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ABSTRACT

This six-author study highlights the most signi icant attributes of Computer Assisted Instruction (CAI) and explains the techniques of authoring CAI lessons in political science. Fourth in a series of Instructional Resource Monographs, the volume has the objective to inform political science teachers and students about what CAI has to offer on a range of topics, including political philosophy and political behavior. The volume is divided into two sections. Section I concerns theory and deals with the capabilities and problems of CAI in general. It is divided into three chapters: "The Computer as an Aid to Effective Teaching;" "CAI: What's in It for Me?;" and "Authoring Made Easier: How CAI Packages Work." Section II deals with CAI practice and presents three experimental examples of CAI in political science. It includes these chapters: "Playing Politics: Reflections on an Experiment in Computer-Based Education;" "Computer-Assisted Instruction in Political Philosophy;" and "Teaching Principles and Methods with CAI." A guide to selected continuing sources of information on CAI is included. (Author/DB)

Computer Assisted Instruction in Political Science

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COMPUTER-ASSISTED INSTRUCTION IN POLITICAL SCIENCE

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Foreword

Among the major activities of the American Political Science Association, the publication of the *American Political Science Review* and the Annual Meeting provide for exchange of information about research. Other major activities aim to adapt research to teaching needs, particularly at the undergraduate level.

Since the Association's establishment in 1904, there has always been a committee concerned with undergraduate education and, in each decade, an education committee has issued a report recommending instructional goals and strategies. Today, we have a different concept of useful educational activity; the Association is helping prepare instructional materials that can be utilized by teachers and students. The regional seminars for college teachers in the 1960's supported by a grant from the Ford Foundation, were a notable first effort of this sort. The seminars helped teachers locate and use new sources of course materials and different methods of instruction. Several hundred political scientists participated in these seminars.

At the end of 1972, with the support of a grant from the National Science Foundation, the Association established a Division of Educational Affairs and began to develop publications providing teachers and students with instructional guides and useful materials. *DEA NEWS for Teachers of Political Science*, a newspaper received by all Association members; SETUPS, that are student learning materials prepared by faculty in a workshop hosted by the Inter-University Consortium for Political Research; and a Bulletin for undergraduates on *Careers and the Study of Political Science* are the initial publications.

Computer technology has become an important aid for many political scientists in their research and teaching. The faculty in approximately four-fifths of the departments offering political science courses in four-year institutions have access to computers for undergraduate education. A considerable proportion of these faculty develop and/or use computer related instructional materials. Many of these materials are data analysis exercises or simulations that introduce students to recent research and quantitative methods of analysis. The *S*upplementary *E*mpirical *T*eaching *U*nits in *P*olitical *S*cience, written, evaluated and used widely by faculty in conjunction with the Association's education program, exemplify such computer related instructional materials.

Computer-assisted Instruction (CAI) provides another and distinctive application of computer technology. Here, the computer is used to organize and present a subject in a fashion designed to assure that each student achieves an understanding of problem solving skills and of the concepts and logic of analysis inherent in the subject.

Faculty developing CAI have control over the design and presentation of what they are teaching. Faculty using CAI have considerable flexibility in structuring their assignments and classtime and in assessing their students' learning achievements.

These attributes, along with the techniques of authoring CAI lessons, are described by the contributors to *Computer-Assisted Instruction in Political Science.* Jonathan Pool, the editor, has extended his scholarship in politics and linguistics to CAI authoring systems. And, with his colleagues at the State University of New York, Stony Brook, he has developed a CAI program for an Introductory Course in Political Science. He has designed this volume, the fourth in our series of Instructional Resource Monographs, to allow political scientists to demonstrate what CAI has to offer to their colleagues and to students on a range of topics, including political philosophy and political behavior.

Evron M. Kirkpatrick
Executive Director
American Political Science Association
March 1976

Introduction

Jonathan Pool

A specter is haunting Western industrial societies--the specter of computerism. The more powerfully and efficiently computers contribute to progress, the greater grow the fears of their abuse: as components of atrocious weapons, tools of social control, invaders of privacy, reinforcers of socio-economic inequality, depersonalizers, and excuses for mental atrophy. One of the arenas in which the hopes for, and the fears of, computerization are wrestling is education,[1] as the current debate about pocket calculators in the elementary-school classroom reminds us. Yet pocket calculators will have only a rudimentary impact, compared with universal student and faculty access to large programmable computers having practically unlimited memories and ever-growing libraries of programs. As such access becomes cheaper, more potential uses of computers in education will become economical. And more educators will need to choose whether and how to use computers. The papers delivered at the Second World Conference on Computer Education, which took place in September, 1975, in Marseilles,[2] indicate that early illusions about the computer revolution that was going to envelop education in a few years have been revised,[3] but that the process has gone far and is not expected to stop.

For political scientists, this means that the original role of computers as tools for data analysis in quantitatively oriented courses becomes only one of several potential instructional roles, some of which are not at all dependent on the subject of instruction being quantitative, or even empirical. Thus the question of whether and how to use computers in instruction becomes relevant to all teaching political scientists, not just those who also use computers in their research.

Instruction that makes use of computers has been given several names: the most common expressions in English are computer-assisted instruction, computer-assisted learning, computer-managed instruction, computer-based education, and computer-related instruction. In German, one sees computerunterstutzte Ausbilding, computergesteuerte Unterricht, and so on. What is important to us is not the distinctions that their several promoters make among such terms and the systems they represent, but the components from which different systems of instruction involving computers can be built.

What, then, are the potential uses of computers in instruction?[4] A broad classification might distinguish four: preparation, management, instruction, and evaluation. In any concrete system, the computer is likely, if used at all, to play more than one of these roles. In somewhat more detail:

One use of computers is in preparing instructional material. Computers can help edit, revise, and duplicate instructional texts, and prepare diagrams and tabular information.

A second use is in managing instruction. Computers can keep student records, give students access to guidance and instruction, and channel communications among students and between students and teachers.[5]

Thirdly, computers can be used in instruction itself. They can present instructional material; administer drills; modify instructional materials and sequences in response to student performance; conduct demonstrations, exercises, and games; provide bibliographic services and access to data; and give students computational power for solving problems.

A fourth use for computers is in evaluation. They can help evaluate students by giving tests, computing grades, and diagnosing needs. They can help students evaluate their own progress and make educational choices. They can be used to evaluate courses by collecting and helping analyze student opinions about them and data about student performance in them. And they can help us do basic research on teaching and learning by administering instructional experiments, whose results can also be analyzed by computer.[6]

It cannot be said, a priori, that the use of computers for any or all of these purposes will necessarily change education in a particular way. Computers are neutral, in the sense that they can be used for almost anything. They can make instruction more uniform than before for all students, or more individualized. They can reduce the diversity of instructional styles, or increase it. They can eliminate student influence over what is taught, or give students more control than before. They can either increase or decrease the amount of contact between teachers and students, and among students themselves. They can differentially benefit the most successful students, or the least successful. They can make the preparation and conduct of courses easier for the teacher or harder. They can consequently require lowering standards for teacher selection, or raising them. And they can make education more expensive or cheaper. Most of us would presumably like to promote at least one of the things just mentioned; computers might well help.[7]

The authors of this book have certain preferences among these goals, and certain beliefs about how achievable they are. In general, we are interested in using computers to make instruction more individualized, to add new instructional styles to existing repertoires, to increase student participation in determining course content and style, to increase the amount of student-student and student-teacher individual contact, and to help the students who learn least easily overcome their problems.[8]

We think these aims can be pursued through the use of computers without adding much to the total amount of time spent on instructional preparation, although preparation will be more difficult in another sense; the instructor will usually have to specify instructional objectives and procedures more precisely, to the degree that computers are being used in the teaching. Although we recognize that the economy of using computers in some aspects of instruction is not yet clear in comparison with the alternatives,[9] we expect the ratios to keep changing to the benefit of the computer.[10] And, more specifically, we expect the efficiency of producing computer-based course material to increase faster than the efficiency of consuming it. Therefore we want to help prepare political scientists not just to administer programs written at a few richly funded centers, but primarily to produce programs themselves for their own courses in ways that may well fit into routine instructional budgets. For this reason we see computers as making individual political scientists perhaps more active cre[illegible] of the courses they teach than they have been before, and thus con[illegible]ing to instructional diversity.[11]

In this book, we use the term "computer-assisted instruction," abbreviated "CAI." By this we mean instruction in which computers are used for one or more of the purposes listed above, provided that these include at least one of the purposes named under directly instructional use other than the provision of bibliographical services, data access, and computing power. With this definition we exclude instruction in which computers are used only for the preparation of course materials, the managing of instruction, the evaluation of students or courses, and/or research on teaching and learning. We also exclude courses in which the only instructional use of computers is their use by students to analyze data. CAI, then, in our sense of the term, is still rare in political science.

This book has two sections of three chapters each, somewhat starkly entitled "Theory" and "Practice," respectively. Although they are related, neither section presupposes that the reader has read the other, and no chapter is a prerequisite for any other. So that readers can move directly to what interests them most, a summary of the contents is given below.

The section on "Theory" deals with the capabilities and problems of CAI in general. Chapter 1, "The Computer as an Aid to Effective Teaching," discusses the nature of learning, the aims of teaching, the criteria for good instruction, the considerations behind decisions as to the role of computers in teaching, and the variables that can be manipulated in designing computer-based instructional material. Clearly, Russell Burris's topics could not be thoroughly analyzed in a single chapter or even book. Burris is telling us what we should think *about* as we explore the uses of computers in teaching. Yet conclusions can be inferred from Burris's analysis. One seems to be: if you want your students to learn something and write cogently about it, but you believe it is not your job to define what they ought to learn, then CAI (i.e., the direct use of computers to conduct instruction) is not for you. Other computer uses, however, may still be appropriate even to the most exploratory of courses.

Chapter 2, "CAI: What's in it for Me?" addresses the question of teacher motivation. If professors who write textbooks do not thereby win professional acclaim, they at least earn royalties. CAI technology allows the development of a similar system of compensation for the authors of computer-based instructional materials, argues Paul Siegel. He presents, as an example, one system that would provide the necessary incentives for the production of high-quality materials.

If professors are to produce computer-based materials, not only for a large market but also for their own classes, the effort required must be reasonable. In Chapter 3, "Authoring Made Easier: How CAI Packages Work," Paul Siegel and Jonathan Pool explain that packaged programs for the production of CAI materials, analogous to data-processing programs, are being developed to cut authoring time down to modest levels. These packages offer additional benefits, too, and are a key to wide participation by teachers in the creation of CAI materials.

Moving from "Theory" to "Practice," Section 2 presents three different examples of CAI in political science. The projects described are new and experimental, and the authors share with readers some of their mistakes as well as successes. Chapter 4, "Playing Politics: Reflections on an Experiment in Computer-Based Education," describes the experience of political scientists in utilizing PLATO, one of the two major CAI systems being developed with the help of the National Science Foundation. The instructional use for the computer in this project is to involve the student in realistic game-like exercises, where the computer simulates a particular political environment in which the student acts. The computer's responses to the student's decisions are derived from models based on available political data. The chapter is written by Fred S. Coombs, a principal developer of these simulations.

Chapter 5 demonstrates that no sub-field of political science is necessarily immune from computerization. In "Computer-Assisted Instruction in Political Philosophy," Roger D. Masters argues persuasively that factual knowledge is indispensable for the study not only of such subjects as American government, but also of the history of political thought. He shows how he has used the Dartmouth Time-Sharing System to help students improve their factual knowledge in this area. Masters also reveals the results of several experimental uses of the computer for other instructional, managerial, and material preparing purposes.

Chapter 6 is about "Teaching Principles and Methods with CAI." This is a subject which, unlike political philosophy, readily comes to mind as a candidate for computer assistance. Most likely the future will see many sets of CAI materials developed in methodology, especially because a given set of materials might be used in courses of several different social sciences. Jonathan Pool describes one series of lessons, being developed at the State University of New York at Stony Brook. This chapter gives an example of what can be produced using a CAI package of the type discussed in Chapter 3. The chapter also gives some idea of the problems that arise when CAI programs need to analyze students' verbal responses.[12]

The example of CAI applications in political science given here are all different, yet by no means exhaustive of potential applications. In all three examples, the computer is a supplementary tool, not the chief vehicle for delivery of course content.[13] All three use interactive computing systems with terminals, rather than batch-processing systems. Many colleges still have only the latter, and they can certainly be used for CAI; but interactive systems are much more versatile for most instructional purposes, and are becoming standard equipment in American higher education.[14]

We would like readers to imagine new combinations of the ideas they find in these chapters. If Masters, for example, uses CAI to teach facts about political philosophy, while Coombs uses it to simulate a particular arena of American politics, what about reversing this? That is, a professor could also use a computer to teach facts about American politics, and another could write a program which simulates a particular political philosopher (or philosophy) for students to interact with. We hope readers will not only combine in new ways the elements we describe, but will also go past the techniques and strategies presented here. Rather than seeing this treated as a book about "how to do it," we would like to see the reaction, "If they had good results even with *that*, then imagine what I could do!"

The appendix to this volume is a "Guide to Selected Continuing Sources of Information on CAI." In it, Betty Weneser shows us through the array of organizations and publications in the field of instructional computing. Her guide will be of use to all readers who decide to become active producers or users of CAI in political science or any other field.

FOOTNOTES

1. See, e.g., Roger E. Levien et al., *The Emerging Technology: Instructional Uses of the Computer in Higher Education* (New York: McGraw-Hill, 1972), p. 60.

2. Reproduced in *Computers in Education/Informatique et enseignement*, 2 parts [vols.], ed. O. Lecarme and R. Lewis (New York: American Elsevier, 1975), this collection of papers is likely to be the most complete and up-to-date survey of the subject for the next several years.

3. See especially Jurg Nievergelt, "Interactive Systems for Education—The New Look of CAI," in *Computers in Education*, part 1, 465-71, pp. 465-67.

4. See, e.g., Levien et al., pp. 60-78.

5. Of course, the use of computers in educational administration, e.g., the administration of universities, is another topic, not considered here.

6. See Lawrence M. Stolurow, "Some Factors in the Design of Systems for Computer-Assisted Instruction," in *Computer-Assisted Instruction: A Book of Readings*, ed. Richard C. Atkinson and H. A. Wilson (New York: Academic Press, 1969), 65-93.

7. For an interesting discussion of how the expansion of the role of computers in higher education relates to the general reform of higher education, see Levien et al., ch. 15.

8. Cf. Peter Naur, "The Impact on Society of Computers in Education," in *Computers in Education*, part 2, 945-49.

9. E.g., Allen L. Hammond, "Computer-Assisted Instruction: Two Major Demonstrations," *Science*, 176 (9 June, 1972), 1110-12, p. 1110.

10. See Felix F. Kopstein and Robert J. Seidel, "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics," in *CAI: Readings*, 327-62; Levien et al., ch. 13; Daniel Alpert, "The PLATO IV System in Use: A Progress Report," in *Computers in Education*, part 1, 181-85, p. 183.

11. This is important, because, as R. E. Levien notes (Levien et al., p. 539), "Most instructors appear to want to retain considerable individual control over the conduct of their courses. . . . The implication for instructional computer use is that faculty members are likely to be more willing to adopt a use in which they retain some measure of independent control and ability to contribute than one in which the instructional process is completely predetermined." Cf. Nievergelt, "Interactive Systems," pp. 468, 470.

12. This problem is, however, described only anecdotally here. See Wayne H. Holtzman (ed.), *Computer-Assisted Instruction, Testing, and Guidance* (New York: Harper & Row, 1970), part v.

13. By contrast, Patrick Suppes has used CAI as a total replacement for classroom instruction in one course and says, "By taking responsibility for . . . two computer-based courses . . . and by offering them every term I have doubled my teaching load at Stanford." "Impact of Computers on Curriculum in the Schools and Universities," in *Computers in Education*, part 1, 173-79, pp. 176, 178.

14. Cf. Nievergelt, "Interactive Systems," p. 466.

SECTION I.
THEORY

Chapter 1.
The Computer as an Aid to Effective Teaching

Russell Burris

The purpose of this chapter is to describe those variables involved in the teaching and learning processes which appear to be fundamental for computer-assisted instruction. While the focus is on various ways in which the computer is being, or might be, applied effectively in teaching, the underlying concern is with the more basic questions of instructional design derived from what is known and theorized about how students develop knowledge and skill. The observations and views presented here are those of an instructional psychologist with several years experience working with faculty members from a variety of disciplines and professions on the construction of new instructional designs and materials, including computer-based approaches. While no attempt is made to deal with the specific content and context of political science, this chapter is addressed to political scientists concerned about how the processes of learning and instruction are involved in the design of more effective instruction—with special emphasis on computer uses. For the most part the research and developmental work upon which this chapter is based has been done in association with the Consulting Group on Instructional Design and the Center for Research in Human Learning at the University of Minnesota.

The computer, as well as a number of other devices and techniques falling under the general label of modern educational technology, offers the introduction of many new possibilities into educational programs. In fact, computer, video, audio and photographic technologies allow the teacher nearly unlimited choices in putting an instructional program together. Indeed, the possibilities are limited more by a lack of understanding of the processes involved in effective teaching and learning than by the restraints of the classroom, laboratory, textbook or technology. As is the case with other areas of modern society, the possibilities offered by the technology tend to exceed our ability to use the products effectively and efficiently. Rather than dismiss or ignore the technology because of this lag, however, this chapter will argue that teachers of political science, or all teachers at any level from elementary through post-graduate and professional, should be challenged by the potential usefulness of the technology for increasing teaching/learning effectiveness.

Available devices allow the teacher to select and control what and how information is displayed to learners. Many of the realities of a field situation can be presented to the learner in ways which would be impossible without modern technologies. Further, data in a computer-based information bank allow even alternative realities, never observed in the field, to be presented to the learner. Again, the complexities and challenges are enormous, but it is not difficult to imagine an exciting and effective learning experience which a devoted and knowledgeable teacher could develop using these technologies.

Note that increasing the use of this technological capability as a means of handling the rapidly growing volume of information within a discipline does not exhaust the potential of the technology to increase instructional effectiveness. Certainly, a teacher utilizing these technological capabilities will do more than present the material and expect mere recall from what was presented. What the teacher expects the students to do by way of processing, analyzing, manipulating and responding to this information is of fundamental concern. Such expectations guide the design of drills for practice, of situations or simulations for experience and of problems for analysis and inference.

Some Illustrative Examples

The identification and discussion of effectiveness within computer based instruction is the basic purpose here. Interesting and exciting dialogues [illegible] students and the material to be learned can be designed in a poten[illegible]nitless number of ways not available to teachers before, and to some degree the dimensions of interest and excitement depend upon the teacher-author's creative ability. Thus the illustrations and models of computer-based instructional materials included here should be studied mainly as a means for identifying criteria of effectiveness, rather than as examples to be copied or modified for teaching political science.

The computer can display drills, exercises, information, data and problems at a terminal, ask for a response, process the student's response and proceed differentially through a program according to features of the individual student's response. Practice can be provided in applying rules, in drawing inferences and in solving problems. By providing immediate feedback to the student according to the correctness of the response, by providing remedial branches according to certain kinds of errors, by tracking a student through a process of analyzing and solving a problem, the instructional environment approximates that of a tutor guiding a student through a learning sequence. Several questions relevant to instructional effectiveness now become important: What material or information is to be given to the student? How is the information to be displayed? In what sequence is the material to be presented? What should the student be asked to do in order to learn?

German

Consider Figure 1, showing a drill taken from a German language learning program in which the student is required to apply a grammatical rule in transforming the verb in order to achieve the indicated change in meaning. At the beginning of the drill the computer display illustrates the application of the rule, and it demonstrates how the student is to proceed through the drill. Next the student is given a sentence and the cue for how

FIGURE 1. GERMAN

An example of a student and program interaction taken from a German language drill

Guten Tag Earl *(n.b. The program greets each student by name because each student has a continuing file. Also, the program starts where that student left the program at the last session.)*

Drill 11.1

Die Leute sind gemutlicher gewesen.
The people were more likable.
would have been
Die Leute wären gemutlicher gewesen.

Ich habe das vergessen.
I forgot it.
would have forgotten
Ich hatte das vergessen.

11.1.1

Die Leute sind gleich gemutlicher gewesen.
The people were more likable.
would have been

Student response: Die Leute werden gleich gemutlicher werden.
Nein, noch einmal bitte.
Die Leute ____ gleich gemütlicher ____. *(n.b. The feedback repeats what was correct but leaves blanks for what was in error.)*

Student response: werden gewesen
Nein, noch einmal bitte.
Die Leute ____ gleich gemütlicher gewesen.

Student response: waren
Gut!

11.1.2

Ich habe das ganz vergessen.
would have forgotten

FIGURE 1. GERMAN (continued)

Student response: Ich hätte das ganz vergessen.
Gut!

11.1.3

Ich habe das schon lange gewusst.
I have known that a long time.
would have known

Student response: .a7.1.0 *(n.b. Here the student has requested an earlier drill for review.)*

Drill 7.1

Maria will Heinz heiraten.
Maria wants to marry Heinz.
wishes
Maria wünscht Heinz zu heiraten.

7.1.1

Der Vater lässt Maria reden.
The father lets Maria talk.
hears

Student response: Der Vater hört Maria reden.
Gut!

