Educational Uses of the PLATO Computer System

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# Educational Uses of the PLATO Computer System

## The PLATO system is used for instruction, scientific research, and communications.

Stanley G. Smith and Bruce Arne Sherwood

The PLATO (*1*) computer-based educational system has been specifically designed to provide interactive, self-paced instruction to large numbers of students (*2*). Lesson material is displayed on a screen 22 centimeters square and may consist of text, drawings, graphs, and color photographs. Students interact with the material through a special keyset that closely resembles a typewriter keyboard, and they receive essentially instantaneous reinforcement of correct work and assistance where they are having difficulty. Students can work at their convenience in classrooms such as the one shown in Fig. 1.

The users of PLATO range from grade school students learning reading and math to graduate students in the medical sciences. The system now has 950 terminals located in universities, colleges, community colleges, public schools, military training schools, and commercial organizations (*3*). The users have access to more than 3500 hours of instructional material in more than 100 subject areas (*4*). We will mainly describe one area of PLATO use—that of university science education and research.

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### Examples of PLATO Lessons

The character of PLATO lesson material varies greatly since the computer system does not impose a pedagogical structure on the authors of the materials. Some appreciation of the breadth of approaches used may be gained by reviewing brief segments of a few programs in chemistry (*5*) and physics (*6*). The examples below are illustrated with photographs of the student's plasma-panel screen (*7*). Unfortunately, however, these static photographs do not fully convey the dynamic nature of the interactively changing displays seen by the student.

A physics lesson on oscillations contains features common to many expository science lessons. The student is given a table of contents for the lesson so

The intent of the lesson is to take students from no knowledge of oscillating systems up to a point where their understanding allows them to solve typical homework problems.

The first part of the lesson deals with an oscillator consisting of a block sliding up and down two smooth inclines, a system that the student analyzes by simple kinematics formulas. In order to help the student understand the system, the computer shows an animation of the motion and allows him to experiment with values of the initial displacement (Fig. 2).

After the student has experimented with the system until he thinks he understands it, the program tests his knowledge by asking a number of questions about the system. Help is provided where necessary, but where help is required the student must answer the same question later with different numerical factors. Such checkup sections follow each expository section of the lesson.

The final quiz is constructed from questions asked in the earlier sections with randomly chosen numerical factors. No help is provided. The lesson distinguishes between incorrect numerical results and typing errors, such as unbalanced parentheses. In this lesson, if the student misses more than two out of six questions, he must take the whole quiz again. He can, of course, review sections of the lesson if he wishes.

Students also have the opportunity to study systems of their own design and to program the computer with a special language so that they may obtain immediate graphical results. Figure 3 illustrates an example of large-amplitude pendulum motion in which the student has used *s* for angle, *g* for gravitational acceleration, *l* for length, *v* for angular velocity, *t* for time, and *d* for a short time interval. The graphs that have been produced for the student correspond to running the program with a starting angle of 45 degrees and with a starting angle of 179 degrees.

Since much of science is based on the results of experiments, it seems important to have students learn to design experiments and interpret the experimental data. However, many of the key experiments in the development of important concepts cannot be carried out by large numbers of students because of the lack of adequate equipment, time, and experimental technique. The use of computer simulation can serve to provide some experience with the concepts. For example, a comparison of the sensitivity of the rates of ethanolysis of *n*-butyl bromide and *t*-butyl bromide as a function of ethoxide concentration serves to clarify some aspects of the concepts of unimolecular and bimolecular reactions. Students can quickly discover what happens through simulated experiments in which the computer plots the percent reaction as a function of time as would be observed under the experimental conditions they suggest. Since the student is free to explore the relation between experimental conditions and reaction rate, it is important to have the program ask questions and, if necessary, suggest additional experiments to assure that a suitable set of experiments has been done. In this case, after the experimental facts have been established and a suitable interpretation has been developed, the system provides a visual picture of the transformations involved by means of an animation that shows the sequence of bond making and breaking which occurs.

In more advanced lessons, students are given a problem that can be solved by conducting some simulated experiments on the computer. The student is expected to design the experiment, select the compounds and reaction conditions, and then collect the experimental data, do the mathematical analysis, and outline the conclusions that can be derived from his experiments. This approach to teaching is possible because the computer can rapidly calculate the outcome of experiments of a given type from algorithms which describe the results of actual experiments that may be beyond the experimental skills of the students and the available laboratory facilities.

