THE USES OF PLATO: A COMPUTER CONTROLLED TEACHING SYSTEM*

Donald L. Bitzer, Elisabeth R. Lyman, and John A. Easley, Jr.

The use of a high-speed digital computer as a central control element provides great flexibility in an automatic teaching system. Using a computer-based system like PLATO permits versatility in teaching logics, since changing the type of teacher merely requires changing the computer program but not the hardware. In addition, having access to the decision-making capacity of a large computer located as one unit permits complicated decisions to be made for each student. Such capacity would be prohibitively expensive to provide by means of decision-making equipment located at each student station. Studies of queuing that occurs with multiple student requests show that the system could teach as many as a thousand students simultaneously without incurring a noticeable delay in processing any student's request.

The educational results thus far have been extremely encouraging. However, reliable conclusions on educational achievement must await the results of more thorough experiments now in progress which

---

*This project was supported in part by the Joint Services Electronics Programs (U. S. Army, U. S. Navy, and U. S. Air Force) under Contract No. DA 28 043 AMC 00073(E) and by the Advanced Research Projects Agency through the Office of Naval Research under Contract No. Nonr-3985(08). Portions of the material in this report have appeared in Computer Augmentation of Human Reasoning. (Symposium). Washington, D. C., Spartan Books, Inc. 1965. Chapter 6, pp. 89-103.

Reprinted with permission from January 1966 Issue of Audio-Visual Instruction.

Donald L. Bitzer is Research Associate Professor and Elisabeth R. Lyman is Research Assistant Professor in the Coordinated Science Laboratory, University of Illinois, Urbana; John A. Easley, Jr. is Associate Professor of Education, University of Illinois, Urbana.

include larger numbers of students learning under a variety of conditions. The adaptability and usability of the system for a variety of purposes in education (including the behavioral and physical sciences) have been clearly demonstrated.

Introduction

During the past five years, the Coordinated Science Laboratory at the University of Illinois has developed and experimented with an automatic teaching system called PLATO in order to explore the possibilities of automation in individual instruction. The PLATO system utilizes a high-speed digital computer as the central control element for teaching a number of students simultaneously, while still allowing each student to proceed independently through the lesson material.

Three successive models of PLATO have evolved, each embodying improvements indicated by the previous model. The first consisted of a single student station connected to ILLIAC, a medium-speed computer built at the University of Illinois.[4] The second model had two student stations, was connected first to ILLIAC and then to a CDC 1604 computer, and was used to study the problems created by multiple student use of the system.[10] The third and current model has 20 student stations connected to the CDC 1604 computer.

The rules governing the teaching process are included in the program read into the central computer. A complete set of rules is referred to as a "teaching logic." The Coordinated Science Laboratory has experimented with two basically different types of teaching logics, a "tutorial" logic and an "inquiry" logic. A tutorial logic is designed to lead the student through a fixed sequence of topics, but it also provides branching between problems (which is under the student's control, voluntary or involuntary). In a lesson that uses the tutorial teaching logic, the system first presents facts and examples and then asks questions covering the material presented. The student composes answers, and when he is ready, he asks the system for a judgment. If he finds the questions too difficult, he may branch to easier material. Involuntary branching occurs when evaluations of the student performance are included in the lesson program, which prescribes branching if predetermined criteria are met by the student.

An inquiry teaching logic, on the other hand, can be characterized as a system permitting dialogues between the student and the computer. Typically, in a lesson that uses an inquiry teaching logic, general problems are presented to the student. To solve them, he must request and organize appropriate information from the computer. In such a teaching logic, the student may be asked to demonstrate his achievement by answering questions, but he may also seek information within a given range of possibilities in order to answer such questions.