7.1.2

Der Vater lässt Maria reden.
sees

Student response: .r *(n.b. Here the student requests to return to where he had been in the program.)*

11.1.3

Ich habe das schon lange gewusst.
I have known that a long time.
would have known

Student response: Ich werde das schon lange gewusst haben.
Nein, noch einmal bitte.
Ich ____ das schon lange ____.

Student response: Ich werde das schon lange vergisst.
Nein, noch einmal bitte.
Ich ____ das schon lange ____.

Student response: Ich werde das schon lange gewusst.
Nein, noch einmal bitte.
Ich ____ das schon lange gewusst.

Student response: hätt
Die richtige Antwort ist:
Ich hätte das schon lange gewusst.

11.1.4

Sie sind zu dem Gepäckwagen gelaufen.
They ran to the baggage car.
would have run

Student response: .o
Auf Wiedersehen Earl.

Author: Professor Cecil Wood, Department of German, University of Minnesota it is to be transformed. The student, then, types the sentence with the rule applied. When an error is made, the feedback is immediate, and the student cannot proceed to the next sentence until the error is corrected. As this illustration shows, the computer provides the answer if the student is not correct within four attempts. Had this student not produced a correct answer for four consecutive sentences, the program would return to the beginning of the drill. At that point the student would be told to sign off and to study the rule as described in the text again before returning to the computer-based drill. Note that in processing the student's response the computer feeds back everything that was correct, but it leaves blanks for the word or words that were incorrect. This particular program will allow the student to jump ahead to the next drill of a grammatical rule at any time five consecutive sentences are correct on the first attempt. Otherwise, the student must continue to practice for all the sentences in the drill—approximately 35 sentences per drill.

In this particular German program there are 176 drills; each is based upon a grammatical rule to be practiced or a review of the rules introduced to that point in the program; about every tenth drill is a review drill. These drills are derived from a linguistic analysis of German which identified some of the transformations and manipulations making up the grammar of the language. Each drill, then, provides practice in making these grammatical manipulations. In addition to the periodic reviews there are diagnostic tests which on the basis of errors made may suggest that students review a drill or several drills practiced earlier. Further, a report is given to the teacher, about every week, which indicates how far in the program [illegible]h student has progressed, what difficulties (errors) each studen[illegible]ad and what drills have caused difficulties (errors) for several or many students.

It should be emphasized that this use of the computer is for drill and practice in the application of German grammatical rules. It is only one component of a more comprehensive language instruction program which includes, in addition, a grammatical text, a reading text, video tapes displaying the language in different social contexts and classroom exercises in writing, speaking and listening.

The computer-based drills are not designed to teach the entire German language, but an important part of what needs to be learned in order "to know" the language—namely, the grammar. Learning the rules by which structures are transformed and manipulated to perceive or transmit meaning, for example, the rules for changing

"The boy hit the ball."

to

"The ball was hit by the boy," or
"Did the boy hit the ball?" or
"Will the boy hit the ball?" or
"The boy will hit the ball."

rather than

"The boy was hit by the ball." or
"Did hit the boy the ball?" or
"Will the ball the boy hit?" or
"The boy the ball will hit."

make up a fundamental and necessary part of learning the language. Merely knowing a vocabulary list which includes "boy," "ball," "hit," etc., is not sufficient for perceiving or transmitting the various meanings contained in the example sentences. At other places in the program the student is given vocabulary drills, but learning to transform and manipulate this vocabulary is a more difficult and a more fundamental aspect of "knowing the language" than is knowing particular vocabulary items.

In summarizing this example from language learning let us recall the questions which were presented as important considerations in judging instructional effectiveness, namely: What material or information is to be given to the student? How is the information to be displayed? In what sequence is the material to be presented? What should the student be asked to do?

What is presented to the student for learning in this case are the grammatical manipulations which were identified as a necessary and fundamental aspect of what is to be learned, that is, what distinguishes one who "knows" from one who does "not know." Among the several aspects which were identified as a result of this analysis, 176 grammatical manipulations were seen as fundamental both in perceiving and in generating meaningful utterances. Further, the need to make these manipulations in different perceiving and generating contexts was clear. A variety of ways for displaying what is to be learned was observed to be necessary; therefore, a text, video- and audio-tapes, writing and speaking assignments, and computer-based drills were considered different, yet appropriate ways. Also, it was obvious that some manipulations are more complex than others and that learning many of the more complex ones depends on a prior learning of the simpler manipulations. Hence, the manipulations were sequenced in order to achieve pedagogical effectiveness. In addition, it seems reasonable to have the student practice the manipulations before expecting grammatical competence in realistic writing and speaking environments. Therefore, practice on the computer-based drills was scheduled prior to any expectation of perception or generation in other contexts. Finally, in deciding what the student should do in order to learn, it was clear that the student had to practice applying the grammatical rules in many sentences and in many contexts. The computer-based drills were designed so that the student was required to generate sentences applying the grammatical rules in order to achieve meaningful utterances. Obviously, to travel on a train or to order a meal it is necessary to know particular vocabulary items in a target language, but to communicate meaningfully in these contexts it is necessary, first of all, to be able to manipulate the items in appropriately grammatical ways.

Law

Before drawing implications for using the computer for teaching political science, let us turn to an example taken from legal education. Figure 2 illustrates a dialogue between a freshman law student and a computer program designed as an aid in teaching the rules of evidence. Within the course of instruction students use the computer-based exercise after reading the text and case book in which the rules of evidence are described and illustrated. The computer-based exercise provides an opportunity for the student to practice applications, i.e. manipulations, of

FIGURE 2. A PROBLEM IN EVIDENCE

An example of a student and program interaction selected from an exercise in applying the rules of evidence for law students

In April 1971, an automobile driven by Defendant collided with an automobile driven by Plaintiff. Two months later Plaintiff filed a complaint in Federal District Court for the District of Fraser alleging that he had been injured by Defendant's negligent operation and/or maintenance of Defendant's motor vehicle, and demanding trial by jury. In his answer, Defendant denied negligence, alleged that he did not have sufficient information to form a belief about Plaintiff's injury, and raised the affirmative defense of contributory negligence.

You are the judge in the case of *Plaintiff v. Defendant*. At the pre-trial conference, you learn that at trial the position of the parties on the issues of fact will be as follows:

Plaintiff will claim that Defendant was negligent because he operated his vehicle at excessive speed (35 m.p.h. in a 20 m.p.h. zone), because he knowingly drove a car with dangerously bad brakes, because he did not keep a proper lookout, and because he ran a red light immediately prior to the collision.

Defendant will claim that he was traveling at a reasonable speed (20 m.p.h.); that the red light was out of order; that he went through the intersection after being signaled to do so by a police officer; that his brakes were in proper repair; and that Plaintiff ignored the police officer's warning not to proceed through the intersection.

You will be asked to rule on the objections in these exercises by indicating whether evidence is admissable. For most objections you will be asked to justify your ruling.

Plaintiff's lawyer has called Plaintiff as his first witness. He is now in the middle of his direct examination of his client:

Q. What happened then?
A. I walked over to the sidewalk.
Q. Did you have any conversation with anyone there?
A. Yes, John Jones Talked to me.
Q. How long after the accident did this conversation take place?
A. About half an hour.
Q. What did Mr. Jones say? Objection 1
A. "I saw that nut run the light just before the accident."

(Sustain or overrule the objection)

Student response: Sustained

You have ruled that the evidence is inadmissible. What are your grounds for excluding this evidence?

Student response: Best evidence rule

Wrong. The best evidence rule does not apply to spoken statements. "The only actual rule that the 'best evidence' phrase denotes today is the rule requiring the production of the original writing." McCormick on evidence, section 229 (2nd ed. 1971).

FIGURE 2. LAW (continued)

Student response: Hearsay

Correct. The lawyer's question sought to elicit testimony about a declaration made out of court, which would be used as evidence of the truth of the matter declared. Hence, the testimony sought was clearly hearsay. Plaintiff's lawyer made no showing that the testimony would fall under any exception to the hearsay rule.

(n.b. This illustration skips to a middle point in the program in order to show more complex problems.)

Plaintiff's lawyer continues his direct examination of passenger:

Q. Were you at the Acme Garage with Defendant earlier in the day?
A. Yes.
Q. Did the garage owner have any conversation with Defendant?
A. Yes.
Q. What did he say? Objection 13
A. "We can't fix your brakes, so I'll give you a refund on what you paid me." (Note: Plaintiff's lawyer has previously introduced evidence sufficient to prove that the garage owner died in an accident three hours after he made the foregoing statement.)

Student response: Overruled

You have ruled that the evidence is admissible. Why shouldn't this evidence be excluded under the hearsay rule?

Student response: It falls under the unavailable witness exception.

Wrong. There is no such thing as an "unavailable witness" exception. See Field and Kaplan, p. 88. Hearsay evidence does not become admissible merely because the out-of-court declarant is not available to testify in courts. The unavailability of the declarant is a necessary condition for the application of some of the exceptions to the hearsay rule, such as the declaration against interest exception (Field and Kaplan, p. 89), but unavailability per se does not make hearsay evidence admissible.

(n.b. For certain incorrect answers diagnostic feedback is given and references made.)

Student response: It falls under the declarations against interest exception.

Correct. The garage owner's statement was against his pecuniary interest. (Push "e" if you are concerned because the statement seems to have been in the garage owner's business interest when made.)

Plaintiff's lawyer continues his direct examination of passenger:

Q. What was the general mechanical condition of Defendant's car? Objection 14
A. Very poor.

Student response: Sustained

You have ruled that the evidence is inadmissible. What are your grounds for excluding this evidence?

Student response: Hint *(n.b. The student has requested a hint before proceeding.)*

Objection 14: Hint: It would be helpful to the jury if the witness was more specific about what was wrong with the car.

Student response: Asks for opinion

Correct. The question calls for a very general opinion about the mechanical condition of Defendant's car. And the passenger has not been shown to have any special mechanical expertise. The Passenger should be asked to describe specific mechanical problems, e.g., the wheels were wobbly, the brake pedal had to be pushed all the way to the floor before the car would stop, etc.

Author: Professor Roger Park, Law School, University of Minnesota the rules. The computer program gives problems within a realistic context, and the student is required to solve each problem by applying the correct rule.

For the law student, knowing the rules of evidence involves more than naming and defining the rule. The law student must know when and how the rules may be applied correctly. Learning the rules of evidence is, in a sense, similar to learning grammatical manipulations in the language case. That is, knowing the rules of evidence requires the ability to process courtroom proceedings in terms of what is objectionable and admissable according to the rules of irrelevancy, best evidence, leading question, hearsay, exceptions, etc. Since "knowing" or "thinking as a lawyer" requires more than the ability to recall or recognize facts, principles or other elements within the law, students need practice manipulating a knowledge structure to process new data and information in ways which are appropriate for a lawyer. The computer provides practice making these manipulations in a setting which could not be duplicated with a textbook or in a classroom; and, as we shall discuss shortly, the dialogue between the student and the program illustrates a number of features which an analysis suggests are critical for effective instruction.

Medicine

An example taken from an advanced clinical level in medical education is offered in Figure 3. This program is one of several designed for medical students in their final year, for residents in pediatrics and for practicing physicians in continuing education programs. In this example a problem is set in a realistic environment so that problem-solving skills can be practiced--and monitored and studied. That is, prior knowledge and experience in physiology, biochemistry, pathology, clinical medicine, etc., is assumed; practice is provided in applying or transferring that knowledge to one of an infinite, or near-infinite, set of possible cases. The student works on a larger number of cases than would be possible in the clinic; and, further, the instructor has control over the nature of the problems the student works through. These medical cases are not a replacement for clinical ward experience--they are viewed as supplementary aids. But each computer-based case takes only about two hours to work through, about one-tenth the time the analogous ward experience would require.

FIGURE 3. PEDIATRIC CARDIOLOGY

An example of a student-program interaction selected from an exercise in clinical pediatric cardiology for advanced medical students

You are a pediatric intern in an intensive care unit of a university teaching hospital. It is 10:30 p.m. of a long day, and you have not yet had an opportunity to have dinner. A seven day old infant from Frozen Falls, Minnesota, is admitted. He is accompanied by an ambulance driver; his father is in admissions and his mother is at

FIGURE 3. MEDICINE (continued)

home. A hastily scribbled note from the family physician indicates the child has eaten poorly for two days and looks ill. He is being referred for further care.

The child is in an isolette; oxygen is being given and monitoring equipment has been attached by the nurse. In the emergency room, an intra-arterial catheter was placed by the pediatric resident in the emergency room, and an intravenous solution of 10% D/W started.

You would (choose one):

1. Examine infant
2. Obtain laboratory data
3. Go to dinner

Phone one of the following for historical information or consultation. Each phone call will take about 15 minutes.

4. Private physician
5. Mother
6. Father in admissions
7. Consultant

8. Symptomatic management

Student response: 1

Physical examination. You would now be especially interested to check:

1. blood pressure in arm
2. blood pressure in leg
3. pulse rate
4. respiratory rate
5. pulse amplitude
6. skin color
7. character of respiration
8. facies
9. thorax
10. lungs
11. heart
12. abdomen
13. umbilicus
14. genitalia
15. extremities
16. neurological
17. done

Student response: 1, 2, 3, 4, 6, 10, 15

1. blood pressure in arm—30 flush
2. blood pressure in leg—30 flush
3. pulse rate—168/min.
4. respiratory rate—70/min
6. skin color—slightly delayed capillary fill; mild cyanosis about mouth, hands and feet
10. lungs—clear
15. extremities—symmetrical

You would now:

1. Examine infant
2. Obtain laboratory data
3. Go to dinner

Phone one of the following for historical information or consultation. Each phone call will take about 15 minutes.

4. Private physician
5. Mother
6. Father in admissions
7. Consultant

8. Symptomatic management

Student response: 2

Laboratory data: You would now order (select as many tests as you consider necessary):

1. CBC
2. U/A
3. pO2
4. pCO2
5. pH
6. Na+

FIGURE 3. MEDICINE (continued)

7. K+
8. Cl−
9. CO2
10. Blood sugar
11. Bilirubin
12. PT
13. Obtain EKG
14. X-ray, chest
15. X-ray, abdomen
16. X-ray, skull
17. Blood culture
18. Urine culture
19. Lumbar puncture
20. Ca++
21. PTT
22. Done

Student response: 1, 2, 5, 11, 13

1. CBC—Hbg=15; WBC=12,500; P=40; L=55
2. U/A—Clear; pH=5.5; sp.gr.=1.010
5. pH—7.1
11. Bilirubin—2.9
13. Obtain EKG—axis +150; PR=10; P wave, okay

You would now:

1. Examine infant
2. Obtain laboratory data
3. Go to dinner

Phone one of the following for historical information or consultation. Each phone will take about 15 minutes.

4. Private physician
5. Mother
6. Father in admissions
7. Consultant
8. Symptomatic management

Student response: 4

Call private physician. It took you 15 minutes to reach the physician. He sounds a little sleepy and a little hostile. You would be particularly interested to inquire about:

1. age of parents
2. mother's health
3. other pregnancies
4. mother's pregnancy
5. medications during pregnancy
6. delivery
7. neonatal course
8. when did first symptoms appear
9. what symptoms appeared
10. what were your physical findings
11. any medications for the patient
12. any illness in community
13. mother's blood type
14. other family history
15. done

Student response: 8, 9, 10

8. when did symptoms first appear—at six days of age
9. what symptoms appeared—mother said infant breathing rapidly and not nursing well
10. what were your physical findings—the kid was breathing fast and looked very sick, so I sent him on down

It is now 45 minutes since the patient has been admitted. Your next step is:

1. Examine infant
2. Obtain laboratory data
3. Go to dinner

Phone one of the following for historical information or consultation. Each phone call will take about 15 minutes.

4. Private physician
5. Mother
6. Father in admissions
7. Consultant
8. Symptomatic management

Student response: 1

FIGURE 3. MEDICINE (continued)

Physical examination. You would be especially interested to check (select as many as you consider especially pertinent):

1. blood pressure in arm
2. blood pressure in leg
3. pulse rate
4. respiratory rate
5. pulse amplitude
6. skin color
7. character of respiration
8. facies
9. thorax
10. lungs
11. heart
12. abdomen
13. umbilicus
14. genitalia
15. extremities
16. neurological
17. done

Student response: 1, 2, 3, 4, 6, 10

1. blood pressure in arm—unobtainable
2. blood pressure in leg—unobtainable
3. pulse rate—170/min.
4. respiratory rate—80/min.
6. skin color—mottled; poor capillary fill
10. lungs—clear

Your next step would be:

1. Obtain lab data
2. Do exchange transfusion
3. Give Digoxin 0.05 mg/kg (digitalizing dose)
4. Give Lasix 1 mg/kg
5. Give THAM
6. Give heparin
7. Order lab data and start therapy with Digoxin 0.05 mg/kg (digitalizing dose)

Student response: 3

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In addition to providing the medical student with a realistic problem-solving situation, the computer program also monitors and records what information the student asks for, the sequence in which it is asked for and what treatment decisions are made. Analyses are made of each student's record of going through the problem for two purposes: to provide feedback to the student about his/her problem-solving skills and strategies and to do research on what distinguishes effective, or "expert," clinical skills and strategies.

These three CAI programs were selected from among more than twenty with which the author of this chapter has been directly involved in development and implementation. The three as well as the others have demonstrated a level of effectiveness across several dimensions. They have not been selected as illustrations of the most innovative or as examples of the most advanced state of the CAI art; but, rather, their selection was based on certain diversities among them which might help us discern the fundamental factors of effective instructional design in CAI.

What is it, then, that makes instructional programs, generally—and CAI, specifically—effective? What characterizes a learner's successful achievement of an appropriate level of performance? What is it a student "knows" when we are willing to say he/she "knows?" The next section of this chapter discusses the elements and characteristics of effective instructional programs within a frame of reference developed to aid program analysis. While the framework itself has not been derived from a particular learning theory, it is intended to present the important variables in a useful manner for teachers considering the use of computers for improving instruction.

A Framework for Analyzing Instructional Programs

Goals of Instruction

Any teacher knows the necessity of having goals for an instructional program, a course, or units of a course, all within the setting of a meaningful curriculum. In a careful consideration of goals, however, several important issues arise which have to do with structuring the subject matter to be learned and with evaluating the performance of learners.

What is to be learned. Perhaps the fundamental issue to be faced is the question of how well the teacher can describe, or at least recognize, the distinguishing features of the performance of those who attain an appropriate level of knowledge and skill. That is, the teacher must be able to describe, to some level, those features of the performance of an individual who "knows" that distinguish that performance from one who "does not know." Inherent in such a question are the considerations of knowledge structure and of performance criteria. As valuable as intuitions, historical precedent and text outlines are to a course design, these may or may not correlate highly with what can be derived from a systematic analysis of what is meant by "knowing" in a specific context.

For example, most good teachers and good instructional programs clearly reflect that "knowing" is more than the ability to recall or to recognize the facts, principles and other elements of a knowledge area. Also, there is a further recognition that "knowing" is more than fitting these facts, principles and elements together in a well-organized structure which is shared by those knowledgeable in the subject matter. To be sure, these aspects are part of "knowing." But beyond these, there is an awareness that an adequate description of "knowing" must also account for how a knowledge structure is manipulated and how new data are processed within that structure in order to solve problems or to otherwise perform appropriately. In short, effective instructional designs recognize the distinctive nature of the rules or skills necessary for processing and manipulating information relevant to the subject matter.[1]

These points can be illustrated also in the "subject matter as language" metaphor implied in the discussion of the CAI programs presented earlier in this chapter. If one thinks of the knowledge and skills associated with knowing a subject matter as a "language," the facts, principles and other distinctive elements of that subject matter can be thought of as its "vocabulary." These elements have a logical organization which can be thought of as its "structure," and the rules for transforming and manipulating that structure in order to process relevant data in the perception and generation of an appropriate performance can be thought of as the "grammar" of that knowledge area. It is the grammar which those most knowledgeable in a subject-matter area seem to share. It is the grammar which seems to distinguish those who can effectively attack problems, who can make correct inferences and who otherwise can perform appropriately within the context of the subject matter. I have argued elsewhere[2] for this use of grammar as a means of distinguishing "expertness" from the less able or novices in a knowledge area, and Mast uses such an approach in analyzing "what is to be learned" in art history.[3] Colby also presents a strong argument for the use of grammars as a research technique in non-linguistic areas.[4]

Glaser and Resnick make essentially the same observation.[5]

> The studies we have chosen to define the field (instructional psychology) come from a variety of sources and only some of them have an explicit instructional orientation. *What is especially striking, however, is their convergence on the analysis of performance in terms of the interaction between task structure variables and the learning and information processing capacities of the individual.* (emphasis added) Such an emphasis seems to us to be crucial for an instructional psychology which seeks to explicate the conditions under which educationally relevant learning takes place.

The key phrase to be noted in the Glaser and Resnick statements is "the interaction between task structure variables and the learning and information processing capacities." What they refer to as "task structure variables" is discussed here as the facts, principles and elements—"the structure"— of a knowledge area, and what they refer to as "the learning and information processing capacities" is discussed here as the rules for manipulating the knowledge structure—"the grammar"—in the processing of data and information.

Such analyses of "what is to be learned" preceded the construction of the three CAI programs presented in Figures 1, 2 and 3. The analyses helped to identify the structures and what was to be learned—*not* the media to be used for presentation. As an illustration of the fundamental nature of the analysis involved, it should be pointed out that designs similar to that of the German CAI program have been used to construct materials for Dutch, Swedish, Norwegian, Italian and ancient Greek at the University of Minnesota—all using a common computer program. However, the grammar to be learned in each of the languages is different—e.g., the grammar of ancient Greek is quite different from that of German.