It is also necessary for students to gain experience in dealing with problems for which there are many possible solutions. The synthesis of organic compounds is an example of this type of situation, in which there are many viable routes from the starting materials to the designated product. This is illustrated in Fig. 4 where the student is given the task of converting a given starting material into a designated product molecule. He proceeds by suggesting a reagent for each step in the transformation. Since there are many possible paths between the starting material and the product, the computer is programmed (*8*) to carry out the reaction suggested by the student and compare the structure of the product with that of the desired material. If they are the same, the synthesis is judged completed. If not, the reagent for the next step is requested. This approach does not impose a specific solution to the problem on the student but recognizes a wide range of acceptable routes.

One way to provide practice problems for organic reactions is illustrated in Fig. 5 where the student has been given 16 compounds and ten reagents and is asked to find at least 20 different ways of interconverting pairs of the compounds with the use of the reagents shown.

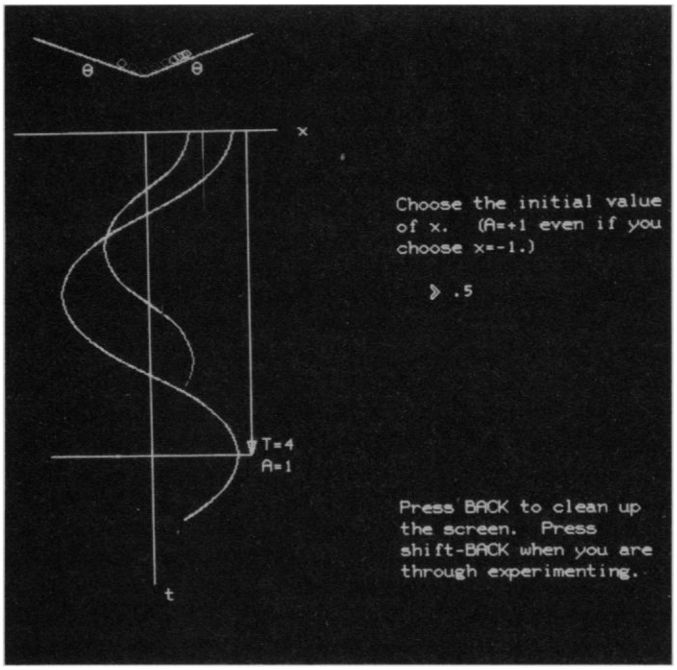
To cause the interaction, the student simply points to a compound and then to the reactant or product side of the reaction arrow to indicate his choice. The computer senses which compound the student is pointing at by means of a matrix of infrared light-emitting diodes and sensors that lie in a 16 by 16 array around the edge of the display screen. The use of such a "touch" sensitive display makes it easy and quick for the student to specify the reactants and products. Errors are corrected by having the computer show either the correct product for a given reactant and reagent or

Fig. 1. One of the PLATO classrooms at the University of Illinois. This classroom in the Foreign Language Building contains 80 terminals.

computer as an aid to teaching comes from the ability to have the computer control the projection of color photographs on the plasma panel. This is illustrated in Fig. 6, which has been abstracted from a lesson on the use of an analytical balance. In this example the student must identify the function of the knob on the side of the instrument.

segments such as those described above to a real teaching situation involves the integration of practice problems and associated help sequences with the development of the necessary theoretical framework to assist the students in understanding the material. The ability of the PLATO system to support a one-to-one dialogue with the student offers the

ing situation. Well-designed lesson material tends to be highly interactive and requires frequent inputs from each student in the form of answers to questions, predictions of the outcome of some experiment, parameters to be used in simulated experiments, and interpretation of a set of data or facts. In addition, since the understanding of the subject matter



