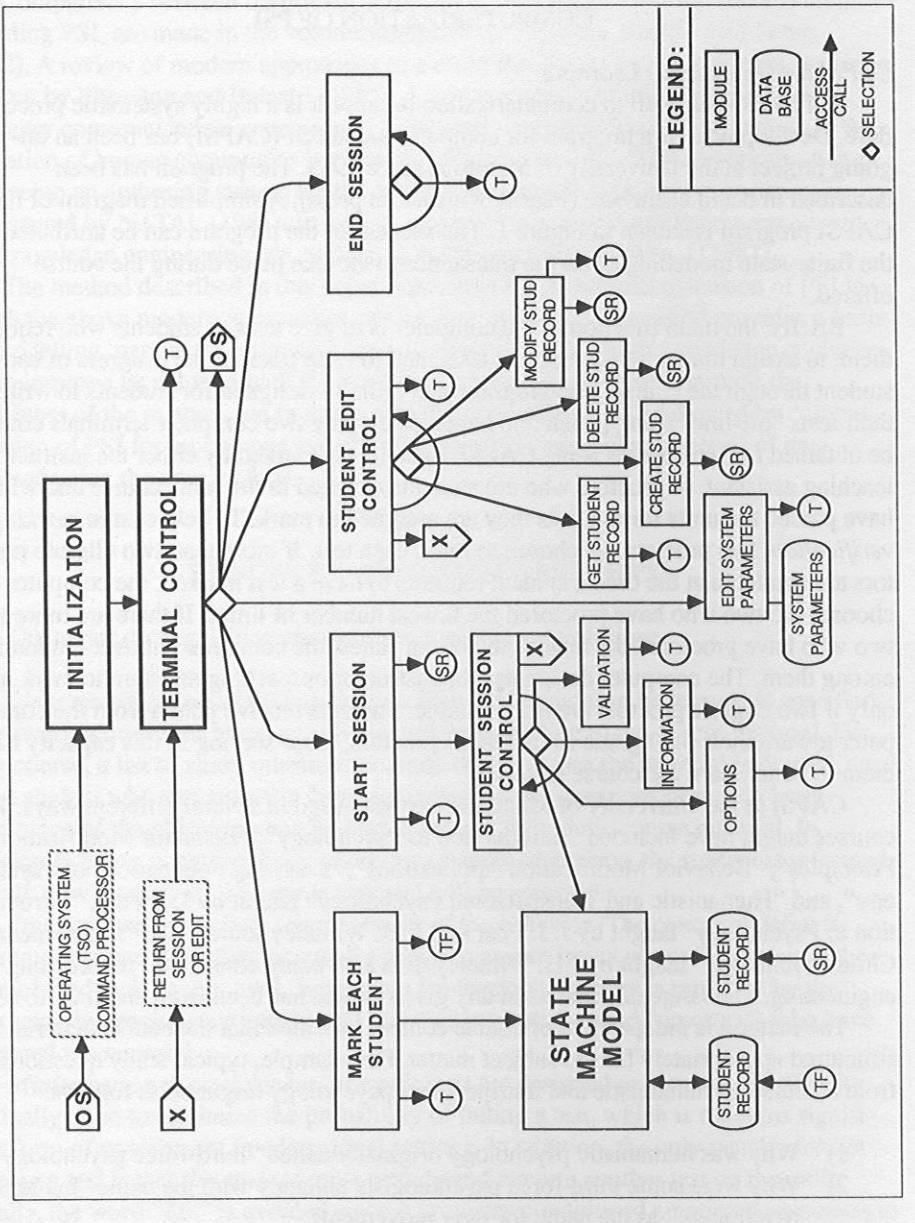
Briefly, the main function of the computer is to give tests to students who request them, to assign markers to completed tests, and to keep track of the progress of each student through the course. The program was initially designed for students to write their tests "off-line" using pencil and paper, since only two computer terminals could be obtained for the courses using CAPSI. Each test is marked by either the instructor, a teaching assistant, or proctors who are students enrolled in the same course and who have passed the units for the tests they are assigned to mark. To help ensure marking verification, two proctors are chosen to mark each test. If more than two eligible proctors are available at the time a student requests to have a test marked, the computer chooses the two who have proctored the fewest number of times. If there are more than two who have proctored the fewest number of times, the computer chooses randomly among them. The computer designates the instructor or teaching assistant to mark a test only if two eligible proctors are not available. Students receive points from the computer toward their final grade for acting as proctors, since serving in this capacity helps them to better learn the course material.

CAPS1 at the University of Manitoba has been used in several different ways. The courses taught have included "Introduction to Psychology", "Behavior Modification Principles", "Behavior Modification Applications", "Learning Foundations of Psychology", and "Humanistic and Transpersonal Psychology" taught by J. J. Pear, "Introduction to Psychology" taught by J. J. Pear and J. H. Whiteley jointly, and "Experimental Child Psychology" taught by J.H. Whiteley. It is also being considered for teaching in engineering. The range of students in any given course has been from about 20 to 65.