In most subjects, the "grammar" is only partly known, even by the teacher. Thus, in the computer-based exercise in applying the rules of evidence, competence at the level of a trial advocate is not required; the competence expected of the law student at this point is only at an initial level of manipulation. The trial advocate's ability to raise objections appropriately is at another level and includes more than the simple manipulation of rules. The same knowledge gap applies to the other programs constructed for legal education, viz., applying the meaning of intent in the law of torts, interpreting the code of professional responsibility, the defense function, trial practice problems, etc. Hence, beyond their instructional use, these programs—and especially the program in trial practice—are used as research instruments to continue the pursuit of the what-is-to-be-learned question. That is, the protocols of law students, lawyers and law teachers help identify what, how and when rules and principles are used; this knowledge, in turn, makes possible the refinement of a "symbolic grammar" for the area.

The use of terms like "rules" and "grammar" in this discussion should not be taken to imply any unrealistic stability in the contexts presented to the student. In the pediatric cardiology program, for example, the situation is dynamic: the condition of the patient changes during the period of the student's working through the case. The program's ability to allow the student to ask for and process data and make treatment decisions, and to analyze the student's actions in light of the patient's changing condition, reflects an important part of the "symbolic grammar" in this area.

What needs to be emphasized in these descriptions is that the instructional design must be based upon goals and purposes which, in turn, have been derived from an analysis of what is to be learned. Of course, many experienced teachers have developed effective programs of instruction without having been aware of making such an analysis, but it is this instructional psychologist's observation that many challenges remain in accounting for instructional effectiveness. It is usually the best teachers who recognize these challenges and continue to work for improved effectiveness. It is argued here that an initial step in this improvement is to establish clearer goals and purposes based upon an identification of the knowledge structure and of how it is manipulated in processing relevant information.

Performance criteria. Clearer goals which have been derived from such an analysis also describe the criteria to be used in evaluating the learners' performances. Performance evaluations are instructional techniques, as well as assessments of competency. That is, an effective instructional program will provide feedback to the student regularly concerning his/her learning progress, and it will have a means of acknowledging those who have "learned." Unfortunately, too few instructional programs have such diagnostic capabilities.

It is of interest to note that CAI programs similar to those shown in Figures 2 and 3 are being used as techniques in accrediting, and reaccrediting, competence. Competence is used here in the (linguistic) sense of generating an appropriate performance within a particular context. Performances, which require manipulation and processing in a realistic situation, can be analyzed diagnostically, however, only to the degree that the goals of instruction clearly reflect what is to be learned.

Context. A number of references have been made to the context of instruction in the discussion above. A brief, but important, elaboration should be made here. Political science is a different subject matter from German, law and pediatric cardiology. An analysis of its subject matter will reveal not only different facts, symbols and structure, but its rules for manipulating and processing that structure will be different from other subject matters. To continue the subject-matter-as-language metaphor—it would be a reasonable expectation to find different dialects within the language. Different theoretical observations, different topical areas, etc., are bound to produce variations in the ways in which data are manipulated and processed. In short, the goals and purposes of the instruction must reflect an analysis of what is to be learned within different meaningful contexts.

Instructional Sequence

Next our frame of reference focuses on how instruction is most effectively and efficiently sequenced. Sequencing deals with the progressions of steps through which the instructional program "routes" the student. Although very little research has been directed toward the problem, especially as it might relate to learning and pedagogical theory, any experienced teacher is aware that certain sequences are more effective than others. Common sense suggests proceeding from the "easy" to the "difficult" in laying out the progression, and trial and error through experience provides a certain empirical base for decisions about sequencing.

Although present theories are not sufficient to guide the sequencing of a particular course, a careful analysis of what is to be learned provides helpful suggestions. Such an analysis combined with continual observations of the difficulties encountered gives a basis for decisions having to do with the order of presentation. Clearly, instructional effectiveness cannot be improved without some attention directed to questions of sequence.

Sequencing was an important consideration in the development of the CAI programs illustrated in Figures 1 and 2. In the construction of the German language program many questions were raised dealing directly with sequence. Obviously, most of the grammatical manipulations could be placed on an easy-to-difficult continuum, but a more important consideration was that initial perception and generation of German sentences depend on an ability to do a few basic grammatical manipulations of which more complex manipulations can be treated as elaborations and extensions. The rules of evidence vary in complexity of interpretation, and the situations in which the rules are interpreted also can vary in complexity. In the evidence program, the learning task structure had to consider these two dimensions of complexity, not just a single scale of "easy" to "hard."

Learning Strategy

The problems of relating our best notions of what must be learned to our best notions of what the learner must do in order to learn characterizes this third dimension of the frame of reference. In the absence of well-formulated and generally accepted theories of learning and pedagogy more practical considerations are required about what and how the learner should practice to attain the knowledge structures and the processing rules of complex skills. However, to the degree the criteria established for knowing and performing within the instructional goals approximate an adequate description of the needed knowledge and skill, the task of specifying these strategies and procedures for learning is simpler.

Experienced teachers are aware, at least intuitively, of many of the factors related to effective learning strategies. For example, they recognize the necessity of active participation in learning, self-pacing, immediate feedback on performance, and contextual meaningfulness. Certainly, a physics teacher recognizes that it is possible to know Ohm's law but not know how to solve a circuit design problem. Similarly, it is possible to know the rules of evidence without being able to apply the rules appropriately in a courtroom situation.

An effective program of instruction, then, must consider what and how different activities are to be practiced. A careful analysis of what is to be learned will suggest what is to be practiced. Clearly, practice is required in manipulating and processing the facts, principles and other elements of the knowledge structure in appropriate ways for handling relevant information. Learning activities should include manipulation critical to knowing, and they should present a sufficient variety to help "internalize" the rules underlying the manipulations.

Research and experience suggest that learning effectiveness increases when the learner is active, when the practice activity is self-paced, when feedback on the correctness of responses is given immediately and when the activity is meaningful to the learner. Although learning theories fail to provide direct guidance to the design of learning activities based on these suggestions, there is evidence, gathered in both laboratory and field situations, which supports each of these suggestions as significant characteristics of effective instruction. The three examples of CAI programs above can be seen to require practice in ways that illustrate these characteristics, i.e., the learner is active, the practice is self-paced, the feedback is immediate and a meaningful context is established. An important point to be made about the potential of CAI as an effective component in instruction is that it allows these characteristics to be designed into an activity to a degree nearly impossible to achieve in other approaches.

Instructional Media and Modes

As the placement of this section implies, the selection of the techniques and technologies follows the considerations of goals, sequence and strategy, i.e., form follows function. Effective use of the computer in instruction depends less on the technological capabilities of the system and terminals than on how the instructional design reflects a consideration of the more fundamental variables involved. Nevertheless, the computer offers unique capabilities for student and subject matter interaction which should appeal to most devoted teachers.

As described elsewhere in this volume computer systems and terminals differ in some of the things they can do, but there are many impressive possibilities in any system. The student interaction with the German program, in Figure 1, shows several features that make significant contributions to effectiveness. The student must actively respond by applying a rule to generate a transformed sentence. The entire sentence is processed by the computer, and immediate feedback is given as to the correctness of the student's sentence. The system is available to the student for a period of about 18 hours a day, seven days of the week. The computer always responds in its usual manner no matter how many students of sometimes marginal competence are processed each day—its tolerance for performances less than perfect impresses any German teacher. At the present time more than 400 students enrolled in German courses at the University of Minnesota and at other colleges in the state use the program for about three to five hours a week each during the academic year. Evidence indicates a time-saving of approximately 40 percent in doing the necessary practice, and performance is at a slightly higher level of achievement than without CAI.[6] Equally impressive is the fact that students rate the computer as a valuable learning resource at about the same level as the text and second only to the teacher—recall that the student has an array of learning resources available, including audio and video tapes and players. Finally, because performance records are made for individual students as well as for all students enrolled, the teacher-author gets feedback concerning student difficulties encountered in the program. By using this feedback the teacher-author is able to make changes which over time improve the program's effectiveness.

Generally, the same features of the technology noted above also contribute to the effectiveness of the evidence and the pediatric cardiology programs. Some additional features in these cases should be pointed out, however. As shown in the evidence program, a dialogue can be established which approximates a tutorial interaction. Indeed, in other law programs in use at the present time the students are free to develop their own approaches to a problem, and feedback is given as to the soundness of the reasoning used in developing their arguments.

The only feedback shown in the illustration of the pediatric cardiology program is the information the student asked for. However, at the end of clinical problems programmed for medicine there is a tutorial segment which reviews with the student the strategy he/she used, in comparison with an optimal strategy developed by the teacher-author. The student is told what information was requested without good reason (the student is also shown the excess laboratory charges which would have to be added to the patient's account) and what information was not requested which good practice or other information at hand would require.

An additional feature of this use of the computer is the possibility of presenting a problem-solving situation in which the student is required to make decisions and bear the consequences of those decisions. For the medical student such a possibility is available only through some sort of simulation, and the computer medium provides an especially attractive practice environment.

Because computer technology is still developing, additional features which can be expected to contribute to greater effectiveness remain on the horizon. Information displays will improve with better graphic capabilities in the terminal and with computer-controlled audio and visual presentations at the terminal. Although such technological capabilities are available, they are not readily accessible to most instruction programs yet. But they should be available in the near future, and, because costs associated with this technology continue to show a decline, they should be available at reasonable cost.

Again the major difficulty in selecting and using the computer as an instructional medium is to relate the technological capabilities to what is to be learned in ways which are appropriate to both aspects of the relationship. Certainly, the computer has considerable potential for improving the effectiveness of many instructional programs, but the possibilities for misuse are clearly present.

Motivation

No teacher doubts the importance of motivation variables- the next issue in the frame of reference- in accounting for instructional effectiveness. In the absence of an adequate accounting derived from motivational and pedagogical theories, attention needs to be focused on a number of practical considerations which clearly contribute to effectiveness.

A major consideration has to do with the degree of similarity or agreement between the student's expectations and the teacher's instructional goals. Further, are the learning activities meaningful to the student in terms of these expectations? Are the student's goals derived more from "internalized" need or more from some externally imposed requirement, and to what degree do these goals relate to the student's long-term objectives? Grades and other forms of evaluative feedback have some apparent motivational effect, and, if used properly, can influence effectiveness.

Clearly, a teacher who strives for instructional effectiveness cannot afford to ignore motivational variables in designing courses and programs. CAI alone may carry a "Hawthorne effect," at least for some students. If exploited wisely, it should not be considered as a negative attribute.

Individualization

The final construct in this frame of reference is an area of obvious importance in a consideration of instructional effectiveness, viz., individualization. The potential contribution of CAI as a means for individualizing a program of instruction is obvious. However, in spite of a number of intriguing possible relationships between individual differences and instructional design supported by the research literature, there is little theory to guide instructional design in the use of individualization to optimize effectiveness. Activities which allow more individualized approaches seem sensible. More fundamentally, and specifically, the ability of CAI to vary the nature and sequence of learning activities in order to provide different routings and different patterns or practice should help to avoid mistakes resulting from the difficulty of taking known individual differences into account.

Some Concluding Remarks

Only within the past decade or so has a more concerted effort been directed toward the development of an instructional psychology. There are complex difficulties in attempting to describe how principles of human learning might be applied to teaching programs. This chapter has not tried to deal with these complexities in a systematic way appropriate for the researcher, but it has tried to point out issues and questions arising from these complexities in a practical way appropriate for the teacher. This chapter offered no easy approaches for the teacher to deal with these complexities in the design of instruction, but a frame of reference was presented which it is hoped can be useful to the teacher as an aid in attempts to improve instruction. The discussion thus far has dealt only with those variables within learner-program interaction. The author is moved, however, to present some issues external to this interaction which are more indirectly relevant to instructional design and which are important to a consideration of effective use of CAI.

Political scientists, as teachers in other professional and subject-matter areas, are under considerable pressure to make changes in the traditional approaches to instruction. Present practices in student selection, instructional design, curricular arrangements, examination procedures and teaching techniques are all under this pressure. The increasing needs of many nontraditional groups for new or modified instructional programs are the objects of a significant portion of the changes being demanded. Different minority groups who, for a variety of reasons, have been excluded from the traditional target population of past instruction are being recognized. The number of men and women over twenty-five who want to return to or to start educational programs appears to be increasing. Many older individuals desire programs which will provide leisure activities or help meet career change desires. Legislation and other pressures are forcing many professionals to return to the universities in order to update their knowledge and skills. Accompanying the increasing number of nontraditional students is an increasing pressure for changes and programs from traditional students. Among these asked-for changes are increased field or clinical experience as a part of educational programs, more individualized or independent study alternatives, different evaluation or grading techniques and procedures, and a recognition of competencies gained outside the traditional course structure. Also, procedural changes are necessary in recognition of greater student mobility, an increasing desire to stop off and the possibility to provide instruction at remote sites—the open-university model.

Alternative approaches to teaching and learning designed to meet these changing requirements are made possible to a significant degree by the availability of computer technology, but the challenge to the responsible teacher is enormous. The quality, effectiveness and success of CAI programs depend primarily on the support given to them by responsible faculty, individually and collectively, in the various disciplines. Excellence in new and more flexible approaches to teaching and learning can be attained only as these responsibilities are clearly defined and accepted by disciplinary faculty members. More is required than the mere introduction of new techniques and technologies in a variety of otherwise unchanged courses, and no educational technologist can supply the needed expertise. In political science, therefore, it is political scientists who will have to analyze the structures of knowledge and the criteria of performance, if they hope to use computers to make their teaching not just more fashionable, but more effective.

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Chapter 2.
CAI: What's in it for Me?

Paul Siegel

"We have harnessed our technology to reach the moon; we must now harness technology to teach our children!" So urges an invited public figure in a keynote address at one of the numerous national conventions of educators or educational support industries. The precise convention is not important since these words or their florid counterparts will be echoed at almost every gathering. What *is* important is the belated confidence these words betray--that the newly developed technology can and *should* be used to take yet another "giant step for mankind." And the bandwagon grows.

This confidence may seem naive. Yet it has some grounds. Today few knowledgeable people would deny the potential of computer-assisted instruction. Some have compared this potential to the revolution which followed the introduction of mass printing. Says Patrick Suppes, "Just as books freed serious students from the tyranny of overly simple methods of oral recitation, so computers can free students from the drudgery of doing exactly similar tasks unadjusted and untailored to their individual needs."[1] One major motivation for teachers to use CAI, then, is the fact that it can probably help them do their job better.

Sustained investigation into the possibilities of CAI began in the 1960's, and the results of experimental studies have been very promising. They show that, with CAI, we can have better defined instructional objectives, more varied and effective instructional strategies, greater accommodation of individual differences, and better evaluation of the instructional process. Teachers, when relieved of tedious and unproductive monitoring of the drill and practice or tutorial situation, are able to spend more hours in activities requiring personal mediation. As a result, students receive more precise recognition of their needs for remediation or enrichment in all areas, and appropriate material is provided at the proper moment. Valuable data on the learning process are accumulated with the consequent improvement of educational techniques in the classroom as well as the CAI laboratory. In short, there is generally a more productive use of the teacher's and student's time, and a significantly higher level of achievement on standard examinations by students using CAI when compared to control groups.

For example, students enrolled at the State University of New York at Stony Brook in the Introductory German course and placed in the group which was assigned one lesson per week in the CAI laboratory did significantly better in reading and writing—although no time was spent on this in class.[2] And the instructors, able to spend more time on conversation and dictation, raised performance levels in these areas as well.

In describing the computer-based education system at Illinois/Urbana, Donald Bitzer states that "The teaching versatility of a large-scale computer is nearly limitless."[3] John Pierce in his report, *Computers in Higher Education*,[4] asserts that at least 35 percent of college undergraduates are enrolled in curricula in which they could make valuable use of computers, and an additional 40 percent are in curricula for which introductory computer training would be very useful. And Fred Tonge, at the University of California, overcomes his uncertainty and grudgingly accedes. "Education by computer," he admits, "is basically a good thing. In fact, we may have to automate just to get the job done; there won't be enough teachers, or sufficient high quality instruction in problem areas."[5]

In spite of its promise, the recommendation that the computer be used as a remedy for some of the pressing problems of our over-burdened educational systems frequently meets with a cold reception. On the whole, most educators have their lives pretty well adjusted to the status quo. Most will probably resist any major disturbance that requires a radically new frame of reference. In addition, many educators have a healthy suspicion that faddish computerization might ruin education instead of improving it.

Adapting the System to CAI

How, then, can the advocates of computers in education motivate teachers to accept them? The first thing to do is to clarify that the intelligent use of computers in instruction will not displace human teachers; it will make their role more attractive instead. Rather than attempting to do everything by computer, we must look at the system and ask fundamental questions. What *is* education? How can the computer fit in? Some of the activities crucial to instruction can presently be programmed; others cannot. Care must be taken that tentative decisions are not implemented in rigid software, difficult to change. Given the flexibility of even today's hardware and software, there is no excuse for this to happen. We need to explore many different technologies and approaches. The tendency, today, to blow up small amounts of experience as definitive is a serious mistake. The computer should free us to try many instructional alternatives—not put us in an educational straightjacket. If we are going to design programs for a constantly changing society, we must learn to design programs which will never be completed. They must be continually evaluated and revised, and instructors must learn to see their role as an evolutionary one always determined in part by present and future developments.

Duncan Hansen and William Harvey of Florida State University, Tallahassee, have come up with a preliminary guide to some of the new ways in which techers may be encouraged to regard their new role when aided by computers:[6]

1. The teachers will perform much less of the informational presentation functions presently found in our classrooms. Undoubtedly, the teacher will become more involved in the managerial and strategy functions found in the sequencing and evaluation of the instructional process.
2. Teachers will play less of the corrective role in terms of their questioning and evaluative behaviors. This undoubtedly will offer a significant step forward in teacher-student relationships in that much of the negative verbal behavior observed in classrooms will now be shifted to a more individualized and private interaction within CAI.
3. Teachers will become more concerned with the host of individual characteristics important in designing an instructional strategy; thus, the array of instructional resources will become more complex. . . .

If history seems to disclose a pattern of workers dispossessed by machines with no new roles created for them, this need not and should not be the pattern in education. The image of the computer as a teacher substitute needs considerable revamping.

This evolution, however, cannot be left to take place without planning. The behaviors characteristic of the modern teacher should be included in any consideration of system changes, and proper training provided. Various requirements of the system can be taken into account, and efforts can be made to maximize the system's chief output—education.

The building of a system model should begin with some clear and precise statements of the expected outcomes of education. Second, the existing system might be analyzed to determine current teacher behavior, the relevance of these behaviors to the proposed system, those aspects of the current system which can be eliminated, and those aspects which must be accounted tor in the new model. Next, the various elements which must be supplied by the system in order to provide students with that "hierarchy of capabilities" necessary to achieve the anticipated outcomes are listed.[7] Then the components of a system that can best help the student to acquire these capabilities is delineated, with each component—teachers, non-teaching professionals, computers, etc.—allocated to the activities it is best equipped to perform. And finally, the essential training programs that provide each person with the necessary skills to perform those activities assigned to him must be developed. The changes can be made less painful and more efficient if the requisite planning is done.

Economic Motivation for the Author

Computers in education should not replace teachers, nor relegate them to instructional delivery technicians. Teachers should be active in the production of instructional programs when they have access to computer assistance. If we assume that teachers can be convinced to appreciate their changed role sketched above, it is still extremely important to make the development of CAI curriculum as inviting a task as possible—economically as well as intrinsically. There are three conditions that must be met, if the authorship of CAI materials is to become economically rewarding: (1) the cost of CAI as a whole must be lowered, (2) the time demanded of an author must be reduced, and (3) a system of use-based compensation of authors must be put into practice.

Costs have been a recurring problem in almost all aspects of computer-based instruction. For CAI applications, in particular, costs per terminal hour are relatively high and have not yet made the dramatic advances common to the rest of the data processing applications.[8] Much of the cost is associated with the terminal hardware itself, and efforts are being made to revolutionize terminal technology.

One cost-cutting advance is a plasma display developed by Donald Bitzer at the University of Illinois. It purports to solve some of the problems associated with the video display devices currently available and will eventually decrease the cost of maintaining an image on display, while increasing the number of terminals (and hence students) that can be handled simultaneously by a given computer.

The long-term trend and the most informed forecasts all point to lower costs in the future, as devices like this are perfected and introduced. As it becomes less expensive to use computer-based instructional programs, the ratio of return will grow, and along with it the amount of money available to compensate authors.

Nevertheless, technical improvements or reduced hardware costs will not suffice. It must be understood that the cost of computer-based instruction is only partially the cost of the computing system and equipment. The instructional materials and the programs are also key factors.

Experience shows that it takes a number of iterations on course materials to gradually perfect the text, refine the conditions of interaction, and choose the appropriate determinants of student progress through a course. In addition, rational pursuit of improvement frequently leads to experimental variations that test alternate versions of essentially the same course. All these iterations and variations would make the production of effective course materials very time-consuming and costly if there were no efficient means of automating certain aspects of the process.

Standard computer programming languages are not suitable for the preparation of CAI lessons. They require a programming proficiency that course authors seldom have or desire to obtain. And the services of experienced programmers are usually costly. In addition, the duplication of effort that generally results where an author works directly with a programmer to produce a course contributes to the lack of cost effectiveness in evidence at many ambitious CAI projects.