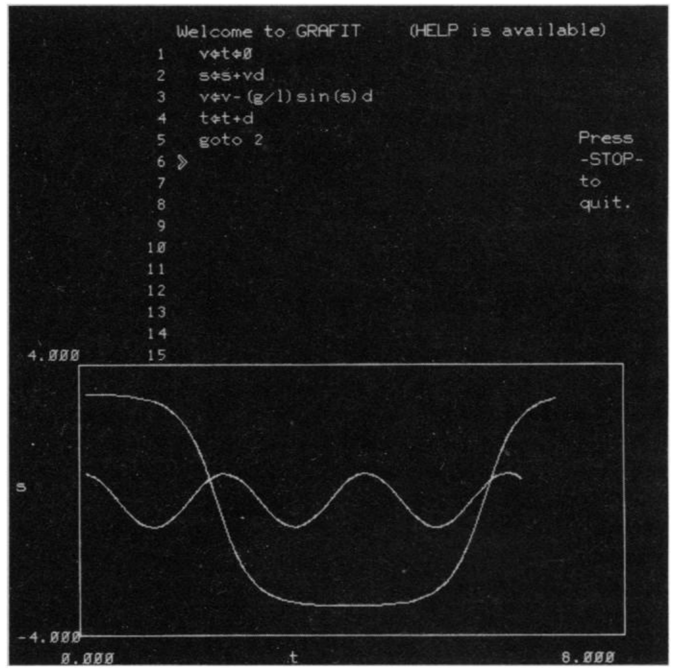
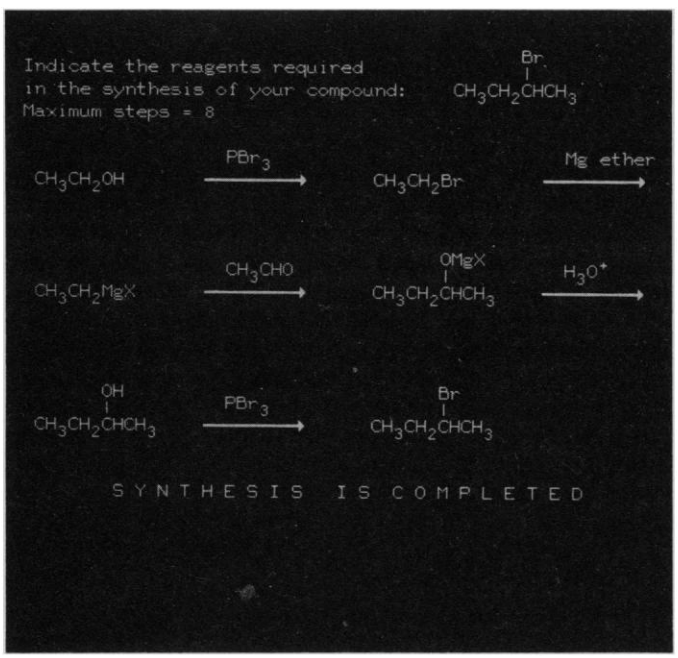




Fig. 2 (left). The student can choose the amplitude of this nonlinear oscillator and study the effect of amplitude on frequency. Fig. 3 (right). The student has written a numerical integration program to study the motion of a pendulum with large-amplitude swings. The two graphs correspond to amplitudes of 45 degrees and 179 degrees.



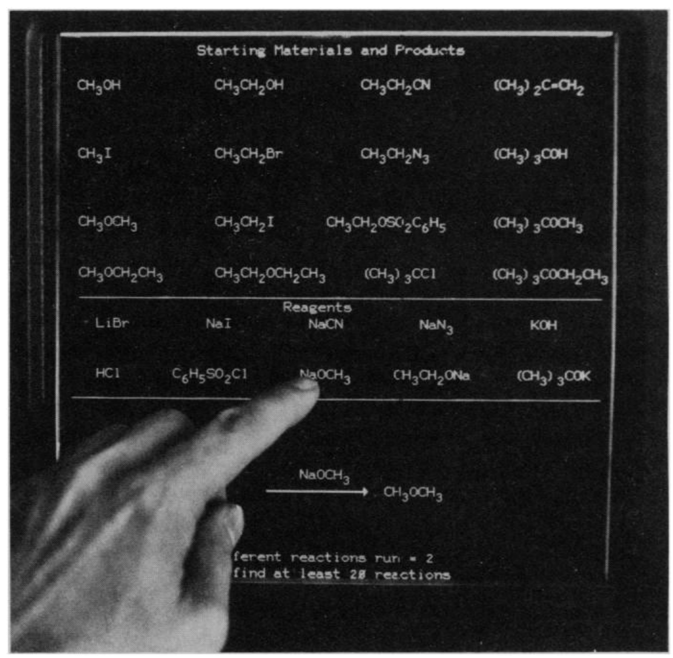




Fig. 4 (left). Typical multistep synthesis in which the student has typed in the reagent for each step as the computer draws the structure of the reaction product. Fig. 5 (right). The student can specify the starting material, reagent, and product by simply touching the compound on the screen. A 16 by 16 array of infrared light-emitting diodes and sensors determines where the student is pointing.

brief review as well as those who are learning the material for the first time. One simple way to provide students with flexibility in the way they study and use a given program is to provide an index to the lesson which allows easy access to any section.

Since students can proceed at their own rate, time spent in the lesson, unlike a lecture, automatically adjusts to the needs of the student. In fact, students proceed at greatly different rates when given the opportunity. For many lessons the time required for students to complete the lesson often varies (*9*) by a factor of 3 to 7.