The method is independent of course content provided that the course material is structured appropriately for the subject matter. For example, typical study questions from a course on humanistic and transpersonal psychology might be as follows:

1) Why was humanistic psychology originally called "third-force psychology"?
2) Why were some third-force psychologists unhappy with the name "humanistic psychology" as the name for their movement?
3) According to Maslow, what are "peak experiences"? What can produce them? Describe a peak experience that you have had, including the circumstances under which it occurred.

FIGURE 1. Simplified Structure of CAPSI Program.



Typical study questions for a coarse on behavior modification might be:

1) Describe five distinguishing characteristics of behavior modification.
2) How does the behavioral approach to abnormal behavior differ from the medical model approach?
3) Describe two examples of positive reinforcement that you have encountered, one. involving a desirable behavior and one involving an undesirable behavior.

Other examples of behavior modification study questions can be found in the behavior modification text by Martin and Pear (1983) which was written specifically for a PSI approach, and which contains discussion relating to behavioral theory.

In the beginning, the CAPSI program could be run on only one terminal. This was a problem for courses having more than 50 students. There were long lineups of students to use the terminal in many classes, and students complained about the waiting time to obtain test questions and to have their tests marked. One solution to this problem was to add a second terminal, subdivide the class into two groups, and assign one group to each terminal. This had the disadvantage of preventing proctors who were available on one terminal from being assigned to mark tests given on the other terminal. Another solution that was tried was to assign each terminal to one of two different courses, and permit students to work on the terminal for their courses during the class period for either course. However, some students who could not come to both class periods felt that this gave an unfair advantage to students who could do so and who could, consequently, progress through the course more quickly and have more opportunities to improve their mark by proctoring.

In January, 1984, a multiuser form of the program was put into effect, so that students could access the program through either terminal. Lineups still occurred in large classes, especially near the end of the academic term, but the problem was greatly attenuated. In addition, a thiid terminal was introduced solely for the use of the instructor and teaching assistant. This permitted the instructor and teaching assistant to enter tests results immediately after the tests were marked, which reduced much of the congestion in large courses. Moreover, a command was provided for tbe instructor to print out tbe names of students who were writing tests at any given time. This was very useful for ensuing that students who were writing tests were in the section of the classroom that had been designated for that purpose, so that these students could be supervised more easily.

CAPSI for Off-Campus Learning

In addition to improving the implementation of the program in a classroom, the multiuser capability permitted a course taught by CAPSI to be offered in more than one location simultaneously. The obvious implications of this for off-campus teaching did not go unnoticed. Like most other major universities (e.g., Montgomerie, 1987), the University of Manitoba provides off-campus courses to people in communities distant from the university who, for various reasons, are unable to attend classes offered on the university campus. With budget cutbacks, paying travel expenses to instructors has become less feasible. A less expensive alternative is for an instructor to deliver lectures through voice (audio) teleconferencing equipment to students located in classrooms in

a number of communities simultaneously (Robertson, 1986). In addition to direct or deferred voice, teleconferencing may also be achieved by using "electronic blackboards" or computer conferencing.

In the fall of 1985, a full-year Introductory Psychology course using CAPS1 and voice teleconferencing was offered from Winnipeg to Thompson, Manitoba — a community over 800 km north of the University of Manitoba. About 20 students participated from a classroom in Thompson. The classroom contained two phone lines -one accessed audio-teleconferencing equipment, while the other accessed the university's mainframe computer running the CAPSI program. Thus, students were in voice contact with the instructor and in computer contact with the CAPSI program. Tests marked by the instructor were marked over the phone and the results entered through the instructors's terminal in Winnipeg; tests assigned to proctors were marked in Thompson and entered through the computer terminal there. In addition, a teaching assistant was available in Thompson to supervise students and to mark some of the tests designated to be marked by the instructor or teaching assistant.

Due to the success of this course, another off-campus CAPS1 course — "Behavior Modification Principles" — was offered during the May-June intersession of 1985. This time the course was taught from Winnipeg to two locations — Thompson and Flin Flon, Manitoba. About eighteen students were enrolled in Thompson, and about 6 in Flin Flon. The procedure was essentially the same that had been used in the previous long-distance CAPS1 course, except that proctors marked tests over the phone when those tests were written by students at the other location. A side benefit of this procedure was that the instructor was able to listen in on the marking interchanges, and to make suggestions or corrections when it was helpful to do so. One of the students in the course supervised test writing in Flin Flon and, as in the previous long-distance CAPS1 course, a teaching assistant performed this function in Thompson.