Teachers must be convinced to use CAI in the first place, and they must be notivated to provide the raw material for lessons. To do this, it should not be necessary that they become programmers. There should be a way for them to specify, in fairly natural language, which material is to be presented to the student and how it is to be presented. All unnecessary obstacles to man-machine communication must be removed at the author's level. The power of the computer should be at the author's disposal, but the control of that power should be relatively simple.

Fortunately, the computer makes it possible to design content-independent instructional procedures, which can be stored in a library for repeated use. Over time, more and more procedures are stored, revised with experience, and incorporated into easy-to-use packages, whose workings are described in Chapter 3. The computer's capability for routine collection of response data enables the curriculum designer to better analyze the process by which various skills are acquired. Such analysis can then be used to further optimize the learning procedure. The result is a commonly accessible and growing library of tested, effective instructional procedures each of which can be described to an author as a sequence of instructional events. Optimization strategies that in the past were usually too complex to incorporate into, or evaluate in, an instructional setting have been made accessible to use and investigation by the ready availability of many packaged procedures. This process, over a period of time, results in an orderly, efficient, and reasonably economic system for CAI course preparation.

As more people get into the activity of designing CAI procedures for public use, it will be important to cultivate an awareness of the fact that the development and evaluation of programmed instructional procedures is a time-consuming, expensive proposition requiring areas of expertise that are multi-disciplinary. When such an investment is made, therefore, we should be assured that each package is as flexible as possible in its parameters and can be tailored to courses in many areas. And completed courses should be amenable to modification at nominal cost. It is also essential that instructional materials and authoring packages into which large sums of money have been invested be capable of transfer from one institution and system to another.

However, for a system which supports authors in the act of creating CAI courseware, it is not enough to remove technical impediments from the production process. Positive incentives are also needed. The system must provide suitable proprietary protection with provision for royalty, thereby encouraging authors to invest their time and expertise in this activity. If anything, the development of computer-based learning materials requires more complex skills than does textbook writing. And, given the limited prestige attached to this activity, many educators write to make money.

At present, CAI authors, if compensated monetarily at all, are compensated on a one-time basis with all materials then placed in the public domain, or becoming the property of the hardware distributor. Recently two commercial hardware manufacturers, Digital Equipment Corporation and Hewlett Packard, engaged in major projects to produce instructional units. Both of these projects relied on a lump-sum payment to the authors because of what was termed "the investment of time necessary to maintain records of individual sales and pay royalties accordingly."[9] IBM relies on their IUP (Installed User Program) system to compensate authors. But this, too, is based on a single-payment distribution mechanism. This situation exemplifies the present primitive state of the market for CAI materials and the low level of incentives for their production.[10]

Preparing a good CAI course is roughly equivalent in effort to writing a good textbook. Most authors are quite willing to produce textbooks at a 10 to 15 percent royalty rate. But many good authors will undoubtedly be lost to CAI if we do not offer them similar incentives to produce the material for computer-based instruction. The involvement of subject-matter experts in computer-assisted instruction deserves high-priority attention. Any CAI system is only as good as the curriculum which it can place at the students' disposal. The best possible hardware with light pens, slide projectors, audio units, and the like acts only as a vehicle to carry out the programs of educators. In our enthusiasm for new delivery systems, we must not lose sight of this fundamental fact.

The technology that permits procedures which can assure authors of adequate protection and return for their efforts already exists on the very large, network-type systems supporting thousands of terminals simultaneously. These systems, such as MULTICS now being marketed by Honeywell to run on its 6100-series computer, typically have elaborate operating systems with sophisticated accounting procedures and the required protection for proprietary information. Courses can be stored centrally on such systems and accessed anywhere, with the user charged on a per-use, per-hour, or per-course basis.

However, recently it has become evident that we need not invoke the economics of giant systems to achieve cost-effectiveness per terminal hour for CAI service. Current technology allows a very small computer system supporting in the neighborhood of 32 terminals to compete with, and provide in some ways better and more reliable CAI service than, the very large centralized machines. These mini- and micro-computers cannot, unassisted, support the kind of elaborate security mechanisms needed to insure adequate protection of proprietary materials. Nor can they supply the necessary accounting procedures to guarantee royalty payments. Nevertheless, there is an answer which is, in some respects, even more satisfactory than a well-functioning accounting system.

The packages described in Chapter 3 would produce courseware coded for cassettes rather than for assembly on a centrally located direct-access device. The small computer system would be required only to enforce the policy that no cassette be played through to the end more than once. This could be implemented in a number of ways using the same underlying principle. For example:

1. The material on each cassette is encrypted with a unique cypher which is also recorded on a magnetic stripe credit card associated with the cassette and purchased with it by the student.
2. The system reads the appropriate cassette after the student has logged on using his credit card. If the cypher does not match the one on his cassette, the student is logged off automatically.
3. If the cassette is positioned at the first record, and it is a legitimate first record (i.e. never read before), that record is changed to a special code which signals the system to log the student off if it is ever read-in again.

The student purchases a kit which includes a cassette, a credit card for the course, and, optionally, any auxilliary materials such as a workbook. The price of the kit is set to recover the cost of purchasing, or leasing, the computer system in addition to returning a profit to the publisher, and a royalty to the author for *each* use of the course--this would surpass even textbook royalties based on book purchases since a book may be re-sold and re-read by another student.

If the average course were to fit on two cassettes, the cost of the distribution materials might be less than $1. The kit, sold at a price comparable with a textbook ($15), could realize a $3 return for the publisher, and a $1 royalty for the author. The educational institution could receive $8 to defray system costs plus $2 for unusual operating expenses. These figures are, of course, only meant to convey a sense of the feasibility of this approach and are in no way hard and fast.[11]

Such cost-effective, small, dedicated, decentralized systems for delivery of CAI services would have a further valuable by-product: reinforcement of the diversity which is such an enduring part of the American educational credo. "There is really no single educational goal; indeed, the beauty of the decentralized American school system is that each . . . is in effect a separate educational 'laboratory.' "[12] CAI systems like the one described could in fact help colleges and universities achieve local control and autonomy with regard to the development, evaluation, and management of computerized educational processes. At the same time, incentives which are likely to attract the best among curriculum specialists can be offered to authors, thereby guaranteeing the development of superior curricular materials. And finally, once such a method of producing CAI materials is accepted, it will generate renewed interest among publishers who have the packaging, warehousing, and marketing organizations needed for efficient widespread distribution of curricular material.

The eventual impact of computers on education will be enormous, as great as the advent of mass printing once was. Computer-based instructional systems present one of the few means possible of fulfilling the growing demand for higher education while retaining the adaptability of such education to individual learners. Computers offer a viable technology which can meet effectively the crisis of numbers vs. quality in higher education.

FOOTNOTES

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Chapter 3.
Authoring Made Easier: How CAI Packages Work

Paul Siegel and Jonathan Pool

Almost no-one finds it painless to write a good textbook. It is an intellectual challenge to put oneself into the shoes of the learner, and it is even more difficult—if not impossible—to do so in such a way that the product will be satisfactory for many different users who learn at different speeds and in different ways. How formidable is the task of writing CAI lessons, then, in comparison with that of writing a textbook or workbook?

With CAI, the basic problem of bridging the teacher-student gap remains crucial. But the secondary problem of having to design a single set of materials for a heterogeneous audience is not so serious, because CAI lessons are *not* the same for all students. Since lessons can be programmed to alter their own content and sequence in dynamic response to student performance, no two students need ever go through exactly the same form of a CAI lesson. This enormous flexibility brings with it a new challenge not faced by the authors of textbooks and faced in only a rudimentary form by the authors of workbooks. It is the challenge of anticipating what the different kinds of students will be, how they will differ in the learning problems they have, how their individual needs can be recognized, and what special treatments they can be given to help them achieve the desired learning goals. Chapter 1 went into these problems and suggested some guidelines for coping with them.

Given the desire to respond to these challenges, how do you, the political science teacher, actually proceed, if you have access to interactive computer facilities and want to try CAI as part of your teaching repertoire? If appropriate CAI course material already exists, you may be able to obtain a copy usable at your installation. This is not very often the case at present, since the number of CAI sequences in political science is currently very small and the technology for transforming CAI programs among dissimilar computer systems is still primitive. We expect this situation to change, however, and even now the question is still worth asking.

In the most common situation, you will thus be faced with the prospect of writing your own materials. Let us suppose that what you want to write is a set of lessons or exercises designed to supplement (or perhaps replace one of) the modes of instruction you presently use. You will naturally want answers to two questions: (1) What do I have to learn in order to begin writing? (2) What is involved in the writing process itself? These are the questions to which we shall provide brief answers in this chapter.

The job of the contemporary CAI author can be best appreciated by contrast with two extreme possibilities. In the most luxurious of all possible worlds, the director of the campus CAI lab would say, "Of course, professor. You just tell us in your own words what you would like the computer to do, and either our staff will find a way to make the computer do it or we'll ask you to revise your request." In the leanest possible world still endowed with CAI, the offer would be, "You give us the program on tape, and we'll mount it."

For the large majority of political science instructors with any access at all to CAI facilities, the former world is a thing of the past or the unforeseeable future, and the latter world is unrealistically dismal. The world of tomorrow, and of today in some colleges, is a world of packages, which authors will be expected to learn how to handle themselves, but which are incomparably easier to use than a CAI programming language. You are probably familiar with the existence of computer program packages in data processing. Most professors and students who want to process data wish to carry out a common procedure, such as word-counting, regression, or cross-tabulation, on an uncommon set of data which they have at hand. Packages like the General Inquirer, DATA-TEXT, OSIRIS, and SPSS allow them to make choices among certain sets of alternatives. This task can be learned and carried out quickly by computationally unsophisticated users. CAI packages, which have begun appearing relatively recently, are analogous. They make accessible a variety of common instructional procedures and alternatives, which users (i.e. authors) can apply with relative ease to their own subjects. These procedures are independent of subject matter, and the bulk of them are general enough to fulfill learning objectives across many disciplinary boundaries.

With both kinds of packages, the user selects options by submitting a deck of control cards for computer processing, or by answering questions which the packaged program asks the user through a computer terminal. In both cases, only commonly demanded options are offered, so the most idiosyncratic users must either modify their desires or, bypassing the package, write their own procedures. But in both cases this limitation is being progressively relaxed. Packages are becoming more versatile; individual users' special procedures are getting documented and stored in libraries available to other users; and jacks are getting built into more packages to allow users to switch from package to package or to plug in a custom-made procedure where necessary, while still using the package where appropriate.

We believe that this trend toward increased versatility will continue in the future for CAI packages as well as data processing packages. Hence, for almost all political scientists, the two questions posed above can be translated: "What is involved in learning to use a CAI author's package and in actually using it?" In the remainder of this chapter we shall try to answer this question both quantitatively and qualitatively.

Using a CAI Package

Quantitatively, a rough estimate is that it will take something like five hours to learn how to use an author's package reasonably well. This can be done in a workshop, or by reading a manual, or through an instructional program. (In the latter case, you are undergoing CAI lessons on how to write CAI lessons.) Thereafter, an experiential estimate is that 5 to 10 hours of writing are required for each hour of computerized first draft ready for trial use with students. Your time expenditure can be cut still further, although not much, by the employment of an assistant to translate your desires into commands acceptable to the package. On the other hand, a need for extensive preliminary research and model-building, as illustrated in Chapter 4, would raise the estimated investment of time greatly. When observation of the lessons in action and analysis of the performance data reveal the need for further editing of the lesson material (which is normally the case), a package allows this editing to be carried out with roughly a proportionate amount of effort: rewriting 10% of a lesson takes something like 10% as long as it took to write the lesson. This is because the package separates content from procedure and one portion of a lesson from another portion, where possible. Whatever needs to be modified can be, and the rest remains intact. For comparison, estimates of the writing effort when no package is available and the author must program lessons directly in a programming language range from 100 to 200 hours of programming per hour of resulting lesson. Learning a programming language also takes far longer than learning to use a package, and the detection of all programming errors made by the author is usually impossible. The package, on the other hand, contains code which has been tested to the point where it is virtually bug-free.

Qualitatively, the process of using a CAI package is likely to be a continued accommodation between what you would like to do and what you can do. Procedures which you might have liked to try out but which are not available may become modified, in practice, so that a packaged procedure can be used. At the same time, procedures that you would never have thought of implementing, perhaps because of their complexity, may be used when you see that they are available in a package. Sometimes, of course, this can take the form of technological infatuation, a danger which is equally present to the users of data-processing packages. The great range of possibilities offered by packages obviously puts increased responsibility in the hands of the author for selecting appropriate procedures. Often you may want to select more than one and see how their results compare; the student performance recording which the package automatically provides will assist you in subsequent evaluation. One important qualitative difference between using a package and programming your own material is that with packages the primary effort is dedicated to developing and elaborating instructional strategies and textual material, while programming forces authors to spend most of their time figuring out how to get the machine to do what they want. Individually programmed materials inevitably contain undetected errors, which become obvious only during student use and require rushed remedial action. With packages, on the other hand, procedural errors are much rarer, and attention can be devoted to such problems as substantive misunderstandings.

Packages are under continual development, but for a concrete idea about what can be done with them let us look at some of the procedures currently available in packaged form.

Three Examples

Example 1: LISTGEN. This is a procedure for varying the frequency of presentation of a stimulus depending on the response difficulty encountered by the student. It can be used when there is a large set of stimuli and you want to be sure that each student has given the correct response once to each stimulus with only one try. You provide the bank of stimuli, a corresponding bank of cues, and a corresponding set of correct answers. The stimuli might, for example, each consist of a term and a numbered set of possible meanings for the term. The corresponding cues might consist of sentences in which the terms are used. With this information, the package generates a CAI program which selects a working subset of approximately 24 stimuli from the bank and presents one of them to the student. If the student correctly responds to the stimulus, it is removed from the working subset, a new stimulus from the bank joins the working subset, and the next stimulus in the subset is presented. If (s)he responds incorrectly, the cue is displayed and (s)he is given additional opportunities to respond. When (s)he finally does give the correct response, the stimulus is not removed from the working subset, but is reinserted at a position determined by the number of attempts the student made before getting the right answer. The most frequently and most badly missed terms are thus seen most often. When the bank has no more terms and the working subset is also exhausted, the lesson is terminated and a new lesson may be initiated which draws on another bank of items.[1]

Example 2: PATMATCH. Pattern matching is a teaching and testing technique employed frequently across many disciplines. Often it is used in its multiple-choice rather than its constructed-response format. For such exercises, a procedure is available which considerably reduces the author's input relative to the number of problems generated for the student. You merely enter a list of subfiles plus a standard instruction. A simple example is:

(1) Secretary General
General Assembly
Security Council
UNESCO

(2) Office of Management and Budget
Capitol
Secretary of Defense
Interstate Commerce Commission

(3) Governor
Lieutenant Governor
National Guard
Board of Regents

(4) Mayor
Dogcatcher
School Board
City Hall

Instruction: Choose the institution that is most likely to belong to the same "level of government" as the first one given.

The package generates a program which in turn randomly generates problems from these files. One such problem might be displayed as follows:

Choose the institution that is most likely to belong to the same "level of government" as the first one given.

Secretary of Defense

1. National Guard
2. Mayor
3. Interstate Commerce Commission
4. Secretary General

The student has an extremely large group of problem possibilities to work on until mastery of the conceptual distinction being taught here ("levels of government") is achieved. Thereupon, (s)he might work on a more difficult version of the same exercise, or on an exercise using the same stimuli newly ordered for a different distinction (e.g. "institutional type").

Example 3: CLUEGEN. This is a more versatile packaged CAI procedure, particularly likely to be of use in non-quantitative applications. The basic strategy of this procedure is the following:

1. present instructions (directions, learning objective, examples of expected performance)
2. present stimulus (question, problem, etc.)
3. request response
4. process response (compare with answer set and determine closeness of match)
5. determine appropriate feedback and subsequent sequence of remaining stimuli
6. present next stimulus according to the determination made in 5 above
7. continue from point 3

Typically, you provide the package with a bank of clues to be displayed to the student in sequence as the student gives incorrect responses to a particular question or problem. When the last clue has been displayed and the student still gives the wrong answer, the computer displays the correct answer. After the correct answer has been given by either the student or the computer, the lesson proceeds to the next item.

This basic pattern is subject to numerous modifications. You can determine where on the screen the question or problem appears (if the terminal displays output on a screen rather than paper). You can determine whether the clues overwrite each other or whether each clue appears below the previous one leaving it intact. You may provide for more than one correct answer, any one of which will be accepted as such. You can also specify temporary right answers, i.e. answers that will be considered correct only if given just after the display of a particular clue. When the right answer is given, it can be underlined and the course can go on, or, if you prefer, a special right-answer message can be displayed as the last action of the program before proceeding. Another option is to ask the student whether (s)he wants to see all the clues remaining in the bank after getting the right answer. Or, if you feel the clues are of value to all students, you can instruct the computer to display all remaining clues at the end of each item without asking the student's permission. When the last clue has been displayed after a series of incorrect answers, the program will give the correct answer to the student (in the case of several alternate answers, you specify which one the computer should choose). Then, if you have so requested, the computer will ask the student to type the answer as displayed and will not go on to the next item until (s)he has typed it correctly.

You have more than a single bank of clues at your disposal to help put the student on the right track. The clues referred to above were general ones: any wrong answer would bring forth the next clue. In addition, you can provide response-specific clues. If you anticipate that a particular wrong answer is likely, you can direct the computer to reply to that answer, whenever it is given, with a special clue. For each item, several different expected wrong answers can each be programmed to call forth their own response-specific clues. When any other, unanticipated wrong answer is given, the next *general* clue will appear.

In addition to these two types of clues, you may decide whether to provide a special dispensation known as "percentage feedback." With this feature, a subroutine is invoked to check wrong answers for the possibility that they are, for example, really just misspellings of one of the right answers. If the answer falls within the author-specified percentage of correctness (in our example, thus being classified as a misspelling), then its correct characters are put back on the screen in correct positions, with blanks where characters were missing, and the student is given a chance to correct the answer. Such a feature can be quite handy when, let's say, the desired answer is "probabilistic," which almost no-one spells correctly the first time around. There is, in addition, a special signal to tell the student that the answer (s)he has given contains the correct answer within it, but also contains incorrect or irrelevant material.

With CLUEGEN, you can decide almost as you see fit what scoring formula to use. Different general clues and different response-specific clues can, when they appear in response to a wrong answer, subtract different amounts from the student's score, depending on the relative deficiency that you think the need for each particular clue indicates. Students' scores can be displayed to them periodically or kept secret, as you prefer. The score received on a given problem or question may be used to determine whether the student encounters it again at a later point. For each problem, you specify how bad a score the student needs to get in order to make the problem reappear. If the score is worse than this level on the repetition as well, the problem is later repeated one more time. Clues need not be the same for each appearance. So, for example, if you think that anyone encountering a particular problem for the third time must be misunderstanding the clues, you can provide a special, easier bank of clues for the third appearance.

Randomization is available when desired: the items (problems) can be presented in random order, or the (general) clues within an item can be randomized. Sequencing can further be modified by skip and exit commands. The author can, in other words, decide that the achievement of a particular score at a given point in the course should exempt the student from the items that follow until a new topic is reached. By the same token, of course, the invocation of such score-based routing can be used to give special remedial work to students having particular difficulty.

As can be seen, CLUEGEN allows you to do many different things, and hence requires you to make many choices. You supply the text of each question or problem, the text of each clue, and the text of any final message to be shown after the correct answer is given. Obviously, you also specify what the correct answers are. In addition, you make all the other choices mentioned above, and several not mentioned. There is a total of 65 parameters, at present, which you can set in your CLUEGEN input deck, i.e. 65 different kinds of choices that the package allows you to make. Normally each choice requires punching one or two control cards, following the format and instructions in the manual for the package user. But this freedom to choose among alternatives does not mean that you are burdened with preparing a painfully large number of control cards. A parameter, once set, remains set until and unless it is reset later in the input deck. Further, every parameter has a default, i.e. an alternative that the package designers expected to be most frequently chosen. If you accept this alternative, you need not specify anything. Thus, in general, off-beat lessons will require more control cards than typical lessons; and inconsistently off-beat lessons will require the most cards of all. But even the most cleverly complex CLUEGEN input deck can be put together in a fraction of the time it would have taken to write the CAI lesson program that this deck generates.

There may be contingencies, of course, which CLUEGEN does not provide for. One example is the sophisticated analysis of the student's response according to some special rule. Situations like this can be taken care of by the "jack" built into CLUEGEN. In place of any clue, a special program provided by the author can be invoked, which sends its result back to the CLUEGEN-produced program for further processing.

CLUEGEN is organized into a hierarchy of instructional units. The highest level is the *course*. Courses are divided into *segments*, these are divided into *lessons*, these into *modules*, and these into *items*. The various parameters are not all set at the same level, but each at what seems the most appropriate level. Student scores, for example, can be shown at the end of each item and/or module; they can be shown at the ends of the items in one module, shown only at module-end in another module, shown at both item- and module-end in another module, and not shown at all in still another module. For purposes of problem repetition, the module is the unit of aggregation. Items on which the student score dictates a reappearance are put back at the bottom of the module's stack and reappear after the other items in the module.