Both types of teaching logics and a variety of lesson materials have been employed in exploratory studies in order to test the capabilities of the system. Some of these exploratory studies have investigated system variables such as data rates between the students and the system.[2] Other studies have dealt with the psychological aspects of the lessons and variations in the teaching logics.[1,7,8]

The PLATO Teaching System

Student Stations. A block diagram of a single student station in the PLATO teaching system is shown in Figure 1. The system provides for communication in two directions. Each student is provided with both an electronic keyset as a means of communicating with the central computer and a television screen for viewing information selected by the computer. The student's main keyset resembles a typewriter keyboard, and the keys can be assigned any functions the teacher desires. Usually, the alphanumeric characters are assigned positions similar to those on a standard typewriter keyboard, and punctuation, special characters, or special control functions are assigned to the extra keys.

Electronic Book. There are two sources of information which are usually displayed on the student's television screen. These sources (called an electronic book and an electronic blackboard) are diagramatically shown in Figure 1. The electronic book consists of a bank of slides prestored in an electronic slide selector which is controlled by the computer. In the latest model of PLATO, the random-access slide selector stores 122 slides and has a slide access time of less than a microsecond. Information stored in the slide selector is the type that would usually be found in a textbook or in class notes. Although the slide selector is shared by all of the students, the students can view the same or different slides simultaneously. This is accomplished by having the video information available from all slides concurrently, and by connecting electronically the student's television display to the proper video output.

Electronic Blackboard. The electronic blackboard consists of a computer-controlled storage tube for each student station. Diagrams, symbols, and words are plotted in a point-by-point fashion on the student's storage tube. Approximately 40 alphanumeric characters can be written on the student's blackboard per second, and the entire blackboard can be erased in two tenths of a second. This arrangement permits information (that cannot be predetermined) to be presented to the student, such as information generated while teaching the student. For example, the system can display a sketch of an experiment the student has requested or an answer the student has composed which cannot possibly be anticipated. The images from the blackboard and the electronic slide selector are superimposed on the student's television display, enabling the student to fill in blanks on the slide and compare his answer with the question. Figure 2 shows a block diagram of two student stations, indicating the shared and the individual parts of the system. Information for a student can appear on his television screen from either the blackboard or the book or from both simultaneously.

Teaching Logics for the PLATO System

Original Tutorial Logic. The tutorial logic was the first of the two main types of teaching logics explored on the PLATO system. In this teaching logic, the keys were divided into two types—those used for inserting constructed responses to questions and those used by the student to control his progress through the lesson material. The lesson material was organized into two types of sequences: the main sequence, consisting of the minimum material that must be used by all the students, and the help sequences, provided for students who had difficulty with questions in the main sequence.

The student began by viewing text material in the main sequence. When he completed reading a page of text, he proceeded to the next page by pushing the button labeled "continue," or he returned to a preceding page by pushing the button labeled "reverse." As the student proceeded through the lesson, he was presented with questions. The teaching logic required that all the questions on a page be answered correctly before the student could continue. The student was allowed as many attempts as necessary to answer the question correctly. If he had difficulty with a question, he could push the button labeled "help," which took him into a help sequence pertaining to the question. After completing a help sequence, the student automatically returned to the question he was trying to answer in the main sequence.

In a later version of the original tutorial logic, as developed by Braunfeld, different types of wrong answers called for different help sequences. An error detector was used for automatically controlled branching. In addition, the later version of the original logic permitted some questions to be designated for monitoring by an evaluator in the computer program. The student's responses to monitored problems were used to determine whether he was branched forward to the next section of the main sequence or routed through material designed especially for students who failed the criterion test in the evaluator.

In order to prepare lesson material for the original tutorial logic, one had to organize the material into a set of slides (with at least one help slide for each question in the main sequence) as well as prepare a parameter tape. The parameter tape contained the answers to the questions, their location on the slide page, and the order in which the slides were logically connected. If the special help sequences and the evaluator were used, error categories had to be specified for the error detector and a list made of monitorized problems and their criteria for evaluation.

The most recent version of the PLATO tutorial logic, which is much more generalized than its predecessors, will be described in a later section of this article.