During the 1986-87 academic year, two half-year off-campus courses using CAPS1 — "Behavior Modification Principles" and its sequel, "Behavior Modification Applications" — were offered in six Manitoba locations: Morden, Lac du Bonnet, St. Boniface, Stonewall, Virden, and Thompson. Because supervisors were not available at most sites to monitor students taking unit tests, more weight was placed on the midterm and final examinations than had been the case in previous CAPS1 courses. About 60 students registered for the first term course. Unfortunately, the necessary computer equipment was not present in the six sites at the time that the first-term course began. This led to a goal deal of confusion, and about 16 students dropped the course very early. Within a month, however, computer equipment was set up at all locations and 35 of the original 44 students who started the course completed it successfully. It was, however, necessary to schedule a number of extra classes to help students catch up to where they probably would have been had the computer equipment been available at the beginning of the term.

Inclusion of Electronic Mailing and Messaging into CAPSZ

At the beginning of the 1986-87 second-term off-campus course, students who had access to computers and modems (e.g., teachers who could use computer equipment

located in their schools) were given the option to access the CAPS1 program on their own outside of the regularly scheduled class periods, and to use the electronic mailing system of the University of Manitoba's mainframe computer to mail their test answers to the instructor for marking. About ten of the 30 students in the course took advantage of this opportunity on a regular basis. The instructor marked and provided feedback within 24 hours on each test received through electronic mail. The electronic mailing system also proved useful for other communications regarding the course.

Generalization of CAPSI to the Virtual Classroom

During the 1986.87 academic term, CAPS1 was also used again to teach on-campus courses. In order to alleviate the congestion that tended to occur with the early system in large classes, extra classes were added and were managed by teaching assistants.

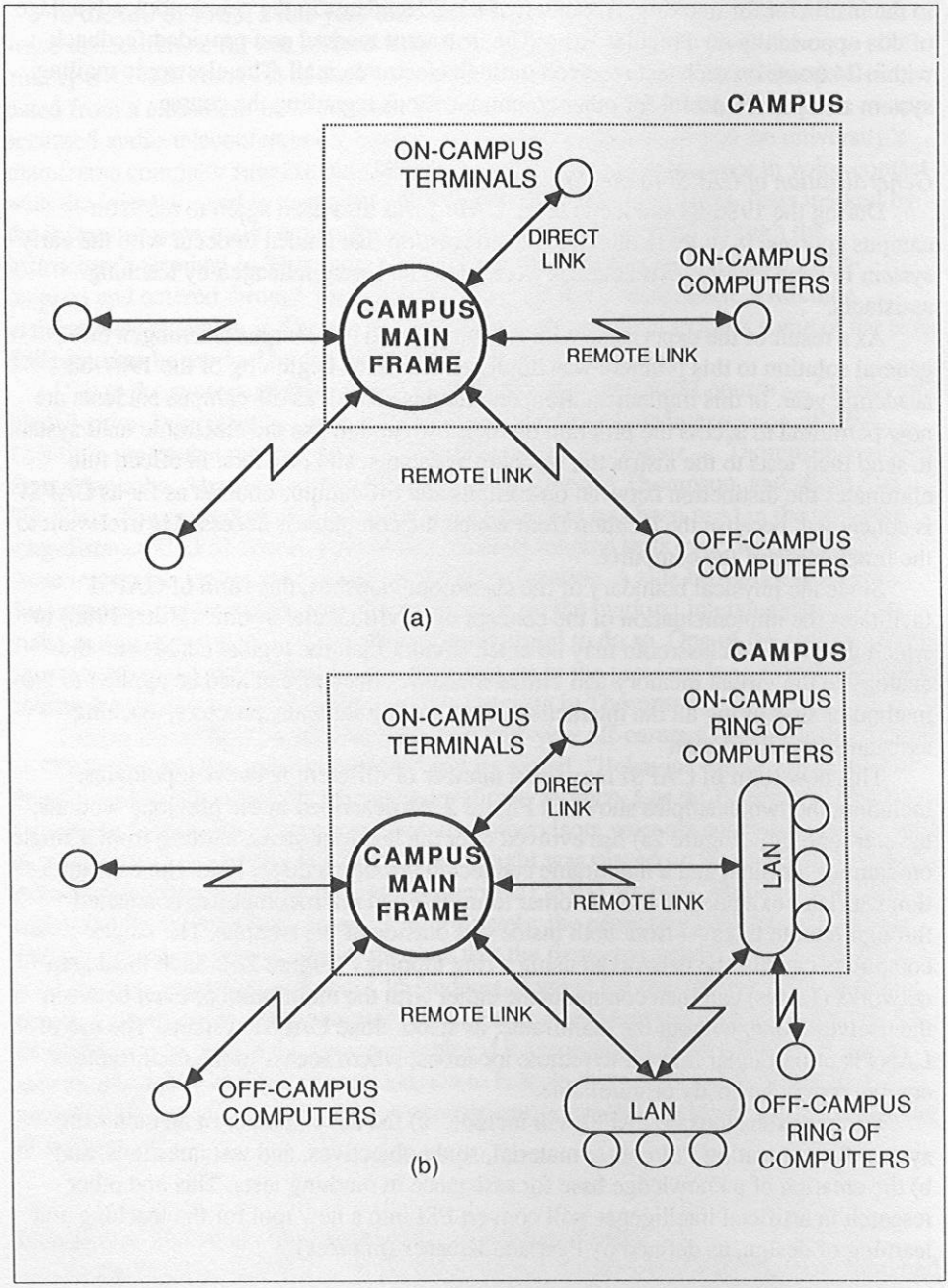
As a result of the experience with on-campus and off-campus teaching, a more general solution to this problem was implemented at the beginning of the 1987-88 academic year. In this implementation, on-campus as well as off-campus students are now permitted to access the program on their own and to use the electronic mail system to send their tests to the instructor, teaching assistants, and proctors. In effect, this eliminates the distinction between on-campus and off-campus courses as far as CAPS1 is concerned, because the location from which the computer is accessed is irrelevant to the functioning of the computer.