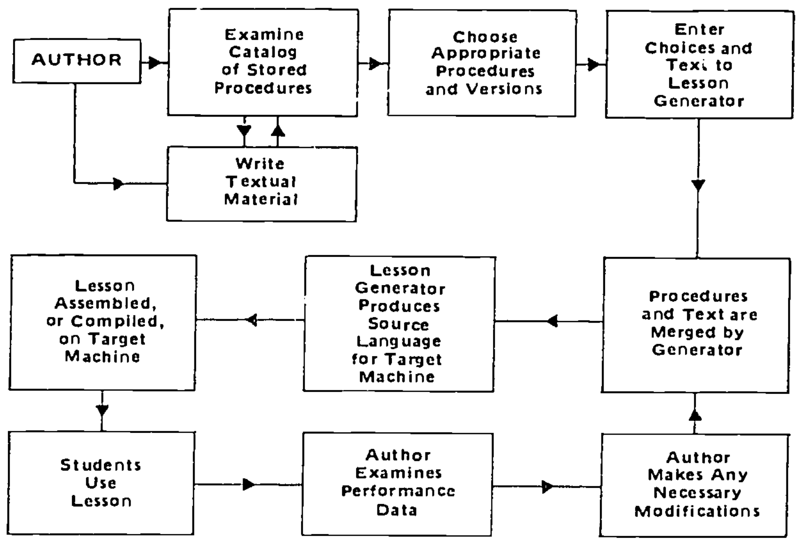
In accordance with this organizational scheme, a lesson might consist of all the material that students were expected to go through in one sitting, analogous to a chapter in a textbook. This lesson, in turn, would have several modules—perhaps one module of reproduction items, one of recognition items, one of practice items, and one of application items, to use the classification of Chapter 6. Or there could be modules of several levels of difficulty, and remedial modules, which would be executed or skipped depending on each student's score up to the end of the previous module.

A few examples of political science applications of CLUEGEN are shown in Chapter 6, so additional illustrations will not be given here. This survey of three available packaged procedures should suffice to illustrate some of the things you can do if you wish to write all your material with packages, and if your computing facilities allow you to use such packages.[2]

Correcting and Revising with a Package

"Authoring," however, means more than writing, in the jargon of CAI. It means debugging, testing, evaluating, revising, redebugging, retesting, and so on. Hence one should not forget that packages have the valuable asset of providing for the recording of many useful data during program execution. Every student response, the display of every clue, every lapse of a response deadline, every score—in short, every step of the way for each student in the course is recorded on tape. These data are available for analysis—including with data-analysis packages like SPSS—to find out which students are having which problems, which items appear unclear, which unexpected wrong answers are appearing often and might be provided with response-specific clues for the next edition, and so on. Furthermore, since experimentation is often a part of CAI materials evaluation, the infallible memory of the computer can be tapped to measure the differences in student performance between two different versions of a course (e.g. one with and the other without the compulsory display of all remaining clues). Because of the modularized way that packages are constructed, and because a single control card can set a parameter for a whole lesson, a change in any of the available choices can be made in minutes (even if it affects the presentation of every item in the lesson), and the new version of the instructional program is ready to use. Thus revision is quick, and the preparation of two versions of a lesson for experimental comparison is hardly more difficult than the preparation of a single version.

The entire authoring process, when a package is being used, looks something like this:



The package is essentially a computer program that, with instructions from the author, produces (or "generates") another computer program. This output program is one which will run the desired CAI lesson. The generation of the program may take place on one computer, and the resultant program may then be taken (on tape, etc.) to another computer which delivers, or executes, the actual CAI lessons. Likewise, the package can be written in one programming language but generate lesson programs in another language. Ideally, users can request that their output programs be written in whichever languages are suitable for the computers on which they intend to run their lessons. Thus a single deck of control cards could be used to generate similarly functioning CAI lessons for two different computer systems—a job that would otherwise require writing the lesson programs separately in the two appropriate languages.

Besides producing output programs, a package also generates print-outs to assist users in checking to see that they are getting what they intended. A print-out may contain applicable error messages, a copy of the input cards, a printed duplicate of the output program that is being written onto tape for later use, and a summary of the resulting lesson.

The printed summary may take a number of different forms. In CLUEGEN, for example, all the items can be shown, or just one or two items from each module. For the items that are shown, the problem, the set of anticipated responses, and the clue bank may all be printed out, or just the problem and the response set, or merely the problem (perhaps for use in a pretest). The print-outs are useful for proofreading and also as documentation from which other institutions can quickly determine the applicability of the material to their needs.

In conclusion, CAI packages serve two main purposes: to economize the efforts required to create computer-based lessons, and to facilitate the sharing of such lessons among institutions. We expect progress on both fronts to continue in the near future. We believe we shall witness the development of these packages, within a few years, to be point where they can be used not only in batch mode, with control cards, but also interactively, so that the author is prompted by the package itself to supply the needed text and parameter choices at a terminal.[3] We also anticipate that in time the major packages will achieve wide transferability, so that a version of any course for delivery on any system can be produced quickly and inexpensively.

FOOTNOTES

1. The procedures described here have been reported on in several unpublished conference papers and internal reports, by B. Weneser and others. Two recent articles are B. Siegel, "The Stony Brook Author System: How it Facilitates Curriculum Development," *ACM SIGCUE Bulletin*, 6 (no. 4, Oct., 1972), and D. McMullen, "Generative CAI: Procedures and Prospects," *Educational Technology*, Feb., 1974.

2. The complexities of making a particular package work at a particular college are so varied and changing that no generally applicable advice can be given here. Also, packages are under continual revision and new ones are springing up. At present, those interested in choosing among available packages and using one or more of them at their colleges will probably find personal consultation to be the only source of reliable information. The best place to start, at colleges without a CAI laboratory, is probably the campus computing center. For general information on problems of transferring CAI programs from one campus to another, or of producing programs usable at many different installations, see J. J. Turnbull, "Transferability of Computer Software for Education," and A. Kent Morton and Arthur W. Luehrmann, Jr., "Project COMPUTe: A Mechanism for Producing and Distributing Instructional Material," in *Computers in Education/Informatique et enseignement*, ed. O. Lecarme and R. Lewis (New York: American Elsevier, 1975), part 2, 989-97. One obstacle to transferability is that terminals at different places are endowed with different capabilities. Some write on paper, others on screens. Most display in black and white, but some display in color. Some can print only letters, numbers, etc., while others can display anything. Finally, auxiliary devices such as microfiche projectors, filmstrip projectors, tape recorders, light pens, music keyboards, and speech synthesizers are attached to some terminals to permit more variegated student input or computer output.

3. Cf. Roger E. Levien et al., *The Emerging Technology: Instructional Uses of the Computer in Higher Education* (New York: McGraw-Hill, 1972), pp. 504-5.

SECTION II.
PRACTICE

Chapter 4.
Playing Politics:
Reflections on an Experiment in Computer-Based Education

Fred S. Coombs

One difference between magicians and computer-assisted professors is that the professor is always ready to tell how he did it. In this narrative I would like to reminisce a little about our Political Process Inquiry (PPI) project[1] at the University of Illinois, Urbana-Champaign—how we used computer games to captivate students in our introductory American government courses, taught them something about political processes and, at times, succeeded only in mystifying them.

Many of our ideas worked well; some did not. In either case, those contemplating similar kinds of curriculum development may profit from our experience and assessments. There are also the inevitable afterthoughts about how we could have done something better, and visions of what we might be doing now if we had just a little more time, talent, or money.

In the Beginning

It was the fall of 1966 when the political science department first looked carefully at a system of computer-assisted instruction—impertinently named PLATO (Programmed Logic and Automatic Teaching Operation)—being developed on our campus. However technologically complex, the logic of the thing seemed simple enough. Students sitting in a booth equipped with a typewriter-like keyboard and a television-like screen (CRT) could interact with a large, pre-programmed computer (CDC 1604). By pressing the usual alpha-numeric characters, plus certain "function" keys (e.g., "NEXT," "HELP," "JUDGE," or "COMMENT") the student provided input to the computer, which was programmed to respond instantly by plotting text or diagrams on the screen. The computer could also select an appropriate 35 mm photographic image from a slide bank for superimposition on the same screen. Thus, in a straightforward program, the student might be presented with, let us say, a problem concerning Ohm's law on the screen, would type in an answer, have it judged by the computer, and, if correct, move on to the next sequential step. If the answer were incorrect the computer could supply "help" routines designed to remedy the difficulty, then let the student try again.

Almost immediately, however, instructors began to design more imaginative teaching logics which the system could also accommodate. A course in practical nursing called upon the student to ask for relevant information about the patient, make a diagnosis, and prescribe proper treatment. A chemistry unit presented an "unknown chemical" which the student was to identify by performing certain "tests" upon it and eliciting data about its molecular structure. Students in a genetics course could perform the familiar "fruit fly" experiment (which takes weeks in a laboratory) in minutes on the PLATO system and see the results of their manipulations neatly portrayed on the screen.

Even the uninitiated professor could become proficient at "authoring" PLATO programs relatively quickly, by virtue of a unique near-English language called TUTOR especially designed for computer-assisted instruction.[2] A teaching program could, in fact, be developed by an instructor from any of the student terminals by simply switching into "author mode." The system also automatically stored the record of every keypress made by each student and this record could be retrieved by the instructor at a later time for analysis of student performance. With a little additional programming, it was even possible to obtain summary statistics of the performance of a class of students, such as the percentage who had required "help" on a given task, or the average length of time taken to solve a certain problem.[3]

Students worked through the programs at their own rate, although a program might prohibit them from moving to the next task until a given level of mastery was obtained on an earlier one. By the same token, students who displayed a command of the subject matter early in a sequential program might automatically be skipped to material more appropriate for their level of competence.

The most distinctive feature of the system, when compared with most other CAI systems, was the almost unlimited flexibility it provided the author in the design of instructional programs. There was ample computing power and space to present sophisticated, complex instructional programs to about thirty students at the same time. It was, even in its early stages, a system which imposed relatively few constraints upon authors, and program designers frequently found themselves changing their approach in mid-lesson as new better ways of achieving objectives became apparent.

Technically, PLATO has undergone major changes in the ensuing decade, but from the author's viewpoint the basic logic is much the same.

Some of the changes have been economically inspired. The student terminal has been redesigned, in PLATO IV, with the CRT screen now replaced by a "plasma display panel." This permits linking the terminal to the central computer configuration by means of existing telephone (rather than video) lines--a major economy when contemplating several thousand terminals blanketing a state. Photographic slides are no longer centrally located but prepared on a fiche which each student inserts into his own station for rear-view projection on the screen. A random access audio device (under computer control) and a "touch panel" feature (to permit student input by touching the screen rather than pressing keys) are optional with the new terminal. The CDC 1604 computer has now given way to a CDC 6500 with vastly expanded auxiliary storage and retrieval capabilities. The TUTOR language has evolved into an even more powerful, if somewhat more imposing, means of coaxing that computer to do the bidding of professors who may still feel more comfortable with the Athenian Plato than the one in Urbana.

The existence of such a system was of special interest to some members of the political science department for a very practical reason. The department's instructional program was taking its lumps. There had been sharp, usually losing, battles with administrators over course size limits, assistantship funds, and advising loads. Furthermore, student course ratings were just coming into vogue, and professors nursing their freshly bruised egos began to sense an unmistakable need to do something differently. The problem was most acute at the lowest level--the one-semester, three-credit-hour "American Government: Organization and Powers" course (PS 150). The symptoms are all too familiar to most university faculty: an introductory course which could be selected to fill sequence requirements by students in the lower classes from a variety of curricula, enrolling up to 1600 students each year, with lecture sections of about 500 students meeting twice a week and dividing into smaller "quiz" sections, manned by graduate assistants, once each week. It was a course remembered by graduating seniors as among the ten "least stimulating" in the College of Liberal Arts and Sciences in College surveys. Student class attendance was chronically low and most faculty members had persuasive reasons they could not teach the course prepared well in advance of the department head's earnest search for volunteers each semester.

An incoming department head with a taste for innovation decided the department should attempt to resuscitate its instructional program by capitalizing on available resources. Toward that end I was hired as an instructor with released time to explore the PLATO system's potential for political science. I had some background in education, but no explicit training in programmed instruction, CAI, or, for that matter, anything connected with computers beyond several all-night sessions spent at balky key punches and waiting for data to be processed by packaged statistical programs. A half-time graduate research assistant was made available and the brainstorming began.

The Early Decisions

What could the PLATO system do for political science instruction? The answer was not immediately clear. Our thoughts turned first to conventional kinds of programmed instruction. One could, using any of the standard government texts as a guide, create a course on PLATO which would consist primarily of textual material frequently interspersed with questions to which students would respond and have their answers judged. The problem with this was that it would have represented an embarrassingly inefficient use of a learning system which was capable of much more. In fact, it is probable that the same educational objectives could have been achieved with a much less expensive programmed textbook.

So we asked ourselves a more difficult question. What could the PLATO system do that can not be accomplished in any other way in the political science classroom? It seemed to me that one of the major lacunae in political education at all levels is that students seldom have an opportunity to observe, in any systematic way, the processes they are presumably learning about. To put it another way, there is typically no equivalent to the laboratory experience that plays such an integral role in biology, or chemistry, or physics instruction Discussion of current or historical political phenomena can provide a sense of what happens when a President pursues strategy "A," but what would have happened with strategy "B" in the same situation is left to undernourished speculation.

One can learn about governmental structure from textbooks, but how does the instructor convincingly portray the process -the "if-then" generalizations that form the nexus of empirical political theory? Could programs be developed which would allow students to discover and test some of these principles for themselves?

A second line of thought was more concerned with motivation. Highly abstract presentations of process theory might dull even the best-conceived lessons for freshmen and sophomores. Why not put students in key political roles and let them experiment with various strategies in trying to achieve their objectives? They would have to commit themselves to real-life choices and could witness the consequences of those choices. Aside from personalizing the process, there would be the challenge of trying to improve their performance as additional principles were discovered.

The decision to concentrate upon role-playing games which would illustrate key political processes had several important implications.[4] First, it meant that we would not develop a course *per se*, but lessons designed to supplement introductory courses. It would be an attempt to do only that which could not be done as well or better through lectures, reading, or group discussion. Second, it meant that much of our effort would go into the development of the models themselves. Even a short computer-based game designed to be played in one class hour or less would take weeks, and sometimes months, to research, create, program, test and refine.

Third, there was implicit in the selection of role-playing games a commitment to student inquiry and discovery as an important part of the learning process.[5] Generalizations would not, as a rule, be supplied to students in verbal form for memorization and application, but would be tucked away in games, to be teased out, piece by piece, intuitively, imperfectly, through experience in playing and replaying the games. One extremely important objective, we reasoned, would be a sharpened sensitivity to regularities in political life and an ability to develop and refine one's own generalizations on the basis of observation and experience. Simplified models incorporating some of the theoretical gems most prized by political scientists would provide an excellent opportunity for students to develop such skills.

Much of the same philosophy, of course, underlies the various simulations designed or adapted for use in political science courses.[6] Our exercises would differ in two fundamental ways from most classroom simulations, however. In the first place, single students would, in essence, be playing against the machine, not with and against classmates. They would, through their terminals, communicate and interact with other "actors" as the scenario developed, but the other actors would be programmed to respond as we believed real political actors would. In a sense, then, the only variable was the student's game behavior. If a student played an exercise precisely the same way twice, (s)he should obtain precisely the same results. This creates a strikingly different learning situation than exists in most simulations where students interact with other students.

The other way in which we were to part company with some existing simulations was by reducing the length and complexity of the games. Any simulation is a simplified abstraction of reality but, from a learning standpoint, the more variables included, the more difficult it is for the student to detect the underlying principles—the "if-then" relationships built into it. It is my conviction that many of the better-known simulations, however valuable they may be for motivating students and raising theoretical questions, fall shy of their promise to clearly demonstrate the principles involved. The typical reaction of many students at the conclusion of such a simulation (which may have run over a period of several days) is that they found it interesting, but are still not quite sure why it came out the way it did. Debriefing may help, and frequently gives rise to a desire to play it again to check out some of their hypotheses about the process. But, even if there were time, there is no assurance that other students would obligingly play their roles the same way, and the possibility of confusion persists.

This problem was to be mitigated by creating short games, each incorporating no more than a handful of basic principles, which could be replayed by students several times, allowing them to experiment with the model until they were satisfied they had ferreted out the principles embodied in it.

These were the major ideas that went into a proposal to the ESSO Education Foundation, which was then supporting innovative developmental programs in undergraduate instruction. It would be over a year before that proposal bore fruit, but we immediately set about developing the first exercise.

Developing the Programs

To speak glibly of role-playing games which would portray key political processes is one thing--to develop them is something else. Our attempts to identify basic principles in a given area of American politics--whether it be legislative behavior, or foreign policy, or the budgetary process--and fashion a believable, interesting, playable game which would incorporate those principles was at once the most taxing and the most intellectually exciting part of our work.[7]

In retrospect, I think we got off on the wrong foot. We started with a cautious, straightforward branching program that was to lead the student to some principles of constitutional law in the due process domain. The student, as police chief, would have to make a number of decisions in connection with a controversy sparked by the visit of a radical speaker to the community. Should the speaker be permitted to speak? How should the crowd be handled? Who, if anyone, should be arrested when trouble broke out? At what point? When students acted in accordance with prevailing Supreme Court decisions, the game continued. When they violated constitutional dicta they were shown the error of their ways by a friendly city attorney, armed with excerpts from court cases, and asked to reconsider their decisions. They were called upon, at several points, to justify their actions to a skeptical mayor and the press.

In our effort to find an area where we could give students a relatively clear-cut "right" or "wrong" response to each decision they made, and in our initial reluctance to let students proceed after making a "wrong" choice, we had hemmed ourselves in. The scope of the exercise was limited, covering only a few specific applications of several constitutional principles. Because it was a branching program, the student was limited to three or four options at each choice point, and a frequent complaint was that there were other actions one thought made more sense, but couldn't try. Most important, it really wasn't much of a game, since the only real challenge was trying to work through it without being told that a decision should be reconsidered. There was no opportunity for students to specify their own objectives and work toward them, and the outcome was always the same, although some students reached it more quickly than others. It served a purpose, however, in acquainting us with the programming idiosyncracies and the potential of the PLATO system.

From that point our thoughts turned toward more sophisticated schematic or mathematical models which would give students more latitude in their choices and provide a far greater range of outcomes. With funding from the ESSO Education Foundation supporting several graduate assistants and consultants, five more games were completed by the fall of 1970.

CANDIDATE: You are a congressional candidate seeking election to the House of Representatives. You may request information at the outset about the composition of the electorate in your district (party identification, ethnic breakdown, social class makeup, etc.). As the game progresses you will also receive information about your opponent's characteristics and moves. Your task is then to make a number of strategic decisions concerning the allocation of your financial resources in the campaign and what stands you should take on various issues. An estimate of the predicted popular vote in the district based upon a voter-type model is calculated from the initial parameters and modified by each strategic decision you make. You may, at various points in the campaign, request a poll of the district to ascertain how you are doing.

CHAIRMAN: This exercise is an introduction to legislative politics in the U.S. Congress. As Chairman of the Education and Labor Committee in the House of Representatives, you are charged with the responsibility for steering a higher-education bill through the House. You are confronted with a series of decisions that will influence the shape and ultimate passage of this critical piece of legislation. Alternative strategies are suggested at each choice point and each decision you make affects the division of sentiment in various committees and the House on that bill. Your objective is to mobilize support for the strongest bill possible without incurring unacceptable political costs to yourself. Information about the current division of vote in the House will be available at a few points during the game to assist you in deciding what kinds of compromises, if any, are called for. Parameters for this game may be changed so that you begin with any desired initial division of sentiment within the House, the Subcommittee, and the Committee.

PRESIDENT: In this exercise we employ a complex scoring and branching system to judge your responses. You are assigned the role of President of the United States and face a severe Middle East crisis. Your objective is to maintain favorable relations with the Soviet Union, Israel, and the United Arab Republic throughout the crisis. There are four discrete episodes which you work your way through as the crisis develops. Each of these will call for a series of decisions on your part, and your performance in the episode will be scored on several dimensions such as "consistency," "power capability," and "tension *vis a vis* USSR." Adroit maneuvering in one episode will result in a score profile which affords you better options in the next. One unique feature of this model is that as you select less than optimal courses of action your range of options on the next move narrows. In the worst situation you may find you have only one course of action remaining in that period.

LEADER: Here you are the organizer of a teacher union and serve as their bargaining agent in negotiations with the board of education. Your task is to mobilize support among teachers for your program and then extract what you can from the district. In the process you must decide which issues to emphasize, what level of demand you should make on each issue, and what tactics to employ in the negotiation at various times. You must take into account the dispositions of the board members on each issue and also how your program and tactics will affect support within your own organization. At the outcome you are informed what you have obtained for your teachers and how much support you have mobilized within your organizati[illegible]

BUREAUCRAT: As Director of a state Department of Mental Health, you are responsible for developing budget recommendations for the next fiscal year. You may request information about the objectives, performance, and operating costs for each of the five divisions within your department and will need to anticipate the reactions of the state budget officer, the Governor, and the legislature in making and justifying your decisions about how to modify last year's budget requests. The model assumes an incremental state budgetary process; you will find that demands for continuation of current services make drastic program cuts difficult while, at the same time, requests for more than the usual increases in the budget of one division usually must be accompanied by cuts in other divisions.