Inquiry Logic. While the tutorial logic serves well for many purposes, there are types of problems in which even more control should be given to the student as well as an opportunity to ask questions of the computer. To accomplish this, the inquiry teaching logics were written.

An inquiry teaching logic permits a student to request information. The computer correctly interprets the request and replies from stored information or calculated results. This logic provides, in effect, a syntax for the student to use in communicating with the computer. The student directs his learning by composing his own requests.

In the tutorial logics, the student communicates with the computer either through one of the control requests—turn the page, judge my answer, give me help—or he composes short answers which usually must match one of the several alternative stored responses. If he should type a question such as "What does 'exponent' mean?" the computer would only respond with a "no" since it treats the student's response as an answer. However, the inquiry logics provide a syntax by which a student can ask questions about the lesson he is studying. The syntax he uses can be viewed as a tree of choice points in which selections are made at each choice point.

Figure 3 presents a simplified flow diagram of a simulated laboratory, illustrating the general form of classification syntax. By pushing the button labeled "lab," the student is shown the general categories of available information. Having chosen one of these categories, he is shown more detailed selections within that category. In general, successive subcategories can be chosen until the detailed classification is specified. However, it is often desirable to have the major categories specified independently, e.g., object, conditions it is exposed to, and particular properties about which information is desired. In such a case, the student can pass repeatedly through several successive levels of selection, once through for each general category. Specifications made within one general category can be stored and used in conjunction with those made within another category. When the requested information has been completely specified, it is displayed on the student's television screen.

Many variations on this classification scheme are possible. Figure 4 shows how a student might have set up two experiments in a simulated laboratory in which the property to be measured is chosen first and the object and the condition specified later. The properties about which information can be obtained are the weight and overflow volume of objects listed. The conditions available are the liquids in which an object is immersed. Figure 4 also illustrates the use of both graphical and numerical display of results. Figure 3 shows only two choices at each choice point, and Figure 4 shows two for the first choice and five for each of the next two in the volume experiment (and six and seven respectively for each of the next two in the weight experiment). Figure 3 illustrates only four specifications on each pass through the tree, but two passes provide 16 combinations of objects and properties. Figure 4 provides 50 possible specifications on one pass through the volume experiment and 84 through the weight experiment. Some combinations have been used involving two passes. Ten choices at each choice point on three levels would permit a thousand specifications on each pass through the tree. PLATO III permits 128 selections at each of 128 choice points, which should be more than adequate for any foreseeable educational purposes.

Specification at choice points may seem a somewhat artificial way of asking a question, but it resembles the way one locates merchandise in a department store, and even elementary school children adapt to it easily. It requires only a slight rearrangement of ordinary language. For example, instead of typing "What's the effect of administering nitroglycerine on the heart rate of the patient?" the student in a PLATO teaching program for nurses who wished to ask this question typed coded numbers for the following sequence of phrases: return patient to original state, give drugs, select nitroglycerine, check condition of patient, vital signs, pulse rate. At this point the computer answered with the pulse rate.[6] Students quickly learned the syntax required and usually formed such coded questions more rapidly than they could type them in English. The computer responded immediately, displaying information obtained by computation or from memory. The student proceeded to try other experiments until she was confident concerning the treatment of the patient.

An inquiry logic written for the PLATO system which deserves special comment is one that permits the student to solve mathematical problems that require many lines of work and for which all possible solutions cannot be anticipated.[9] In this teaching logic, the student is informed whenever he violates any of the rules of mathematical logic. The computer does not store a set of correct solutions, but it does store the mathematical principles available to the student. The rules of mathematical logic are built into this teaching logic by means of decision programs. Thus, this logic simulates a teacher who watches students at work and tells them whenever they make an error but doesn't tell them what they should have written. The student is, in effect, asking whether each move he proposes is a valid one, a question to which he gets an immediate reply.

The PLATO Compiler. A PLATO compiler was developed in 1964 which permits simple preparation of all types of new teaching logics. With this compiler, educational researchers have prepared several new teaching logics suited to their own purposes in fields ranging from mathematics to the behavioral sciences.