Since the physical boundary of the classroom vanishes, this form of CAPS1 facilitates the implementation of the concept of a "virtual classroom" (Hiltz, 1986) in which the physical classroom may be much smaller than the logical classroom. the analogy to the virtual memory and virtual machine concepts can also be applied to the method of structuring all the interactions between the students, proctors, teaching assistants, and instructor.

This new form of CAPS1 may use a number of different network topologies, including the two examples shown in Figure 2. As described in the previous sections, the star topology (Figure 2a) has evolved over the last four years, starting from a single on-campus terminal and a mainframe connected through a direct link. The configuration was later extended to include other terminals and microcomputers connected through remote links-from both inside and outside of the campus. The single computers can also be networked using a ring topology (Figure 2b). Such local area networks (LANs) can then communicate either with the mainframe or even between themselves alone, without the mainframe, as stand-alone CAPS1 systems. The use of LANs is of particular interest to remote locations, where access to the mainframe computer may be costly or unreliable.

Further extensions of CAPS1 will include: a) the development of an authoring system for generating PSI course material, study objectives, and test questions, and b) the creation of a knowledge base for assistance in marking tests. 'Ibis and other research in artificial intelligence will convert PSI into a new tool for the teaching and learning of design, as defined by Pear and Kinsner (in press).

FIGURE 2. *Two Network Typologies for CAPSI: a) Star Typology; and b) Star-ring Typology.*



STUDENT REACTIONS TO CAPSI

Most students who complete CAPS1 courses have evaluated them to be as good as or better than courses using other methods. Many students are enthusiastic about the method, and feel that they learn better with this method than with the lecture method. Aspects of the course that students often rate as major strengths are the self-pacing and the opportunity to be a proctor. Students also like the fact that the material they are expected to learn is clearly specified by the study questions, that there are no "trick questions", and that it is possible to get a good grade if one learns tbe material. Aspects of the method that are often rated negatively are the absence of lectures or discussions, and the opportunities for cheating that are present in large courses with few supervisors. Technical difficulties regarding shortage of equipment have also been a source of complaint.

We find the positive evaluations by the students to be very encouraging and anticipate that the above negative aspects of CAPS1 will be reduced or eliminated by the present use of electronic mailing. The incorporation of the electronic mailing system by CAPS1 should put students into closer contact with the instructor the teaching assistants, and other students, and thus pmvide the kinds of interchanges students expect to obtain from classroom lectures and discussions. Moreover, since students are now able to access the program at any time, class periods can be used for lectures and discussions for the purposes of supplementing the learning process rather than being viewed as the main method of teaching. Of course, since unit tests are unsupervised, the opportunity for cheating is increased. The solution to this potential problem is to give a low weight to unit tests and more weight to the midterm and final examinations in determining the final mark. Students are encouraged to understand that CAPSI is being used primarily for teaching rather than evaluation, and that students who do not follow the procedure properly will be unlikely to do well on the midterm and final examinations. Finally, permitting students to access tbe program at any time solves the above-mentioned problem of shortage of equipment in the classroom. Today, any campus has many computer terminals from which students can access the mainframe computer. Off-campus students also should have little problem obtaining access to computer terminals and modems. For example, such equipment exists in all school divisions in Manitoba, many of which appear to be willing to make it available for courses offered to members of their communities.

DISCUSSION OF DATA

An important feature of the CAPS1 program is that it saves data describing the interactions that occur during the entire course, including: all marking transactions, the type and result of each transaction, and the date and time of the transaction. These data can later be accessed and analyzed in any desired manner. Several examples are presented here of how these data can be used to provide information about the progress of students in the course and information about the functioning of the course itself.