There is an inescapable dilemma in constru[illegible] such models. The requirements of the game tend to push one, ra[illegible]ickly, beyond the limits of current theory.[8] Most of us, in lecturi[illegible] writing textbooks, develop the art of stating principles ambiguous enough to slip off almost any hook. In developing a computer-based game one seldom has that luxury. Take, for example, the version of CANDIDATE where the student is in the r[illegible] of a Republican congressional candidate running in a competitive district. O[illegible] principle we want to convey is that it is easier to mobilize Republicans and Independents than to convert Democrats. Thus the student sh[illegible] experience more success (as reflected in public opinion polls and the fin[illegible] vote) by utilizing limited campaign funds for advertizing and canvassing designed to activate potentially sympathetic voters than by allocating resources to an attempt at getting Democratic votes. But how large should the differential be? And exactly where is the point of diminishing returns? For purposes of the game we need a model that calculates a running turnout figure and a division of the vote based upon campaign decisions.[9]

Our resolution of this dilemma has been to devise functions which seem reasonable and reflect the best theory we can find in the literature, but admittedly go beyond it. In some cases evidence for the validity of the resulting model can be obtained from real political actors who play the game and indicate where they think the results are realistic and where they miss the mark. A still more demanding test would be to compare the performance of professionals on their initial play with that of students. It was heartwarming to see a high Magnavox official experienced in labor negotiations achieve a more favorable settlement in the bargaining game (LEADER) than anyone, including the authors, had previously gained. We have not, however, pursued such validation very systematically to date.[10]

One reason for this lapse, not entirely a rationalization, is that we would like students themselves to challenge the models in subsequent discussions. Once they have gained some understanding of the process as portrayed in the game, they are encouraged to attack it on empirical as well as normative grounds. If they cite a certain outcome as unrealistic, we can present what evidence we have for it and concede that we have made some estimates that go beyond available theory. Students may, on the other hand, grant the realism of the model in, for example, the BUREAUCRAT game, but politely suggest that that is a lousy way to allocate state revenues. They will then be challenged to suggest structural changes in state government which would lead to a budgetary process more to their liking.

There were times, however, when the paucity of theory in an area subdued even our usually audacious approach. We wanted, at one point, to create a game called NATION-BUILDER, where the student would be the president of a young country deciding what kind of nation to build over the next twenty years, and how available resources should be used to achieve those aspirations. Although there were ample correlational data available on GNP, agricultural development, capital development, literacy, education, regime legitimacy, and other factors we wanted to build in, we could find little basis for estimates as to the time lag between investment in a road-building program, for example, and increases in GNP, much less when and how investment in universal elementary education could be expected to impact upon economic or political variables such as "value added through manufacture" or "regime stability." The effort was finally abandoned.

If the development of models proved more demanding than anticipated, getting them coded and working on PLATO was less traumatic than envisioned, once we knew what we wanted to do in a game and had it worked out schematically or mathematically. PLATO authors are strongly encouraged to learn to do their own programming, on the theory that an intimate awareness of the capabilities of the language and the system leads one to attempt things one might not have thought of otherwise. But directors and staff of the laboratory housing PLATO were always available to get us over a technical hurdle or suggest a more elegant way of programming an exercise. Since our project was one of the first major efforts in the social sciences, they were more than a little curious themselves about what could be done in a field like political science and anxious to demonstrate the applicability of the system in a new area.

The Experiment

It still remained to be seen how the exercises could be employed to best advantage in an introductory course and just how effective they were.[11] An experimental section of "American Government: Organization and Powers" (PS 150), scheduled for the fall of 1970, enrolled slightly over 200 undergraduate students. The ensuing experiment had two major objectives: to compare the best course we could devise with the course the department typically offered, and to evaluate several different modes of instruction, including the computer-based games, used in the experimental course. We were especially interested in comparing students who played the computer games with an equal number who spent the same amount of time in discussion groups working toward the same objectives.

The experimental course was based upon a premise that, above all, greater variety was needed.[12] The number of lectures was reduced somewhat, but lecturing remained an important part of the course. Two weeks were set aside for an in-class "presidential election simulation."[13] A basic text was employed but supplemented with numerous readings dealing with current political controversies. Half the students were randomly assigned to discussion sections of about 30 students each, led by graduate teaching assistants. The other half were assigned to spend a similar amount of time playing and discussing the computer-based exercises. A novel schedule was d vised which brought half the students into lectures for all three days some weeks and sent them into either discussion groups or the computer classroom for three consecutive sessions on alternate weeks while the other students attended lectures. Thus, from the student's vantage point, eight weeks was spent in lectures, two weeks in the in-class simulation, and six weeks either in discussion groups or working on computer-based games.

There were the usual problems in assuring equivalence between the experimental course and the large conventionally taught section which ran concurrently. The lecturer in that regular course was an experienced and respected senior professor. The choice for the experimental course was a talented young instructor who had obtained favorable student ratings from students the previous two years. Teams of graduate teaching assistants assigned to the two courses did not differ substantially in talent or experience. The courses were listed in the same manner in the timetable in an effort to avoid bias in the kinds of students they would attract, but they were offered at different times and it was necessary to restrict the enrollment in the experimental course due to the limited availability of PLATO stations. The conventional course had a total enrollment of approximately 500 students meeting for one hour twice each week for lectures and in "quiz" sections (devoted largely to discussion of lectures and readings) of about 30 students each on the third day. Little attempt was made to standardize the content of the two courses. The conventional course was taught much as it had been in recent years, whereas the experimental course focused somewhat more upon analysis of political processes.

A pretest, including achievement items and political attitude scales, was administered to 75 percent of the students in the experimental course and a smaller sample of the conventional course.[14] One set of 38 multiple-choice items, selected from exams used in the PS 150 course over recent years, constituted what we called the "conventional achievement" measure.[15] Scales designed to measure several kinds of political orientations (e.g., "sense of political efficacy," "political cynicism," and several scales measuring commitment to democratic values) were also included in the pretest.[16] The post-test, administered at the end of the course, included all the items on the pretest plus a set of 23 items which constituted our "process achievement" measure intended to gauge students' ability to recognize and apply "if-then" kinds of generalizations in the political realm.[17]

Also included in the post-test were semantic-differential measures of attitude toward the four types of instruction utilized (lectures, in-class simulation, discussion groups, and computer-based games) and some isolated questions about the student's reaction to the course as a whole. All students in the experimental course and the same sample from the conventional course were retested in the last week of the course.[18]

We hypothesized that students in the experimental course would have a more favorable attitude toward PS 150 than those in the conventional course, as well as toward "political science" as a discipline. We also predicted that they would achieve as well as conventionally taught students on the conventional-achievement subtest and better on the process-oriented subtest. Finally, we hypothesized that the computer-based games would be more favorably evaluated as an instructional form than the discussion sessions.

As the experimental course got underway students assigned to the computer games quickly developed their own styles of coping with the terminal. Some approached it timidly, almost reverently at first, taking careful notes of messages that appeared on the screen and trying not to make "mistakes" even on their first run through a game. Others attacked it more like a pin-ball machine. But the reaction from the beginning was almost universally positive. Attendance was high and some students returned on Saturday mornings to try a game one more time, sometimes bringing friends or parents with them. As the semester progressed, students began to compare notes informally and vie with one another to see who had achieved the largest election victory (CANDIDATE) or the largest salary increase for their union's teachers (LEADER). There were also occasional wails of despair as a "floor manager" failed to get the President's bill passed in Congress for the third or fourth straight time (CHAIRMAN). Ultimate student outrage, however, was reserved for those rare occasions when there was a system breakdown. The same students who might have greeted news of a professor's illness with thinly disguised glee were simply unwilling to tolerate mechanical frailty on the part of PLATO.

Students were encouraged to type free-form comments at any time (after pressing the COMMENT key), and PLATO preserved both the profound and the profane for our inspection. This record alerted us to specific points of difficulty in the games as well as providing a more general sense of what students found interesting and annoying. It quickly became apparent that, far from viewing the games as an academic exercise, many students placed a high value upon "winning," or at least improving their performance from one run to the next. Expressions of frustration could occasionally be traced to awkward or ambiguous programming, but were more frequently the result of having played a game several times with no noticeable improvement. Later in this paper we shall address the question of what can be done for students who find themselves in this position.

What Happened to the Students

The most striking finding with respect to the experimental course was that students liked it. When asked at the end of the term if they would have preferred a regular section of PS 150, 91 percent responded that they preferred the experimental course and would enroll in it again if they had it to do over.[19] As for the computer games, an independent survey of student attitudes, conducted near the end of the semester by the Computer-based Education Research Laboratory, found 86 percent of our students ready to advise friends to take the section of the course using the computer exercises.[20]

It would be a mistake, however, to attribute the favorable response solely to the use of computer-based games. Differences in course evaluation between students who had played the games and those who had attended discussion sections on the same topics were typically small and not statistically significant. Both liked the new course in almost equal measure. A more reasonable interpretation would point to a cluster of factors—the variety of instructional modes employed in the experimental course, the reduction of the size of the lecture section, the appeal of the lecturer, the emphasis upon process as opposed to structure or definitions, the attempt to provide current and stimulating supplemental readings, and the use of computer-based games—as important in assuring the success of the experimental course.

Since it was the first experience most students had had with political science courses, we were interested in determining how their beliefs about the discipline might be shaped by it. The ratings of "political science" by students in the experimental course and those in the large lecture course used as a control are presented in Table 1. It is clear that students in the

TABLE 1

Mean Ratings of the Concept "POLITICAL SCIENCE" by Students in the Experimental and Conventionally Taught Courses*

"POLITICAL SCIENCE"	Students in Experimental Course	Students in Conventionally Taught Course
Good (bad)	+1.13	+0.51
Exciting (boring)	+1.25	+0.30
Useful (useless)	+1.64	+0.92
Meaningful (meaningless)	+1.54	+0.81
Challenging (unchallenging)	+1.49	+0.68
Flexible (rigid)	+0.81	+0.19
Interesting (uninteresting)	+1.59	+0.70
N =	130	38

*Ratings were made on a seven-point bi-polar scale (ranging, for scoring purposes, from +3.00 to −3.00) with the adjectival opposites on either end. While in the original instrument half of the items were reversed, we have here assigned +'s to those ratings nearer the positive end of the scale.

experimental course section viewed political science as more exciting, interesting, meaningful, and challenging, for example, than students in the regular section.

It should be noted, however, that attitudinal differences observed between students in the experimental course and those in the conventional course appeared to be limited to their evaluation of the course and the discipline of political science. We had thought that we might be able to detect differences in their characterizations of "politics" or their orientations on standard scales such as "political efficacy," "political cynicism," or commitment to various democratic principles which would be attributable to their different course experiences. While such differences did not emerge, analysis of changes between the pretest and post-test did reveal a startling general finding that students in all groups appeared somewhat more cynical, felt less efficacious, and displayed less commitment to democratic principles at the end of their course. Reflection upon the nature of the standard measures employed suggests that this finding should not be interpreted too literally. It seems probable that most students come to college with notions of their own efficacy and basic democratic values fairly well developed. The effect of their first college course in political science, which frequently emphasizes the complexity of the political system and the imperfect rendition of democratic values in the real political world, may give them pause in checking the "strongly agree" response to an item such as "The way people vote is the main thing that decides how things are run in this country" (political efficacy).[21] If this is true, one function of introductory courses in American government may be to complicate pre-existing beliefs about how democracy works rather than reinforcing democratic values or one's sense of efficacy.

On the cognitive, or achievement, side we found no differences between the experimental and control groups on the set of "conventional" items drawn from multiple-choice exams previously used in PS 150. Students in the experimental course apparently missed little of what had historically been expected by professors, or at least learned by students, in PS 150. In the set of items developed to measure an understanding of political processes, the students who had played the computer games performed at a somewhat higher level than either students in the control class or students in the experimental course who had been assigned to discussion sections (Table 2). The difference, while statistically significant, was not

TABLE 2

Performance of Students in Experimental and Conventionally Taught Courses on Conventional Achievement and Process-Oriented Achievement Post-Tests (Mean Percent Correct Responses)

Treatment Group	Conventional Achievement Post-Test	Process Achievement Post-Test	N
Experimental Course:			
Computer Games Group	62%	67%	63
Discussion Group	62%	62%	67
Conventionally Taught Course:	62%	62%	38
Number of Multiple Choice Items	38	23	

large enough to warrant great celebration. We had, frankly, expected them to do even better.

The comparison of student evaluations of the four types of instruction employed in the experimental course indicated that each of the four played an important, but somewhat distinctive, role in the eyes of students (Table 3). While the computer games were rated (by the students who

TABLE 3

Student Ratings of Four Types of Instruction Employed in the Experimental Course

Semantic Differential Item*	Computer-based Games	In-class Simulation	Lectures	Discussion Sessions
Interesting (uninteresting)	+1.94	+1.57	+1.31	+0.80
Challenging (unchallenging)	+1.36	+1.42	+0.69	+0.36
Pleasant (unpleasant)	+1.79	+1.45	+1.17	+0.61
Useful (useless)	+1.66	+1.33	+1.35	+0.78
Exciting (boring)	+1.65	+1.38	+0 [illegible]	+0.36
Good (bad)	+1.60	+1.30	+1 [illegible]	+0.74
Meaningful (meaningless)	+1.44	+1.27	+1.34	+0.81
Active (inactive)	+1.63	+1.74	+0.65	+0.45
Relevant (irrelevant)	+1.57	+1.66	+1.51	+0.99
Rational (emotional)	+1.52	−0.36	+0.73	+0.32
Valid (invalid)	+1.32	+1.11	+1.31	+0.91
Complex (simple)	+1.03	+0.87	+0.50	+0.08
Precise (vague)	+0.97	+0.07	+0.69	−0.10
Varied (repetitive)	+0.86	+1.15	+0.94	+0.55
Deep (shallow)	+0.80	+0.44	+1.06	+0.34
Reassuring (threatening)	+0.27	+0.25	+0.41	+0.50
Flexible (inflexible)	+0.24	+1.19	+1.13	+1.32
Personal (impersonal)	−0.02	+0.72	+0.56	+0.50
Usual (unusual)	−1.69	−1.71	−0.72	+0.26
Important (unimportant)	+1.13	+1.25	+1.20	+0.52
Clear (hazy)	+0.42	+0.05	+0.87	+0.30
N =	63	130	130	67

*Ratings ranged from +3.00 to −3.00 on a seven-point scale.

played them) as more "interesting," "useful," "exciting," "pleasant," "meaningful," "challenging," "rational," "precise," and "complex" than the other three forms of instruction, the in-class simulation was seen as the most "active," "unusual," "varied," "relevant," and "important." Discussion sessions were rated the most "flexible," "personal," and "reassuring" instructional activity, whereas the lectures were seen as the most "clear" and "deep," and virtually tied with computer games for the most "valid" form of instruction.

Each of the four modes of instruction used in the experimental course was positively evaluated on a "good-bad" scale ranging from +3.00 to −3.00. By contrast, students in the conventional course, which relied principally upon lectures and discussion, judged both of these conventional forms of instruction substantially less charitably. One plausible inference is that, in a course with varied instructional format incorporating new educational techniques, even the more conventional modes of instruction, such as lectures and discussion sessions, are better received and more valued by students.

Second Thoughts About Learning With Computers

As a result of our experience in the experimental course and use of the computer games in subsequent semesters I have become at once more sanguine about some of the frequently-heard criticisms of CAI and more skeptical with respect to certain claimed advantages. I see, for example, little evidence of the "dehumanization" of learning feared in some quarters. While it is true that our students rated the games as somewhat less "personal" than lectures or discussions, they still saw them as more "personal" than "impersonal." Furthermore, when PLATO evaluators asked 50 of our students to rate the statement that "Computer-based education dehumanizes the student," 48 percent "strongly disagreed," 38 percent "disagreed," 8 percent were "uncertain," 6 percent "agreed," and no one "strongly agreed."[22]

I do, however, now have an increased sense of the desirability of providing opportunity for social interaction of various kinds in connection with the games. Because of the limited number of terminals, we were often forced to assign two students to a single terminal and ask them to take turns, help each other, or perhaps compete with each other. The results were revealing. Aside from the obvious advantage that two people are likely to discover more than one, the students verbalized and defended their influences about the model to their partners, which served as a clarification and reinforcement of what they were learning. Short discussion sessions following a game-playing period served something of the same function. Even the student who has learned virtually everything contained in a game likes to compare notes with others who have played the same game, and those who end the session still mystified may profit from hearing their peers' ideas about what principles are operating in the model. There are also value implications in most of the games which students are eager to discuss.

Other critics see computer-based education as threatening the role of the instructor. It does change that role markedly, but in some desirable ways. We have already alluded to the intellectual challenge of preparing instructional materials, but there is also a sense of satisfaction that derives from working *with* students at a terminal to help them comprehend the mysteries of a particularly grudging model. Students may even come to view professors and teaching assistants as people who are on their side for a change, in their struggle to figure it all out.

On the other hand, I am less sanguine than before about that often-claimed objective of CAI: allowing every student to work at his own pace.[23] In the first place, individual differences in pace are enormous. It was not at all unusual for some students to take three times as long to complete a game as others. To keep the quickest students gainfully occupied for scheduled periods requires a staggering repertoire of programmed materials. More importantly, I am no longer certain that the student's own pace is always best. Some will work more slowly than they should, and others might profit from being a little more reflective about their play.[24]

The most fundamental advantage of computer-based education is not self-pacing, or even the diagnosis of learning problems and individualized remedial help which a good program can provide, but the simple fact that students are actively and continually engaged in the learning process. Twenty, thirty, forty times a game, a student must make a decision, and that decision usually represents a commitment to some hypothesis about what will happen as a result of his choice. One mark of a good lesson is that it helps students develop accurate hypotheses about political processes rather quickly and gives them an opportunity to test them. One should not lose sight, however, of the importance on both cognitive and motivational grounds of that requisite first step which is too often missing in lectures and even discussion sessions: obtaining the attention of the student and his or her active engagement in the business at hand.

It is often suggested that the enthusiasm students display for computer-based education is attributable to the fact that it is novel, topical, and glamorous. Students do see the experience as novel, but also as a meaningful learning opportunity, and we have witnessed no diminution of enthusiasm over the course of a semester. If, however, one means "Wouldn't they get tired of all-day sessions at a terminal throughout four years of college?" the answer is almost certainly "yes." While I could conceive of students profitably spending as much as one-fourth, or even one-third of their college careers on well-conceived computer-based programs, my view that it is not the best or most efficient way to accomplish all educational objectives is stronger than ever. Computer-based education will be valuable as a distinctive instructional mode which contributes to the variety of learning experiences students encounter. Those who view it as a panacea (or threat) which will ultimately monopolize the educational process miss this important point.

Finally, I now have a heightened appreciation for the paramount role of good lesson design and development in computer-based education. This is not to denigrate the importance of the system itself, which sets the limits on what an author can do. Unfortunately, however, even with a system comprising the most ingeniously designed hardware and computer language imaginable, it is much easier to write bad lessons than good ones. The state of the art is still primitive, and in many substantive areas there are few guidelines to follow. If computers are to take their place alongside textbooks, lectures, discussions, student simulations, and other forms of political science instruction, high priority must be given to the development and nourishment of a cadre of political scientists with a flair for designing programs that are both substantively and educationally sound.

What Should Be Done Next

The case is persuasive, I think, that computer games can contribute significantly and distinctively to an introductory American government course. When CAI is made an integral part of that course, students respond positively and the games play a role in engendering interest and more favorable student attitudes toward the course and toward political science as a discipline. There is also some, but less impressive, evidence that students can gain a better understanding of political processes through computer-based games than through lectures or discussion sessions. While comparisons are encouraging, one senses that we have only begun to exploit the full potential of computer-based education in this cognitive domain.

Part of the problem may lie in our initial estimate of students' ability to induce generalizations from even short, relatively simple political games. Many students can, but others proved perfectly capable of playing a game not just once, but two or three times, discovering little other than a sense of growing frustration. What do we do about them?

Several possibilities exist. One could develop routines in which, at the end of the game, the computer would analyze the students' play, diagnose problems in achieving the desired outcome, and gently set about attempting to rectify students' misconceptions by presenting helpful analyses of their play or even entering into dialogues with them about their strategies. If all else failed, students might request a list of those underlying principles which they had successfully (although perhaps intuitively) employed in playing the game, and those they had failed to comprehend and use. Students would then replay the game with their new-found knowledge. This represents a modification of the pure discovery approach to a paradigm in which, for students who need it, discovery and verification would be mixed with judicious tutoring.

Another worthwhile development, directed at the same kind of problem, would be what might be called an "instant replay" feature in the games. One kind of question students frequently ask at the end of a session is "What would the outcome have been if I had threatened armed intervention back at the beginning of this Middle East crisis instead of seeking agreement with the USSR that we would both pull back our forces?" (PRESIDENT). In principle the game could be replayed, changing only that one decision, but that may strain both the memory and the patience of the student. An analytic program could be devised to change any decision (or series of decisions) the student had a later question about, calculate, and display the consequent change in outcome holding other decisions constant. This would provide students with a powerful means of dissecting the games in their effort to determine the assumptions built into the model.