Although lesson material can make some adjustments to meet the needs of individual students, it is important to develop criteria and data that indicate how the difficulty of the programs matches the abilities of the students. One criterion that has been used is the percentage of the questions posed within the program which students answer correctly on their first try. The assumption in this approach is that if nearly all student responses in instructional material are correct, then the programs are not adequately challenging them, while a very small percentage correct suggests that the lesson is unduly discouraging. The plot of percentage OK on the first try as a function of the number of students, shown in Fig. 7, suggests that for most of the students the level of the material was adequately adjusted for the class (*10*).

In addition to allowing multiple entry points and the ability to review as frequently as desired, lessons should tend to adjust to each student within each section. For example, help should be provided either when requested by the student (there is a key on the keyset labeled HELP) or when it is clear that he is having difficulty. The number of problems presented can be easily adjusted to the student by such simple means as requiring that he get two right in a row of a certain type or, perhaps, simply by returning a given problem to the list of those that need to be worked if the student needed assistance in working it. Data from lessons are used to check that the lesson is adjusting properly to the students' needs.

## Computer-Managed Instruction

A complete lesson on PLATO has many of the characteristics of a chapter in a textbook. Like chapters in a book, such

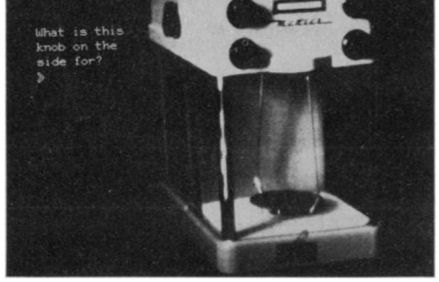



Fig. 6. The student must give the function of the knob on the side of the analytical balance. The computer controls the projection of color photographs from a microfiche onto the back of the plasma panel.

lessons need to be assembled in a form that is easy for students to use. All of the lessons associated with a particular course can be made available from an index. Then, when a student signs on to the PLATO system with his name and the name of the course, he may choose topics or lessons to study. He makes his selection from a list of descriptive titles, much as chapters in a book are selected from the table of contents. (As mentioned above, many lessons have, in addition, a table of contents for the subsections of the lesson.)

If there are a large number of lessons associated with a particular course, it may be desirable to provide the student with some guidance in the selection of lessons that are appropriate to the course at that time. The PLATO system makes this possible by a course management scheme that allows an instructor to set up an index of lessons by simply selecting the lessons from a catalog of lessons displayed on the screen. Many such indexes may be set up for a course. For example, all of the lessons associated with a given topic or concept may be placed on one index. The instructor then specifies the criteria for allowing students to move from one index of lessons to another. For example, the student might be required to complete three of four lessons before moving ahead to the next topic. Or, this criterion may be modified so that at a given date the next set of lessons is made available even if the specified number of earlier lessons has not been completed, so that a student who has gotten behind at one point in the course can keep up with the new material. If on-line quizzes or exams are included in a given module or set of lessons, a satisfactory score can be included in the criteria specified for completion before new topics are presented.

guidance to the student on current work, makes it easy to review earlier lessons, and allows students to work ahead of the rest of the class. The result is an efficient and effective integration of the techniques of computer-based teaching and computer-managed instruction. While this generally available management scheme is used by many instructors, it is also possible to create other management structures to meet special requirements.

## Integration of PLATO Activities

PLATO has been integrated into the structure of courses in several ways. For example, in a classical mechanics course (*11*), computer-based tutoring made it possible to drop one of the two weekly lectures. The remaining lecture is used chiefly for demonstrations rather than for basic instruction. The discussion period is spent in the physics PLATO classroom (which has 30 terminals), where students work individually but can get help from the instructor. Students spend additional study time at a terminal on a nonscheduled basis. Thirty terminals used 60 hours per week, providing 4 hours of contact to each student, can serve 450 students. Large numbers of terminals are required to make an impact on instruction.

There are three main components of the PLATO aspects of the course: instructional lessons, homework, and an on-line gradebook. Students are assigned instructional lessons to study, and part of their grade is based on how many of these lessons they complete. Homework is graded by PLATO rather than by the instructors. The student is given printed homework problems that he is encouraged to work at home. When the student is ready, he goes to a terminal to enter his results. If the problem involves numerical quantities, each student has different numbers. A convenient calculator is always available. The student obtains a numerical score on the homework; homework scores form another basis for the course grade.

Both lesson completion data and homework scores flow automatically into an on-line gradebook. Instructors also enter other grades into this gradebook, such as exam scores and lab report scores. Each student can look at his own scores and can see his position in a graphical display of distributions throughout the course to compare how he is doing

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