Student Performance

Figures 3a, 3b and 3c show the performance of typical students A, B, and C,

FIGURE 3a. *Examples of Test and Proctoring Scores (solid line: test score; dotted line: proctoring score). Student A. Total Test Score = 13; Total Proctoring Score = 4.75.*

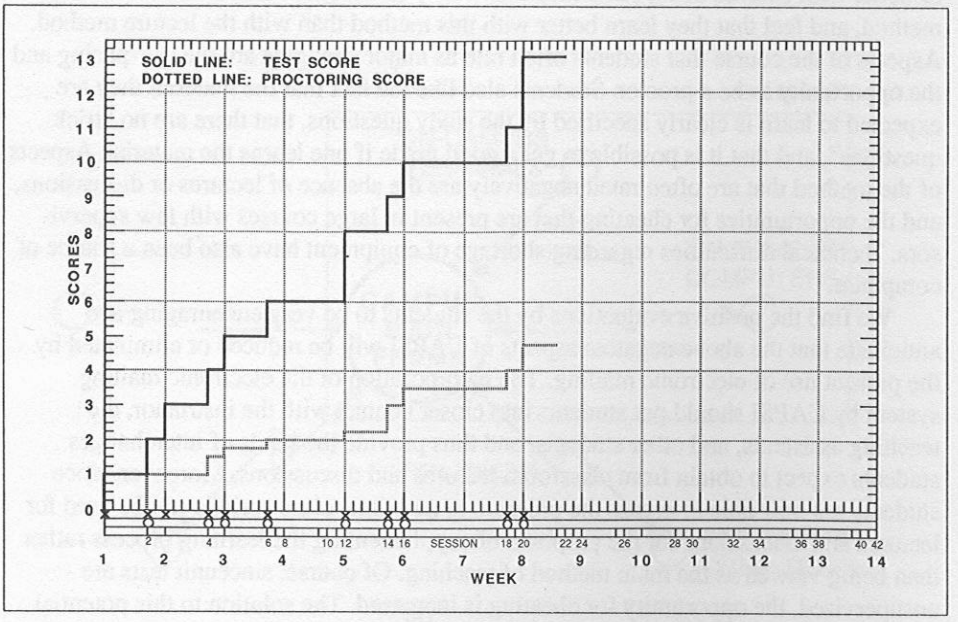


FIGURE 3b. *Examples of Test and Proctoring Scores (solid line: test score; dotted line: proctoring score). Student B. Total Test Score = 13; Total Proctoring Score = 6.75.*

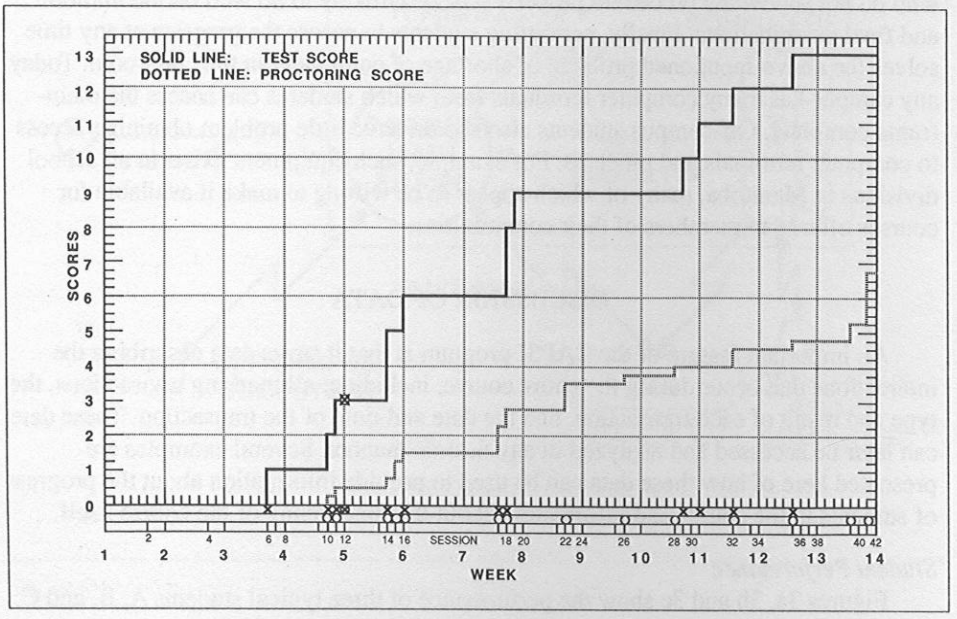
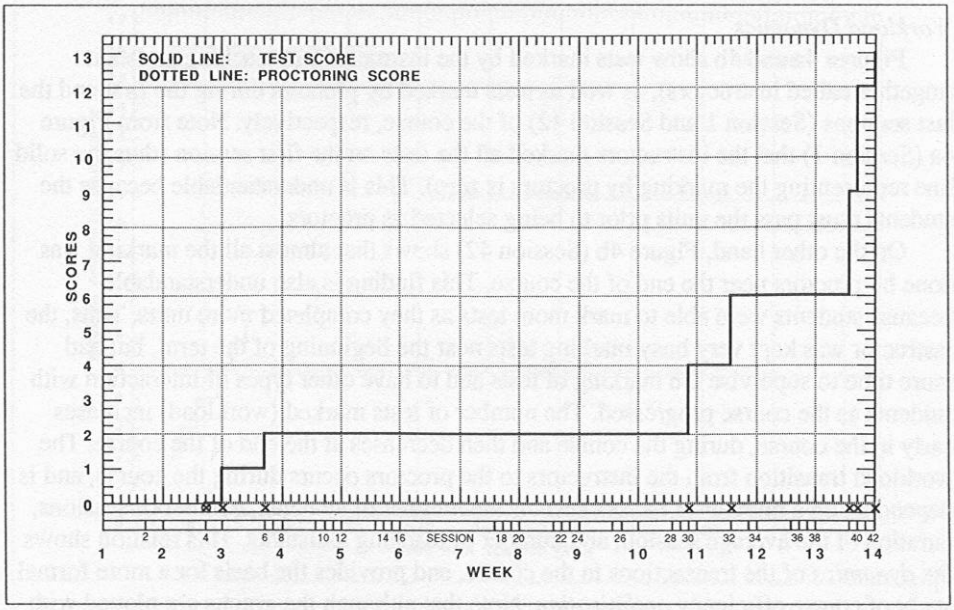