What, then, of students who play the games with relative *savoir faire*—how can the exercises be made more challenging to them? Some of the exercises already developed, and several others we have thought about, have multi-dimensional outcomes. The leader of a teachers' union, for example, will be interested not only in the various aspects of the package (s)he is able to negotiate with the Board of Education, but in increasing the membership and resources which the union enjoys. Frequently there will be tradeoffs where the student will have to sacrifice one objective to get something else. A simple feature could be added to such games which would require students, after gaining a preliminary understanding of the model, to "call their shots," i.e. to specify the outcome they want on each dimension, and work toward those outcomes in their next play of the game. Their original objectives would then be compared with the actual outcome at the end of the game, and their performance evaluated by how closely the results approximated their own goals.

Elaboration of the games themselves, and experimentation with different kinds of games, are also in order. We are strongly committed to role-playing, but have not begun to exhaust the possibilities inherent in such an approach. Once a workable model is developed for a game it may make sense to let the student play several roles in succession. One could envision, for example, a judicial process game in which the student played, on successive runs, the role of defendant, police officer, defense counsel, prosecuting attorney, and judge. One could also make a case for some "data-based" models. We have made a gesture in this direction by providing in CANDIDATE three quite different districts (with different socio-demographic composition, party alignments, and political histories) for students to choose from before they begin the game. There is no reason, in principle, that such models could not be modified to accept various data configurations (real or hypothesized) which students want to read in at the beginning of the lesson. Thus, the student who wanted to see if (s)he could be elected as a Democrat in a district approximating his or her home district would bring the relevant data from that district to class and feed them into the terminal, then proceed with the role-playing.

Two other lines of development, frequently urged upon us, are tempting but perhaps more questionable on educational grounds. One of these is the creation of "interactive" games in which several students would each assume a different role in the same game and interact with each other through their terminals. The potential of such games for motivation of students is obvious. I am much less certain, however, of their relative merits (as contrasted to our games) when it comes to teaching students what you want them to learn about political processes. The point may be debatable, but I would argue that, however imprecise our models may be, political scientists ought to be able to program the "other actors" in a game to behave in more realistic fashion than they would if students were playing those roles. Furthermore, as with in-class, all-human simulations, in a multi-person computer lesson one loses the opportunity to replay the game, experimenting with different strategies in an otherwise controlled setting.

The other tantalizing line of development would be to employ stochastic models in place of the deterministic models we now use. For research purposes the use of stochastic models is eminently sensible, since virtually all of the propositions in empirical political theory are stated in probabilistic terms.[25] From the author's standpoint, developing games with stochastic elements would mean that, instead of estimating each actor's most probable behavior in a given situation, one would estimate a probability curve for several different behaviors. It is easy enough to do this with most large CAI systems and we have, in fact, experimented with probabilistic features in two of our games. The upshot of this, from the student's point of view, however, is to make it more difficult to divine the nature of the model and its basic process laws. A student can never be sure whether "B" responded differently the second time (s)he played the game because "A" had acted differently or through chance alone. One could now, in fact, make exactly the same decisions in two runs and obtain quite different outcomes. In a sense this would be a more realistic model, because chance factors (or exogenous variables) do play a role in political processes, but it may also complicate the cognitive task of the learner unnecessarily.

None of the kinds of things we have discussed to this point can be accomplished overnight, but they are all feasible with the system, language, and talent at hand. There is yet another logical extension of our work which, while far more difficult to accomplish, would pay even greater dividends in student learning. Note that we have concerned ourselves almost entirely in the preceding pages with the most effective way to convey an understanding of political processes to students. This objective presumes a body of theory which we as political scientists possess, and they as students need to learn. Yet we are painfully aware just how tentative and incomplete empirical political theory is in most areas of inquiry today. We forge ahead and create games incorporating principles about political process (some of which may still be subject to dispute among scholars within the discipline) and even go beyond those principles to try to create games with a general verisimilitude.

This procedure, as any approach which attempts to convey current political theory, prompts humility, and our attempts to encourage students to challenge the resulting models in post-game discussions is partly a confession of vulnerability, but it is something else as well. Sometimes I have suspected that the professors and graduate assistants who helped research and develop our models have learned more about politics than any undergraduate who has played the games to date. Is there a way to let students build theory as well as learn it?

Let us assume, for a moment, that our students have arrived at as complete an understanding of one of our models as we can expect. Couldn't we then take them out of the role of consumer of theory to try their hand at theory construction? If they find parts of our model unrealistic, let them change the model itself—modify the functions, add variables or delete factors they consider unimportant, or inject new propositions—in an attempt to make it more realistic. They could then test their own modified models by repeated plays to see whether they appear more realistic than the original. The practical and technical problems of including such an option are, at first glance, staggering, but the appeal of the objective—giving students an opportunity to engage themselves in theory-building experiments—is sufficient to place it high on our priority list of work to be done.

And Why It May Not Be Done

Any major effort at curriculum innovation, and especially an effort involving computer-based education, requires some mobilization of resources if it is to succeed. I do not mean to dismiss peremptorily the possibility of professors striking out, on their own initiative, to develop imaginative materials for use in their own classes, but the investment they must make, and the attendant risk, may be substantial. Work in CAI is at once demanding and absorbing. There is always one more twist needed to make a program better, or the vision of a new kind of lesson which will make a difficult point crystal clear to students. Usually professional advancement will come more quickly and surely if professors stick to more conventional forms of research in their own areas of expertise.

Yet, developers of computer-based materials work under a major handicap in their entreaties to university administrators for support. It is difficult to make a convincing case for the proposition that you are going to save them money, at least in the short term. The cost of most of our development work has been borne by outside funding agencies, but it does not take perceptive administrators long to realize that their budgetary problems will not be relieved by providing students with computer terminals and original, high-quality learning materials. This is not the place to explore the economics of computer-assisted instruction in detail.[26] The founders of PLATO are optimistic that they can approach, and perhaps reduce, the current cost of providing college students an hour of traditional instruction. They do not include in their estimates the cost of program development, assuming that ultimately this will be accomplished much as textbooks are written and published today in a market system. For the department head faced with the limited availability of political science materials, however, some resources will have to be provided.

Even relatively modest efforts toward developing CAI programs in political science will usually entail pulling people with a variety of skills and interests together, providing initial financial and assistantship support, and gaining the assurance of departmental and university administrators that such instructional work will be valued and rewarded. Only under certain conditions—including widespread concern over the undergraduate program, availability of outside funds, a receptive faculty, the existence of a suitable CAI system, and the encouragement of innovative departmental administrators—can such efforts succeed.

Those conditions prevailed at Illinois in the late 1960's. They no longer obtain here, and perhaps not in very many departments. There have been three changes in departmental leadership since the inception of the PPI project, and department heads found themselves under increasing pressure to restore the prestige of a department which had lost several nationally prominent scholars. Professors who have used the computer games in their introductory courses request space for more students each succeeding semester, but, just at a time when sufficient terminals are becoming available, administrative support has waivered. PPI games were being proudly demonstrated to the Governor and the staff of the Illinois Board of Higher Education at about the same time the young lecturer who had played a central role in the development of the experimental course was terminated and the director of the project was apprised that it was now time to get back to writing articles and books. The lessons continue to be used in courses and to be cited as evidence of departmental instructional innovation in administrative reports, but support for continued development to realize the potential of this kind of instruction—the money, released time, research assistance, and, above all, the willingness to countenance within a department of political science the kind of professional specialization necessary for this sort of work—is, at best, problematic.

Problems in undergraduate instruction are too persistent, and too potentially explosive, to be ignored for long. Though attempts to cope with them have an episodic character, it is essential that the political science profession continue to develop means to accumulate and share information, ideas, and experience relating to instruction. The belated but energetic efforts of the American Political Science Association toward that end, even in times of academic depression, are an encouraging sign. Still, we have only begun to learn what kinds of learning experiences will best achieve diverse objectives or how to employ them in the most sensible manner.

Visionaries as well as skeptics abound in areas like computer-assisted instruction, but here, as in most complex domains, truth lies somewhere between their strident claims. Computer-based games, as well as other forms of CAI, can make an important contribution to our teaching of American government. They will not revolutionize it single-handedly, and the attack must be pressed on a broad front to improve perhaps the most neglected aspect of our professional responsibilities—the political education of undergraduate students.

FOOTNOTES

1. The Political Process Inquiry project has received financial support from the ESSO Education Foundation, the Computer-Based Education Research Laboratory, University of Illinois, and the Department of Political Science, University of Illinois. Authors, consultants, and assistants who have made diverse contributions to the project include: Stephen A. Douglas, Louis Gold, Lawrence V. Grant, E. W. Kelley, Deborah Oakley, John G. Peters, Marvin G. Weinbaum, and James P. Zais.

2. More complete descriptions of the PLATO system may be found in Daniel Alpert and Donald L. Bitzer, "Advances in Computer-Based Education," *Science*, 167 (March, 1970), 1582-90, and in Daniel Alpert, "The PLATO IV System in Use: A Progress Report," *Computers in Education/Informatique et enseignement*, ed. O. Lecarme and R. Lewis (New York: American Elsevier, 1975), 181-85. How one goes about writing course material in TUTOR can be discovered by looking through Bruce Arne Sherwood, *The TUTOR Language* (Urbana Ill.: Computer-based Education Research Laboratory, University of Illinois, 1974).

3. This feature renders the PLATO system valuable for many kinds of experimental research as well as for instructional uses. For an example of a research application of the PLATO system in political science, see Fred S. Coombs, John G. Peters, and Gerald S. Strom, "Bandwagon, Ballot Position, and Party Effects: An Experiment in Voting Choice," *Experimental Study of Politics*, 3 (February, 1974), 31-57.

4. For an excellent treatment of the place of games in the learning process, see James S. Coleman, "Social Processes and Social Simulation Games," in *Simulation Games in Learning*, ed. Sarane S. Boocock and E. O. Schild (Beverly Hills, Calif.: Sage Publications, 1968), 29-51. A discussion of the potential role of games in political education, with particular emphasis upon the possibility of resocializing students for future political behavior, is presented by Philip M. Burgess and James A. Robinson, "Political Science Games and the Problem Solver State," pp. 243-49 in the same volume.

5. Numerous learning theorists and curriculum developers have argued that generalizations which students "discover" in the course of their own analyses of relevant information are retained longer and are more likely to be applied to novel situations than generalizations presented in an expository fashion. Some laboratory evidence, however, suggests that these assumptions about the superiority of discovery learning, at least with respect to retention, may be premature. See John T. Guthrie, "Expository Instruction Versus a Discovery Method," *Journal of Educational Psychology*, 58 (1967), 45-49, for a brief review of that literature and a report of his own experiment which found the discovery paradigm leading to no greater retention but to better transfer of learning.

6. One of the earliest treatments of the role of simulation in the learning process is still among the most insightful: see Richard C. Snyder, "Some Perspectives on the Use of Experimental Techniques in the Study of International Relations," in Harold Guetzkow, Chadwick F. Alger, Richard A. Brody, Robert C. Noel, and Richard Snyder, *Simulation in International Relations: Developments for Research and Teaching* (Englewood Cliffs, N.J.: Prentice-Hall, 1963), 1-23.

7. Perhaps the most enduring contribution of Harold Guetzkow to thinking about man-computer simulations is his insistence that computer simulations are theories which require verification just as any other form of theory: Harold Guetzkow, "Some Correspondences Between Simulation and 'Realities' in International Relations," in *New Approaches to International Relations*, ed. Morton Kaplan (New York: St. Martin's Press, 1968), 202-3. One does not entirely escape this requirement by basing a model upon propositions for which there is prior empirical support. It is still all too easy to create a model in which several propositions, all supportable when considered separately, combine in ways which yield an unrealistic simulation.

8. A helpful discussion of the way model construction exposes the inadequacy of social science theory and may lead to theory building is contained in John R. Raser, *Simulation and Society: An Exploration of Scientific Gaming* (Boston: Allyn and Bacon, 1969).

9. The process of model building for several types of simulation is examined in Harold Guetzkow, "A Use of Simulation in the Study of Inter-Nation Relations," in *Simulation in International Relations*, 24-42. See especially pp. 33-36.

10. Concern over validity has been, with good cause, a major preoccupation of much of the literature about political science games and simulations. We should remind ourselves occasionally, however, that validity is not the only criterion of a game's utility as a learning tool. Even a highly valid game might still be trivial, dull, confusing, or educationally indefensible on countless other grounds. Political scientists have devoted relatively little attention to the question of what makes a game educationally valuable.

11. For a somewhat more formal account of the results of this experiment, see Fred S. Coombs and John G. Peters, "Computer-Based Games as a Political Laboratory," *Teaching Political Science* (forthcoming).

12. The plea for a variety of teaching techniques within a college course is not new. Sarane S. Boocock makes much the same point, as well as an argument for shorter simulations, as a result of her experiments in urban sociology and social psychology courses. See her article "Using Simulation Games in College Courses," *Simulation and Games*, 1 (March, 1970), 67-79.

13. Marvin G. Weinbaum and Louis H. Gold, *Presidential Election: A Simulation With Readings* (New York: Holt, Reinhart and Winston, 1969).

14. One-fourth of the students in the experimental class did not take the pretest to permit a later check for sensitization effects due to exposure to the pretest. No such effects were found.

15. Items from the "conventional achievement" sub-test were of the following kind:

> A federal system of government is one in which: (a) power is divided constitutionally between two branches of government--legislative and executive. (*b*) power is divided constitutionally between the general (national) and constituent (state) governments. (c) power is divided constitutionally among three distinct units of government--national, state, and local. (d) power is given constitutionally to one general (national) government and such other constituent (state) units as the general government creates.
>
> The concept of "separation of powers" is associated with: (*a*) Montesquieu. (b) Plato. (c) Gabriel Almond. (d) David Easton.

16. Scales administered included the "sense of political efficacy" (5 items) developed at the Survey Research Center, Michigan, "cynicism toward government and politics" (14 items) developed by Herbert McClosky, and "specific applications of free speech and procedural rights" (8 items) also from McClosky. Documentation for these measures may be found in John P. Robinson, Jerrold G. Rusk, and Kendra B. Head, *Measures of Political Attitudes* (Ann Arbor, Mich.: Institute for Social Research, 1968). Student responses were obtained on a four-point (strongly agree, agree, disagree, strongly disagree) continuum.

17. Items for the "process achievement" sub-test, administered at the end of the course, were of the following kind:

> In exercising political influence, a threat is more credible, hence more effective, when it is: (a) unexpected. (b) communicated secretly. (*c*) accompanied by evidence of a commitment to carry it out. (d) drastic.
>
> If you were responsible for successful management of a bill through the U.S. House of Representatives, which of the following would you view as *least* damaging: (a) unfavorable treatment of the bill in the Senate. (b) unfavorable treatment of the bill in the Rules Committee. (c) lack of support from the Bureau of the Budget and relevant federal agencies. (*d*) the appearance of some unfavorable witnesses during committee hearings on the bill.

This sub-test was not an ideal instrument for our purposes. To obtain a comparable measure for control and experimental groups, we resorted to developing a set of new, unvalidated multiple-choice items of uncertain reliability. These items were designed to measure the student's grasp of basic process principles presented in the computer games, in group discussions, and in lectur s. They differed from items in the "conventional achievement" sub-test in that a 'nowledge of process (i.e., the probable consequences of various actions or events) was required to answer them correctly. It is probable, however, that multiple-choice items are not the most appropriat means of measuring such knowledge. A far better criterion of whether students learned the principles included in the computer game would be a comparison of their performance on their first play with performance on a "test" play conducted after they had experimented with the model. Such a technique could not be applied, however, to control groups who did not play the games but might have learned the pr nciples in other ways during the course.

18. To provide greater co p rability across the three treatment groups (i.e., the comp s group and the discussion-session group from the experimental vell as the conventional-course control group) we include in th ly those students in each category for whom we obtained con on both pretest and post-test. There was no significant diff n the means of these three treatment groups on the "conventional achievement" pretest.

19. There is good reason to believe that some of the differences in attitude and performance between students in the experimental and conventional courses can be accounted for by the familiar Hawthorne effect [see F. J. Roethlisberger and W. J. Dickson, *Management and the Worker* (Cambridge: Harvard University Press, 1939)]. Although students came into the experimental course expecting the usual PS 150, it did not take them long to sense that new things were being tried. The pretest itself confirmed that an experiment was underway and that they were part of it. By the same token, the instructor and the graduate assistants employed in the experimental course may have been spurred to greater efforts at times because of their desire to see the experiment succeed. If so, that in itself constitutes a good reason for experimentation with novel instructional modes and course formats.

20. To the question "How would you advise a friend who had a choice between taking this same course (including PLATO) or another section which covered the same material but without PLATO" students in the PS 150 comput r games section responded as follows:

"Avoid PLATO section like the plague."	0%
"Avoid PLATO section if convenient."	0
"Take PLATO section only if convenient (it makes no difference but is a new experience)."	14
"Take PLATO section if at all possible."	60
"Fight tooth and nail to get into PLATO section."	26
N = 50	100%

"Student Attitudes toward PLATO–Survey Results,' CERL Evaluation Report (January 28, 1972), unpublished.

21. This is one of the four items in the "sense of political efficacy" scale originally appearing in A. Campbell and R. Kahn, *The Voter Decides* (Evanston, Ill.: Row, Peterson, 1954), 187-94.

22. "Student Attitudes."

23. See Patrick Suppes, "On Using Computers to Individualize Instruction," in *The Computer in American Education*, ed. Don D. Bushnell and Dwight W. Allen (New York: John Wiley and Sons, 1967), 11-24, for a brief discussion of the ways in which individual differences in students may be accommodated by CAI systems and some of the limitations of this endeavor.

24. There are, of course, other forms of CAI in which self-pacing might become a much more important advantage.

25. Excellent descriptions and critiques of several of the leading simulations developed for political research can be found in *Simulation in the Study of Politics*, ed. William D. Coplin (Chicago: Markham, 1968).

26. See the Introduction to this volume, fn. 10; and Chapter 2.

Chapter 5. Computer-Assisted Instruction in Political Philosophy

Roger D. Masters

"Souvenez-vous toujours que l'esprit de mon institution n'est pas d'enseigner à l'enfant beaucoup de choses, mais de ne laisser jamais entrer dans son cerveau que des idées justes et claires. Quand il ne sauroit rien, peu m'importe, pourvu qu'il ne se trompe pas. . . ."

Rousseau, *Emile*, Book III

Introduction

The title of this essay is bound to raise eyebrows if not induce snickers: how could one presume to use computers in teaching political philosophy? Computer-assisted instruction in traditional courses on political theory would seem to be technology run wild, attributable to base motives (an attempt to "keep up with the Joneses" in the more behavioral branches of the social sciences, a desire to be different, or disdain for the substantive issues raised by "normative" theorists). On the surface, such a use of modern technology apparently justifies the worst fears of Rousseau, who complained over two centuries ago that the development of the sciences and arts is highly correlated with moral corruption.[1]

I should like to argue, nonetheless, that the computer can have an effective role in courses devoted to political philosophy. Moreover, these innovations can function both to improve the students' intellectual grasp of such thinkers as Hobbes, Rousseau, or Marx, and to increase student-faculty discussion of the theoretical issues they raise. Far from standing in the way of the customary approach to philosophical issues, in other words, I believe that innovative uses of computers can strengthen it.

Before going further, however, it is essential to clear away a common misconception. There is a widespread belief that the computer is primarily a tool for complex mathematical computation. There is no doubt that computers are highly effective in statistical calculation (as one who spent days at a hand calculator producing a single multiple regression coefficient can attest). But computers are not merely--or even essentially--efficient calculating machines; rather, they are complex devices for handling large amounts of information, and hence can also be utilized with non-quantitative data in radically new ways.

The following report concerns a series of experimental uses of the Dartmouth Time-Sharing (computer) System in courses dealing with political theory. These innovations reflect the view that computers can improve the relationship between faculty and students in so-called "soft" areas, where the primary objective is an increased understanding of complex problems. It will not be assumed that the issues of political philosophy are in any way *quantifiable*, nor indeed that such a quantification would be anything but an absurdity.

While the following report focuses on the uses of computer-assisted instruction in political philosophy, therefore, the methods should be of relevance to a wide range of teaching situations. Indeed, one of the courses in which they have been applied--a survey of the theoretical and practical relationships between the biological sciences and politics--is comparable to most social science courses in the kind of substantive materials taught.

Conceptualization

The Problem

The decision to experiment with CAI in political philosophy was based on an observation and an assumption. The observation, widely shared by those who teach political theory, is that many students make egregious errors in their study of famous political theorists. While false statements litter the final examinations of undergraduate (and even graduate) students in many fields, they seem even more frequent in courses in political philosophy. No matter how carefully one has prepared traditional lectures, it is disconcerting to realize that, for some students, St. Augustine greatly influenced Cicero or that Rousseau claimed all men have a natural right to property.

Frustration with such trivial errors led to an awareness that informed analysis or discussion of political philosophy is impossible with students who do not know a minimum of factual details. It is all too easy to feel that, since political philosophers discuss what are today called "normative" questions or values, students need only express their *opinions* about the works assigned in a course. On the contrary, political philosophy is as much a scientific discipline as any other field in the contemporary curriculum—at least in the sense that it is concerned with an identifiable body of data which must be analyzed according to accepted canons of method.

Without wishing to go into the epistemological status of philosophy, therefore, suffice it to say that one cannot learn anything without a knowledge of the subject-matter being studied. In political theory, this subject-matter takes the form of difficult written works, normally in prose, which both explain and evaluate political life. While it is tempting to speak of different theoretical positions as competing "paradigms"—using the now common terminology of Thomas Kuhn—one need not refer to the sociology of knowledge to state the fundamental problem in teaching political philosophy: the student must learn the position of a thinker, be he Aristotle or Marx, *before* it can be analyzed, discussed, or disputed.