Preparing an inquiry type teaching logic requires specifying the tree structure of the syntax the student uses to communicate with the computer. Preparing a tutorial logic also requires specifying the structure which the student or teacher uses in communication decisions with the computer. The PLATO compiler permits the logic designer to specify for each choice the next choice point to which each response leads. Each choice point can present a slide, some message printed on the blackboard, operate a piece of auxiliary equipment, etc. All of these details are specified in pseudo-English. Special decision rules are written as necessary using an augmented Fortran language.

All of the PLATO programs or lessons written since the fall of 1964 have been written for the compiler. Many of the old lessons have been revised and reprogramed using the compiler.

New PLATO Tutorial Logic. The new PLATO tutorial logic, written for the compiler, allows very flexible rules for the teacher.[3] The teacher may allow the student to respond with long answers. Several help sequences are permitted, and many judgers are available, including a spelling judger (which prints "SP" instead of "NO" on the blackboard when a spelling mistake is made). Eight special effects are available for 16 different keys, such as disallowing certain keys at specific times in the lesson or introducing an inquiry procedure such as curve plotting, available upon student request. Special remedial or challenge sequences are possible. A comment page allows a student to make comments on the lesson at any time; an instructor page allows the student to communicate with the instructor via the PLATO display. Finally, as the most important feature, the new logic contains an author mode so that the teacher may insert or change page answers and page descriptions on line with the computer.

Interconnection of Student Stations. Although independence of student stations was initially thought desirable, many uses of station interconnections were later suggested. The interconnection was accomplished with a short addition to the resident computer program.

This development has allowed teacher-student interactions, negotiation studies, and concept development exercises.

New Logic for Problem Solving. The more generalized version of the mathematical problem-solving logic is being written with the use of the compiler. This logic, incorporating improvements indicated through experience with the prototype, will allow the student to formulate his own problems and conjectures and work them out with the same supervision as if they had been problems stored by the author of the lesson. The judgment of student errors could be postponed, if desired, until the student requests that his work be marked. It is expected that this logic will be able to cope with problems in elementary algebra, logic and set theory, and some portions of geometry.

Student Records. One of the important features of the PLATO system is the "perfect workbook" of student performance kept by the computer. The student records include a record of each button pushed and the time at which it was pushed. This information is available in two forms: one form is a printed history of events that can be immediately scanned by the teacher; another form is one stored on magnetic tape that can be processed by the computer for a detailed statistical analysis.

Exploratory Studies Using the PLATO System

Student Performance and Queuing Studies. Several studies, some of which have already been mentioned, have been completed using both the tutorial and the inquiry teaching logics. Lesson material drawn from mathematics, computer programing, and electrical engineering initially were programed with the original tutorial logic. Most of these studies employed approximately 10 to 12 students as subjects, each of whom attended three of four one-hour sessions. Results of some of these studies are available in another report.[2]

Briefly, the results from the early investigations showed the following: (a) There was no significant difference between the posttest scores of students who received instruction via the PLATO system and those who attended regular class. However, the amount of time spent on the lesson material was significantly less for the students working on PLATO; and (b) using over 50,000 student requests obtained with the lesson material, queuing studies were performed. It was determined that a general purpose computer, having a high-speed capacity of 1.5 million bits, would allow 1,000 students to be tutored concurrently on eight different lessons without incurring a noticeable delay on any student's request.

University Courses. Recently, the new PLATO tutorial logic was used to program half of the material for a semester's work in a course in circuit analysis offered to electrical engineering junior and senior students. Although no detailed analysis or evaluation of the students' responses was made, some of the more obvious results showed that the students appreciated flexibility in the system, enjoyed features such as curve plotting, and thought the course material was markedly clarified by the PLATO lessons. At present, the logic is being used for credit courses in "How to Use the Library" and "Fortran Programming for Business and Commerce Students" as well as for the electrical engineering course. Evaluation of student performance will be made from the detailed records provided from the system.