FIGURE 3c. *Examples of Test and Proctoring Scores (solid line: test score; dotted line: proctoring score). Student C. Total Test Score = 13; Total Proctoring Score =0.00.*



respectively, in a second-term on-campus "Behavior Modification Applications" course (Course 1) from the beginning of the course on 8 January 1987 to its closing date of 9 April 1987. Test scores on units completed and proctor scores are plotted against the time of the course. The course had a total of 13 units, and 0.25 point was received by a proctor for each test marked. In the three rows under each graph, successful test attempts are indicated by crosses, while each unsuccessful test attempt by a cross in a circle; proctoring interactions are indicated by circles; and dates on which class sessions were held are indicated by the vertical ticks. Session numbers are also place under the graph.

Note from Figure 3a that Student A started the course during Session 1 (8 January), passed units at a high rate, and completed the units during Session 20 (26 February), before the middle of the course. As shown in Figure 3b, Student B started three weeks later, progressed through the course at a slower pace, and completed the units during Session 41 (8 April). Despite progressing through the units at a lower rate, Student B earned more proctor points as a result of serving as a proctor over a larger number of sessions (6.75 against 4.75 of Student A), while Student A probably stopped attending class after completing the units, and therefore did not serve as a proctor after that date. Also note that Student B unsuccessfully attempted a test during Session 12. As shown in Figure 3c, Student C started two weeks later, completed the first few units fairly early in the term, and then did no further work until about three weeks before the end of the term. This student then passed unit tests at a very high rate and managed to complete all the units by the last day of class. However, the student did not earn any

proctor points in the course, which was probably due in part to insufficient time to mark tests during the last three weeks. Also note that Student C unsuccessfully attempted a test during Session 4.

Workload Dynamics

Figures 4a and 4b show tests marked by the instructor and teaching assistant (together called instructors), as well as tests marked by proctors during the first and the last sessions (Session 1 and Session 42) of the course, respectively. Note from Figure 4a (Session 1) that the instructors marked all the tests on the first session (thus the solid line representing the marking by proctors is zero). This is understandable because the students must pass the units prior to being selected as proctors.

On the other hand, Figure 4b (Session 42) shows that almost all the marking was done by proctors near the end of the course. This finding is also understandable because students were able to mark more tests as they completed more units. Thus, the instructor was kept very busy marking tests near the beginning of the term, but had more time to supervise the marking of tests and to have other types of interaction with students as the course progressed. The number of tests marked (workload) increases early in the course, during the course and then decreases at the end of the course. The workload transition from the instructors to the proctors occurs during the course, and is dependent on a number of factors such as the number of students, number of sessions, duration of the average session, and number of teaching assistants. This relation shows the *dynamics* of the transactions in the course, and provides the basis for a more formal study of course efficiency *optimization.* Note that although the graphs are plotted with resolution of one minute, CAPS1 time is recorded to a second.

Analysis of Student Evaluation Process

For two different courses (Behavior Modification Applications [Course 1] and Humanistic and Transpersonal Psychology [Course 21). Figures 5a and 5b present the following data: a) the number and percentage of times students cancelled their tests, b) the number and percentages of passes, c) conditional passes (where students are permitted to correct a minor error), and d) restudy — all issued by the instructor or teaching assistant (left bars) and by proctors (right bars).

One point that is clear from these data for both courses is that considerably more tests were marked by students than by the instructor or teaching assistant, while proportionately fewer restudy results were given by proctors than were given by the instructors. This could be taken to indicate that the instructor and teaching assistant marked more strictly than did proctors; however, this conclusion may not be warranted because it does not take into account the fact that the instructor and teaching assistant did more marking early in the course, before. students had adjusted to the stringent requirements of the course. It is also interesting to note that students cancelled tests more times than they were given restudy results by all markers combined. This indicates that students realized when they had not performed adequately on a test and did not submit it for marking when a restudy result was likely to be the outcome.