Text Testing. Worthy of mention is a study now in progress which uses a logic basically tutorial in nature to record performance of students as they test new textbooks. The student works freely through a textbook, which is reproduced on the PLATO system, answering problems or questions at will. The on-line author input allows on-the-spot changes and revisions by the author. Data retrieval programs will give the author a variety of information useful in his next revision.

Studies Using Auxiliary Equipment. It should be noted that the PLATO system can include auxiliary devices operated under computer control. The inquiry training lesson used a computer-controlled motion picture projector.[5] Physiological recording devices have also been used with the system.[1] A more unusual study is one substituting a piece of experimental apparatus for a student at a station, with input from the experimental setup replacing the operator response at that station. A student at a second station can manipulate a real experiment through his station without ever touching the apparatus and can obtain the experimental results on his display.

Teaching with the PLATO system can be extremely varied since laboratory as well as classroom work is possible. Experiments may be performed which are either real (like those just described) or wholly simulated (like those referred to in the discussion of inquiry logics).

Other Research. Other teaching research projects have included drill sequences for remedial arithmetic studies, physiological studies relating to mathematical discovery,[1] and work in the area of verbal learning and retention. The wide range of exploratory studies possible with the PLATO system serves to demonstrate the versatility and flexibility of the system.[11]

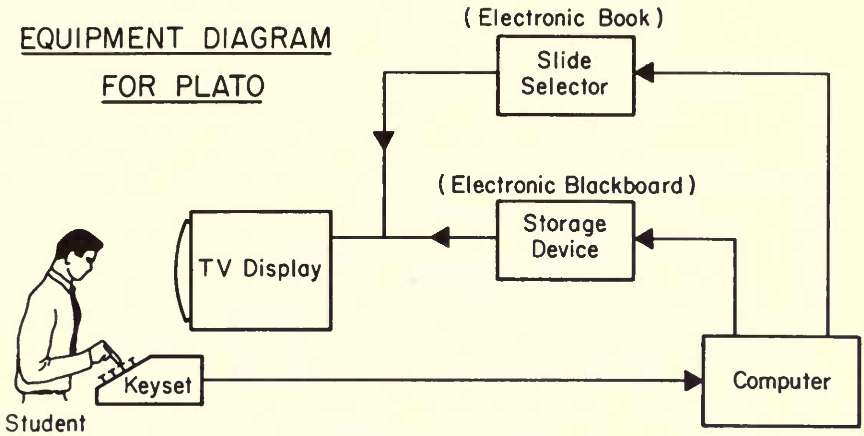

Figure 1
Block Diagram of the PLATO Teaching System (One Student)

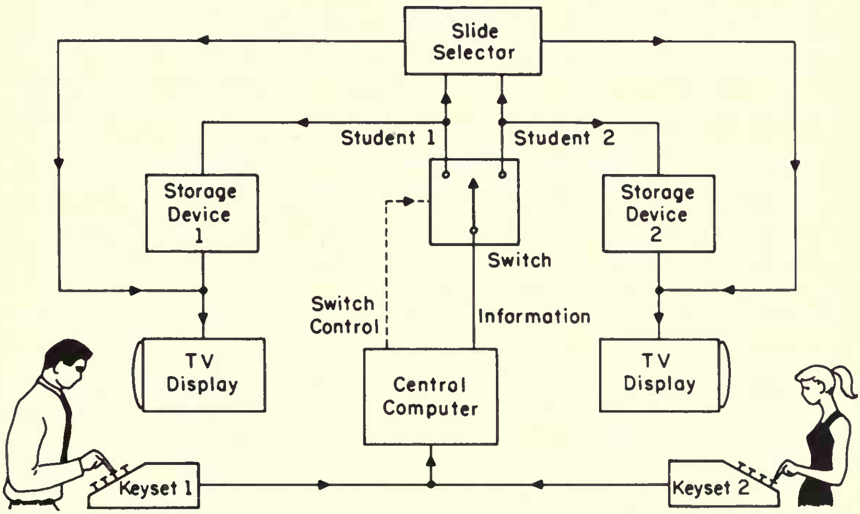

Figure 2
Block Diagram of the PLATO Teaching System Showing Shared and Individual Parts of the System

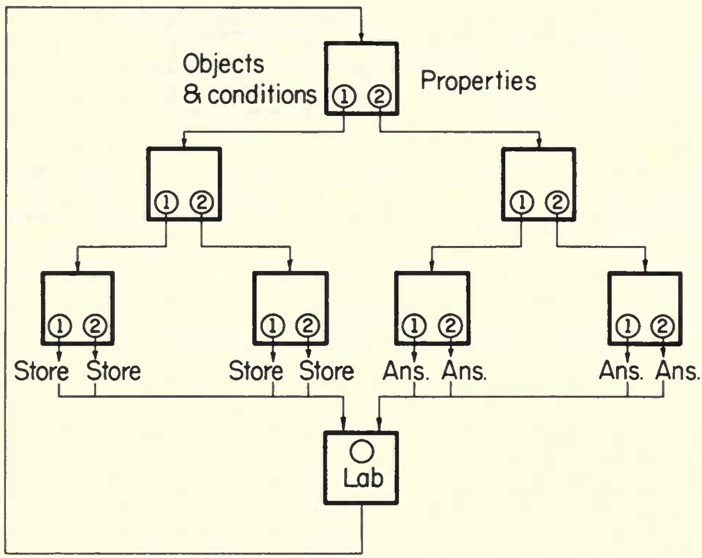

Figure 3
Simplified Flow Diagram for Simulated Laboratory Experiments
Using PLATO III Inquiry Logic