With the modified CAPS1 in which students are permitted to access the program whenever they wish and to send the test answers by electronic mail, another type of

FIGURE 4a. *Examples of Tests Marked by Proctors (solid line) and Instructors (dotted line). Session 1. (Note: No test was marked by proctors.)*

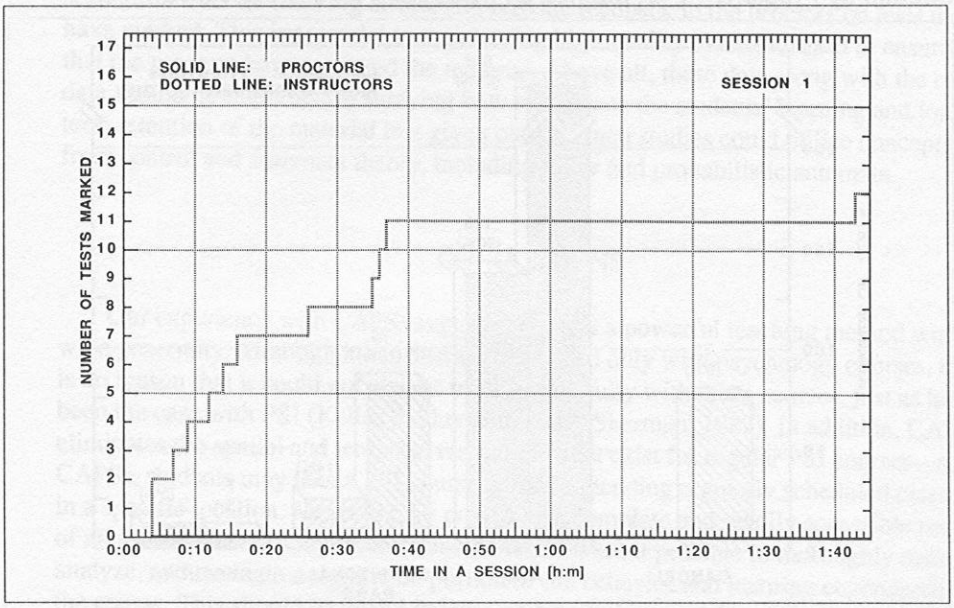


FIGURE 4b. *Examples of Tests Marked by Proctors (solid line) and Instructors (dotted line). Session 42. (Note: Only one test was marked by instructors.)*

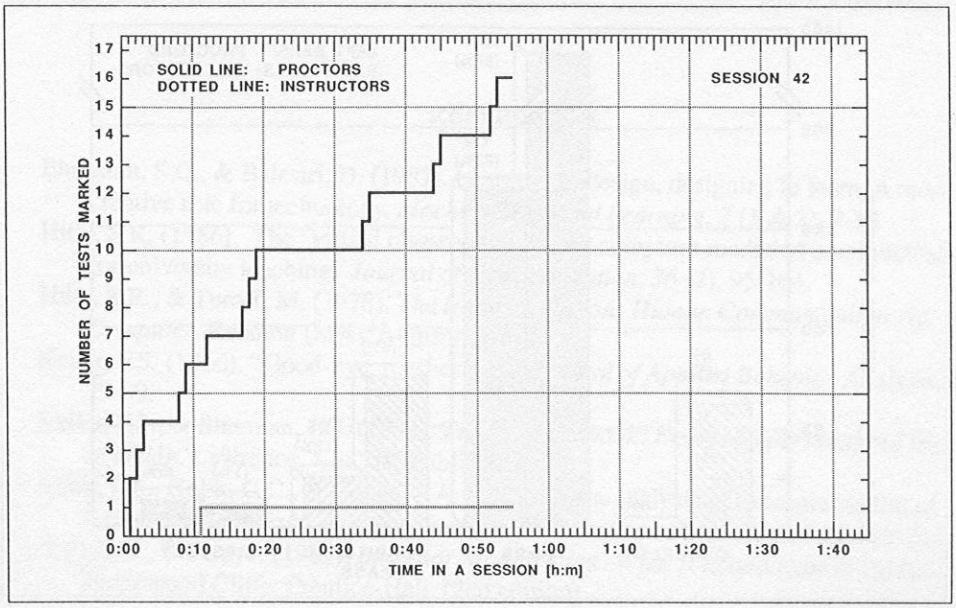


FIGURE 5a. *Marking of Tests (Left Bars: Proctors; Right Bars: Instructors and Teaching Assistants). Course 1. Total Number of Tests Attempted = 990; Marked by Proctors = 749; Marked by Instructors = 169; Cancelled = 72.*