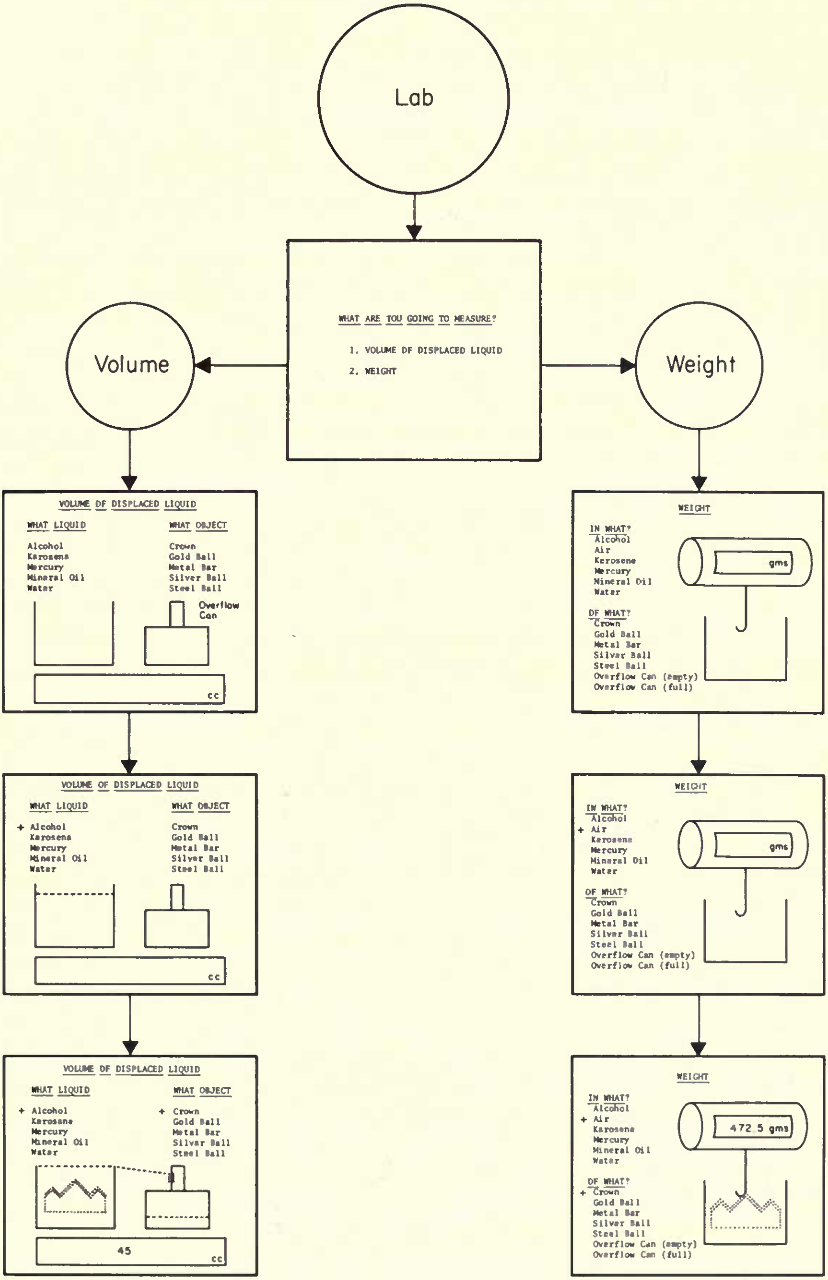

Figure 4
Example of Student's Use of an Inquiry Teaching Logic

REFERENCES

1. Avner, R. A. "Heart Rate Correlates of Insight." CSL Report R-198. Urbana: Coordinated Science Laboratory, University of Illinois, 1964.

2. Bitzer, D., and Braunfeld, P. G. "Description and Use of a Computer-Controlled Teaching System." Proceedings of the National Electronics Conference, Vol. 18. Chicago: Rogers Printing Co., 1962. pp. 787-92.

3. Bitzer, D.; Chan, S.; Johnson, R.; and Walker, M. "Lesson Preparation for the PLATO Tutorial Logic (Compiler Version)." CSL Report I-130. Urbana: Coordinated Science Laboratory, University of Illinois, 1965.

4. Bitzer, D.; Lichtenberger, W.; and Braunfeld, P. G. "PLATO: An Automatic Teaching Device." IRE Transactions on Education E-4: No. 4, pp. 157-61; December 1961.

5. Bitzer, D.; Lyman, E. R.; and Suchman, R. "REPLAB: A Lesson in Scientific Inquiry Using the PLATO System." CSL Report R-260. Urbana: Coordinated Science Laboratory, University of Illinois, 1965.

6. Bitzer, Maryann. "Self-Directed Inquiry in Clinical Nursing Instruction by Means of the PLATO Computer-Controlled Simulated Laboratory." CSL Report R-184. Urbana: Coordinated Science Laboratory, University of Illinois, 1963.

7. Braunfeld, P. G. "Problems and Prospects of Teaching with a Computer." Journal of Educational Psychology, 55:201-11; 1964.

8. Braunfeld, P. G., and Fosdick, L. D. "The Use of an Automatic Computer System in Teaching." CSL Report R-160. Urbana: Coordinated Science Laboratory, University of Illinois, 1962.

9. Easley, J. A., Jr.; Gelder, H.; and Golden, W. "A PLATO Program for Instruction and Data Collection in Mathematical Problem Solving." CSL Report R-185. Urbana: Coordinated Science Laboratory, University of Illinois, 1964.

10. Lichtenberger, W.; Bitzer, D.; and Braunfeld, P. G. "PLATO II: A Multiple Student Computer-Controlled Teaching Machine." Programmed Learning and Computer-Based Instruction. (Edited by John E. Coulson.) New York: John Wiley and Sons, 1962. pp. 205-16.

11. Lyman, E. R. "A Descriptive List of PLATO Lesson Programs." CSL Report R-186. Urbana: Coordinated Science Laboratory, University of Illinois, 1965.