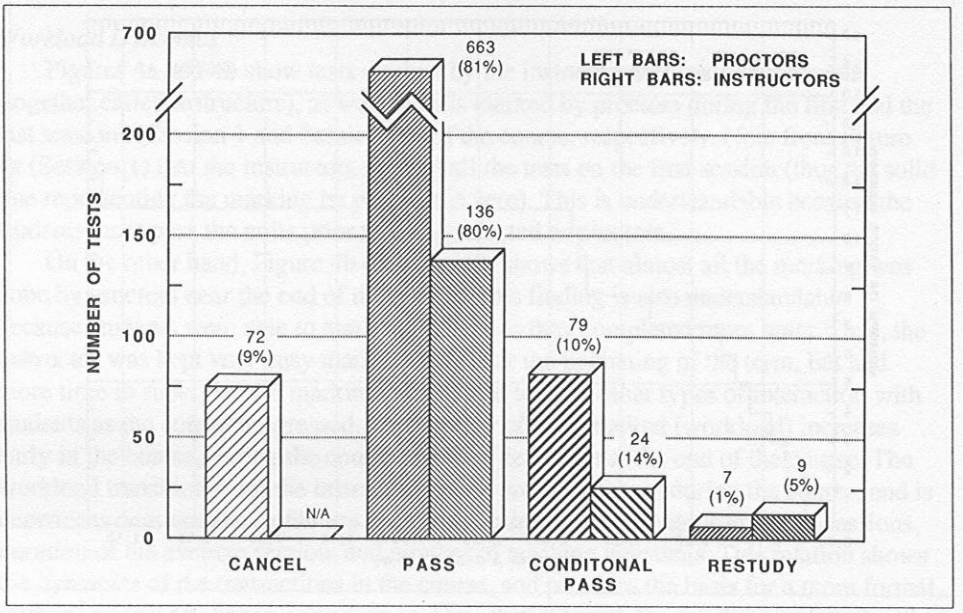
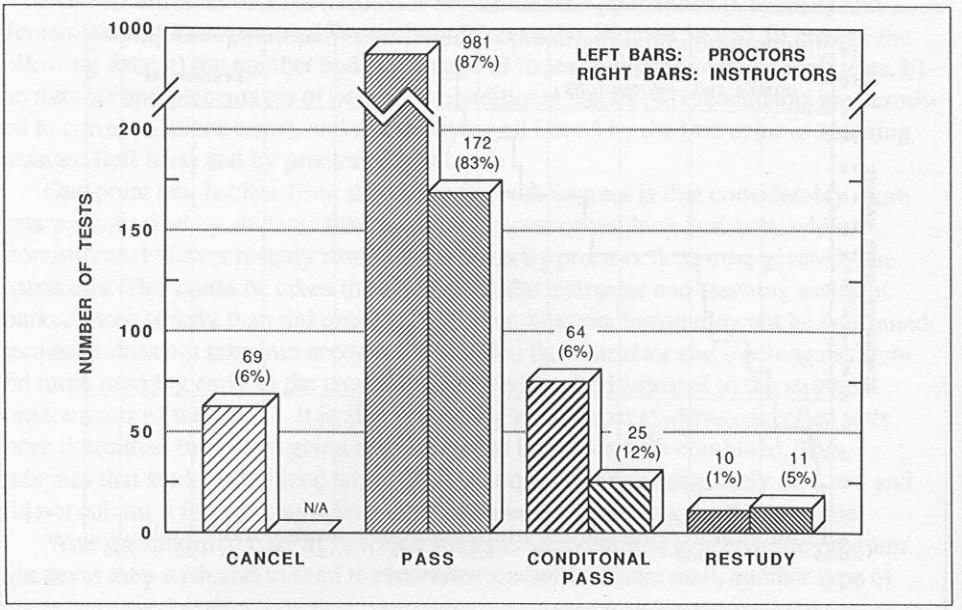


FIGURE 5b. *Marking of Tests (Left Bars: Proctors; Right Bars: Instructors and Teaching Assistants). Course 2. Total Number of Tests Attempted = 1332; Marked by Proctors = 1118; Marked by Instructors = 208; Cancelled = 69.*



data is being collected. All tests and the feedback given to students by the proctors are stored in a dataset that the instructor can access. The instructor can thus periodically scan these tests for marking errors, and provide feedback to the proctors on tests they have marked. This is essential in maintaining high-quality evaluation and in ensuring that the proctors have mastered the material. Above all, these data along with the other data should be important in studying how to enhance the students' learning and long-term retention of the material in a given course. Such studies could utilize concepts from control and automata theory, including fuzzy and probabilistic automata.

CONCLUSIONS

Our experience with CAPSI suggests that it is a powerful teaching method with wide generality. Although it has thus far been used only with psychology courses, there is no reason that it could not also be used successfully with other courses, just as has been the case with PSI (Keller & Sherman, 1982; Sherman, 1982). In addition, CAPSI eliminates the spatial and temporal restrictions that exist for regular PSI courses-with CAPSI, students may take a PSI course without attending regularly scheduled classes in a specific location. Moreover, by providing a complete and readily accessible record of all testing and marking interactions, CAPSI makes it possible to thoroughly monitor, analyze, and evaluate a significant portion of the behavior and learning engendered in the course. This should be useful in learning how to improve the educational process, including the instructional presentation and upgrading of the objectives. Finally, CAPSI opens a door leading to the next stage of computer-aided instruction, in which the computer will become more intimately involved in the educational process by aiding in the development of course materials and in the evaluation of the student's learning.

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