Political Theories as Sets of Propositions

A simple way of conceptualizing this problem is to consider the work of a major political philosopher as a set of propositions (using the term "set" in its technical, mathematical sense). This data-set has a structure, since the different statements made by a theorist are obviously not all of equal status. Hence one of the primary purposes of scholarly research in political philosophy is to elucidate the ordering or priority of a philosopher's statements, emphasizing those which are somehow fundamental, showing how they are related to others, and inquiring into apparent or real contradictions between propositions.[2]

Frequently, a course in political theory will follow a given concept (e.g., "freedom") or proposition (e.g., "all men are created equal") in the history of Western thought. If one assumes that a theorist's work forms a set of propositions, such an approach concerns the intersection of the data-sets known as the political theories of Locke, Rousseau, Mill, etc. Similarly, historical analysis traces the evolution of a given concept or proposition as it is utilized in (or excluded from) the sets of propositions elaborated by a sequence of philosophers.

From this perspective, the tendency of students to make blatant errors in restating the theories of major political philosophers is more readily understandable. In our attempt to focus the students' attention on the perennial issues of Western political thought, we often emphasize the intersection of sets whose content has not yet been learned. As a result, the student is encouraged—and rewarded—for comparisons between thinkers before (s)he has fully understood their theoretical arguments.

It follows that one would do well to stress accurate learning of the propositions in each philosopher's work as a precondition for discussing broader theoretical issues. Some might object that this approach rests on the debatable assumption that each political theorist was "consistent." For example, it is sometimes argued that philosophers evolved throughout their lives, either changing their views or contradicting themselves fundamentally from one work to another.[3] While logical contradictions or major changes in emphasis are of course well known in the writings of some theorists, such a finding presupposes factual understanding of the data-set constituted by each philosopher's texts.[4]

As a result, it seems valuable to assume, when teaching political philosophy, that a theorist's writings form a set of statements, and that the first task for the student is to learn the most important of these propositions with a high degree of accuracy. Courses in political philosophy can therefore be assumed to require a considerable amount of cognitive learning, not as an end in itself, but rather as a precondition for intelligent discussion, analysis and writing.

This approach to teaching political philosophy underlies the experimental uses of computers described below. It presumes that new methods which increase the reliability of student cognitive learning are desirable, insofar as exact knowledge of the subject-matter is an essential prerequisite. But such learning tasks cannot be the ultimate focus of an examination of political philosophy, since the ability to understand the implications of different theories and ultimately to make informed political judgments must remain the ultimate objective.

As will be noted, the main emphasis has been on cognitive learning. It is also possible that philosophical argument and analysis could be more directly taught by means of computer-assisted instruction. For example, the Socratic dialectic is characterized by a dialogue in which the learner is presented with a series of questions in the form of a branching tree (often based on "yes/no" options), where the learner's answers help determine the next question. In principle, there is no reason why this method, which is sometimes used in classroom recitations, could not be adapted to computer programming. To date, however, our experiments have been limited to the simpler and more general problem of promoting cognitive learning of specific propositions.

Our experience suggests that innovative techniques can be seriously considered for courses in political theory if they satisfy two criteria: first, improved learning of the theoretical works being studied; second, absence of negative side-effects inhibiting the analysis and discussion which are the primary aims of the educational process. While the issue of possible side-effects requires more concern than is often evident in proposals for technological innovation, it will be deferred until the experimental uses of computers in political theory have been presented.

Why Use Computers in Teaching Political Philosophy?

Computer-assisted instruction (CAI) rests on the observation that the computer can serve as a means of improving the student's knowledge. Computer simulation, gaming, or quantitative data analysis provides *experiences* leading the student to findings that are less effectively taught in a more didactic way. In contrast, so-called "programmed instruction" (which may or may not be administered by computer) focuses more directly on specific concepts or propositions that the student is expected to learn.

The basic principle adopted here is simply that computers can be utilized to learn key propositions in the writings of a political theorist. Although ultimately intended to improve students' understanding of philosophic issues, computer applications were designed with the immediate aim of increasing the accuracy of learning.

While the techniques to be described below are still frankly experimental, and evaluative data fragmentary, it must be emphasized that the computer is NOT used as a substitute for *any* major element of the teaching process. Reading assignments, lectures, classroom discussions, papers, and examinations continue to be the core of the course. Rather, computer applications are intended as reinforcing devices in order to reduce the frequency of error in cognitive learning.

Traditionally, several devices have been used for this purpose. In the old-fashioned "recitation"--still utilized in many law schools--a randomly selected student is asked to restate or explain a given proposition during class. Although this may well be one of the more effective learning techniques ever devised (since the fear of public ridicule provides a strong stimulus to careful study), such "recitations" have generally disappeared from undergraduate education as classes have increased in size and a more sophisticated style has spread. Students now rebel at the notion that the prime function of a college-level course is rote recall of reading material, and the recitation technique is difficult in large classes for those who lack the exceptional skills of Prof. Kingsbury in "Paperchase." Because the number of classroom hours per course has declined since the turn of the century in most colleges, moreover, use of this technique limits the time available for the lectures or informal discussions sought by most contemporary students.

Another traditional technique which efficiently assisted learning was the short quiz. Like the recitation, however, contemporary students tend to object to in-class written assignments because they seem "punitive" and appear to waste valuable minutes of contact with faculty. For the faculty, moreover, increased pressure for research and scholarly publication makes it less attractive to devote time to preparing and grading frequent quizzes, to give five or more hours of class per week in each course, or to offer three or more courses per term (all of which characteristic of many colleges a generation or two ago).

As a means of surmounting these problems, I experimented a number of years ago with daily quizzes consisting of one or more multiple-choice questions on the assigned reading. Such fixed-option items have several clear advantages: they are easy to administer and grade, incorrect responses can be designed to reflect typical errors, and the set of options can readily serve as the basis of classroom discussion.

For a large class, however, this device also has drawbacks. Grading and the sheer volume of paper-work become inconvenient with more than 25 students in a class. If more than one multiple-choice question is used during a normal class session, detailed discussion of the quiz can take up too much time, preventing full coverage of other issues relating to a particular text. Yet if some items are not discussed in class, the student does not know why these questions were asked, nor how they relate to the overall context of the theory being studied.

It therefore seemed interesting to utilize the interactive possibilities of the computer to administer similar exercises outside class hours. The principle of encouraging correct recognition of theoretical propositions remained primary, although pre-programmed responses, *explaining* the alternative answers, also permitted better understanding of each option chosen by the student. Moreover, since administration of multiple choice or true/false questions on the computer permits the use of more items, the resulting worksheets allow an emphasis on the relationships between different concepts and propositions.

The precise type of computer-assisted instruction involved will be described in more detail below. First, however, it would be useful to indicate how this use of the computer was related to other aspects of the learning situation. In particular, it is important to see this innovation as a way of altering the rhythm of student work and the character of student-faculty interaction.

Rhythm of Student Work

One of the curious discontinuities between teaching in the natural sciences and in other disciplines concerns the role of structured learning experiences outside the formal classroom or lecture presentation. Whereas students expect laboratories in many natural science courses, the equivalent does not usually exist in the social sciences and humanities. Although the reasons for this are obvious, the consequences deserve consideration.

In most traditional courses in the social sciences and humanities, students are assigned readings, occasionally write papers, and take exams. Their contact hours with the faculty are usually lectures or at best seminar discussions. One result is that students typically read at an uneven rate. To be frank, one very normal pattern is a day or two of hurried reading before the midterm exam, an all-night exercise in writing a term paper, and a couple of days of frantic study before the final examination. In this type of course, class meetings provide an inefficient means of diffusing information--and a minimal sense of continuity between the spurts of attention and energy required of the student.

Few learning tasks or individual responsibilities in the modern world are like the student's work in courses just described. Instead, one is usually in situations that require prolonged and sequential work as a problem unfolds. For this reason, it seems useful to develop pedagogic methods which encourage (and require) students to work more continuously on structured tasks outside the classroom.

While the above comments could apply to most college courses in the humanities and social sciences, they are particularly applicable to the study of political philosophy. One can hardly hope to grasp the thought of Plato or Marx during an all-night cramming session for a mid-term examination. A more continuous process of learning and understanding throughout the term is clearly preferable.

In addition to structuring student reading in *time*, creating the equivalent of short laboratory-type experiences, the computer programs described below also structure the student's reading in *content*. By emphasizing specific tasks to be completed, and by providing immediate feedback on their completion, not only can minimal recognition of selected propositions and concepts be improved, but the understanding of the overall argument of a theoretical work can be clarified.

Structured materials administered outside the classroom also permit some of the valuable student-faculty contact hours to be devoted to dialogue and discussion—or even individual tutorial. The use of computers need not, therefore, represent a reduction in student interaction with faculty, as is sometimes feared. On the contrary, as the data below will show, it can improve that interaction by encouraging more coherent planning of the student's learning experiences.

Interactive computer routines have a further virtue, analogous to the laboratory in science courses. As Rousseau pointed out, purely passive reading is generally unreliable as a method of learning.[5] Recent psychological research has emphasized the role of active *use* of cognitive information in the process of converting short-term memory to long-term memory. By giving the student something to *do* after he has read a book, and by providing immediate feedback on the accuracy and relevance of the student's work, the computer becomes an effective supplement to traditional educational procedures.

Finally, from the perspective of the faculty member, computer routines—once developed and tested—become a "capital" investment which facilitates teaching. Computer exercises can be stored on magnetic tape, disk, or punched cards to be used when needed; like the interpretive text-book or a previously given set of lectures, they can then be assigned without requiring that the teacher rethink each alternative every time a course is given. Hence these devices permit faculty-members to devote larger portions of their time to specific problems encountered by students, to reconsidering substantive issues, or to research.

The Context of the Experiment

Before describing in detail the instructional applications of the computer which are the basis of this report, it would be well to mention the nature of the courses in which they were introduced. The first experiments with the computer in teaching political philosophy were conducted in College Course 2, entitled "Science, Revolution, and Moral Corruption." An experimental interdisciplinary course taught jointly with Professor Joseph Harris of the Department of Physics,[6] this course introduced numerous innovations in media and pedagogic approach thanks to a grant from the President's Venture Fund at Dartmouth College. Substantively, College Course 2 focused on the relation between science and modern society, particularly as reflected in the writings of Marx, Rousseau, Sartre, and Lévi-Strauss.

In this course, CAI was developed to accompany Marx's *Communist Manifesto* and *1844 Manuscripts*, Rousseau's *First and Second Discourses*, Sartre's *Search for a Method*, and selected readings from Lévi-Strauss, Ortega, and other contemporary writers.[7] Since College Course 2 was offered twice, in the Spring Terms of 1973 and 1974, experience with these experimental uses of the computer can be compared in two different classes. (Indeed, it was only during the second offering of the course that the benefits of previously prepared computer exercises became fully evident.)

After the first experiments with computer exercises in College Course 2, they were also utilized in Government 97, "The Nature of Political Inquiry"--an advanced course on alternative approaches to the study of politics taught jointly with Prof. Denis Sullivan of the Department of Government. Here the problem was sufficiently unusual to deserve some mention: in surveying scientific as well as philosophic approaches to political analysis, it was necessary to give a highly compressed survey of the Western tradition of political philosophy. To this end, computer exercises were developed to structure and help learn assigned readings from Antiphon the Sophist, Plato's *Republic*, Aristotle's *Politics*, Hobbes' *Leviathan*, Rousseau's *First Discourse*, and Marx's *German Ideology*.[8]

Finally, similar applications were introduced in Government 96, "Politics and Biology"--a new course which surveyed the theoretical and practical interrelations between the bio-medical sciences and politics. This course, offered for the first time in the Fall of 1973, was similar to most courses in the field of political science with respect to the type of reading and analysis required of students. Hence experience with the computer applications to be described below has not only been gained in three offerings which focused on specific works of political philosophy, but has been extended to another course with contemporary, non-philosophic readings in the social and natural sciences.

Computer "Worksheets" in Political Philosophy

Building upon prior experience with multiple choice or true/false quizzes administered with paper and pencil, I have developed a number of computer "Worksheets" on philosophic texts. These Worksheets, consisting of a series of questions, are distributed to students in advance of their reading (Figure 1). All students in the course are given a special computer account number on the Dartmouth Time-Sharing System and instructions on how to access a program based on the Worksheet.

After the student has done the assigned reading, using the Worksheet as a guide, this computer program is run. The interactive capacities of a time-sharing computer system permit the student to enter an answer to each question, and to receive immediate feedback, not only on the correctness of the answer, but on the significance of the proposition concerned and its relation to the theory being studied. Programs can either be written so that the student has only one chance to answer each question, or they can permit repeated trials until the correct answer is given.

Although the paper copy of this computer run can be saved for review (Figure 2), students are also given a complete "Answer Sheet" with detailed answers to *all* options (Figure 3). Therefore those who wish to restudy the Worksheet in detail can do so at their leisure. In the meantime, computerized record-keeping provides the instructor with a listing of those students who have done the Worksheet, together with their scores and the time required to run the program. For most students who have done the reading, the computer run usually takes no more than 5 or 6 minutes.

Because records of all student work are maintained by the computer, one need merely list the appropriate program to find out which students have completed the program and what their scores were (Figure 4). Moreover, since the records program indicates automatically the number of correct answers to each question, it is extremely easy to identify items which caused difficulty in the class (a task which is very tedious with paper-and-pencil quizzes). Hence the instructor can distribute a supplementary analysis of the class's performance on a Worksheet, indicating which questions were frequently missed--and why.

It should be obvious that computer exercises on assigned reading, like other forms of programmed instruction, can be used to improve recall of propositions in any discipline. I have experimented with similar Worksheets in the course on "Politics and Biology," which included a discussion of the legal and political issues arising from new bio-medical technologies such as psychosurgery.

The effectiveness of the computer in administering rather simple learning routines would thus seem to be generalizable to a broad range of materials not usually viewed as appropriate to programmed instruction. It should be remembered that the computer exercises described above were a supplement to traditional educational techniques. Lectures, discussions, papers and examinations were not *replaced* by the Worksheets, nor was the *score* recorded for students in the computer run taken as a component of the term grade. Rather, the exercises were graded on a "pass-fail" basis, with refusal to run the computer programs normally the sole reason for failure. (The reason for this policy was to reduce the incentive for cheating--an issue to which I will return in evaluating the technique.)

Before evaluating these computer exercises, it needs to be added that the computer was used in several *additional* ways, enriching the students' experience and expanding student-faculty interaction. If several uses of the computer are introduced simultaneously, student interaction with the computer becomes less artificial. Whereas a single application of computer instruction may create hostility and the appearance that technology is intruding in inappropriate areas, a combination of related uses has a rather different effect (as will be seen in student evaluations of these innovations). Precisely because the following uses of computers are *not* normally included in discussions of CAI, they may be of interest to readers who identify the computer with numerical calculation.

Additional Uses of Computers in Instruction

Computer-Generated Quotations in Classroom Presentations

By linking a computer terminal with a video projector or TV monitors, it is possible to use a file of quotations stored in the computer as a visual display accompanying a lecture or classroom discussion. In political philosophy courses, this visual image focuses the students' attention on basic passages which form the underlying structure of the lecture. In technical terms, visual display of the passages being read by a lecturer can be described as "redundancy," multiplying the channels through which information is conveyed. In information theory, such redundancy has been found in both phonemic contrasts and the genetic code, and seems to be a characteristic of efficient communications systems. Practically speaking, this simply means that students are less bored and their attention is focused more effectively on the substance of lecture material.

Some instructors use slides or overhead projectors for an equivalent effect, but computers have several advantages. The file of quotations can be modified more easily and quickly than new slides could be produced. Students can list the file on paper before the lecture, or the professor can do so and distribute copies to the students, so lecture notes can be taken directly on the margins of the print-out (Figure 5). The order of presentation of quotations during the lecture can be varied at will. And, when the quotations are machine-readable, students or the instructor can select them for display on the basis of their topics, keywords, etc.

Computer Generated Bibliographies

Bibliographical references are usually distributed as part of a course syllabus or written in a haphazard manner on the blackboard. Neither of these devices, however, is entirely satisfactory for the student who wishes to do more detailed reading on a topic, particularly if this desire is not shared by the class as a whole. Here again, the capacity of computers to handle large amounts of qualitative information rapidly can contribute to undergraduate instruction.

Using a program which alphabetizes entries automatically, annotated bibliographies to specified subjects have been stored on line. Students are invited to list bibliographies of interest at their leisure. Hence those who seek additional bibliographical material can access it quickly, without taking classroom time for so doing and without presuming that all students will do so.

This point is important, since such computerized bibliographies efficiently reward those students with high motivation. All too often, innovations in teaching are designed to compel minimal work from all students, rather than encouraging further study by the concerned and highly motivated members of a class. In the future, automatic indexing and bibliographical retrieval will permit students who are ready for advanced work to jump from the listings described here to professional retrieval services.

Computer Message System for Student-Faculty Interaction

In moderate-sized classes (35 students or more) and especially in large lecture courses communication between students and faculty is often inhibited by the apparent difficulty of access to the professor. A few students may cluster around the podium to ask a question immediately after a lecture; some will take advantage of regular office hours to discuss problems informally. But many students feel inhibited from raising points in a [illegible] discussion (especially if they feel the question will *seem* "[illegible]"), and there is a general sense that faculty are less accessible than [illegible] should be.

[illegible] difficulty is compounded [illegible] a difference in the daily rhythms of [illegible] which distinguishes many students from most faculty. Whereas [illegible] normally have families and complete their day on campus in the [illegible] afternoon, a large number of students tend to study at night. [illegible] curricular activities, sports, or part-[illegible] employment often occupy [illegible] during the daytime hours when a professor might be able to [illegible] with them; in the early evening, just as students are able to take greater advantage of informal [illegible], typical faculty-members go home to their families.

The computer can provide a means of escaping from these [illegible]. Our two-way message system permitted any student to [illegible] with the instructor from his or her course user number; these messages could be either signed or completely anonymous. For return communication, messages could be sent to a single student, any group, or the entire class. In this way, it was possible for students and faculty to communicate with each other without being simultaneously present.

To provide for rapid replies to students, each morning the file of incoming messages was listed on a Departmental terminal by the secretary (a routine task taking only moments), and was on my desk when I arrived for work. During one term, as an experiment, I had a portable terminal installed in my home. This further improved the speed of response, since student messages could be listed both the first thing in the morning and the last thing at night, at times when access to the computer was particularly rapid.

It might be thought that this system would interpose the computer between students and faculty, depersonalizing their relations. Just the reverse was the case. Many messages were answered in person, and, when they were answered via the computer, the exchange frequently led to additional conversation between student and faculty before or after class. Indeed, the increased communication with students greatly facilitated name recognition, so that almost all students who used the two-way message system were known by name within several weeks.

Moreover, the computer facilitated a type of feedback which is otherwise rather rare. Many students felt free to make anonymous complaints which they would probably not have communicated directly to a professor, and others felt free to sign questions or criticisms (as well as praise). In addition, there may be an effect of communicating through a computer terminal not entirely unlike the "confessional": one student admitted attempting to cheat--and signed his message!

Computerized Comments on Student Work

In courses where students are required to do a moderate amount of work at the computer, the message system just described can also be used for a more substantive form of feedback--namely grading student papers and assignments. If the faculty member has a computer terminal available, it is possible to comment on written work by typing a message directly into students' course user numbers. In this way, students need not try to decipher handwritten comments in the margins, and have access to the faculty member's assessment of their work without delay.

Student Evaluation of Courses

A final use of the computer might be mentioned, though it does not deal with instruction in the narrow sense. In several experimental courses, it was felt useful to secure student assessments of the teaching innovations used. For this purpose, a student assessment questionnaire was prepared (Figure 6); quite obviously, computer handling of the data permitted rapid and effective tabulation of the results. Although this is more typical of the quantitative analysis for which computers are best known, it does reflect the way that a fuller integration of computer technology with undergraduate instruction can improve feedback between faculty and students (especially when such course assessment questionnaires are anonymous).

Description of the assessment questionnaires may be helpful, since the data will be utilized below. Students were asked to rate a number of aspects of the course on a 0 to 10 scale, with 0 being the "worst" and 10 the "best" educational experience in their judgment. Questions on the best and worst course taken at Dartmouth were included to provide a base-line for data. Computer runs of the data can readily give not only means and medians (Figure 7), but a display of ratings by quartile, a histogram, or, of course, more complex statistics (though the latter have not been computed because sample sizes are still relatively small).

Evaluation and Discussion

Many of the above uses of the computer are applicable in a wide range of courses in the undergraduate curriculum. Indeed, the computer-based bibliographies and the two-way message system have already been used by colleagues in fields such as anthropology and geography. While the following evaluation will emphasize the relevance of the computer in political philosophy courses, it should be obvious that what is said could often apply to other subjects.

An additional remark is also in order. It goes without saying that the flexibility, speed of response, and general accessibility of the Dartmouth Time-Sharing System were a major asset in the experimental programs described above. Batch-processing computer systems would probably not be able to handle most of these teaching techniques as well or at all. There is good reason to believe, however, that a time-sharing system which treats the computer as a "free" good, like a library, is at least as efficient as (if not more so than) other methods of allocating computer facilities; in particular, student use of computer time under this system does not appear to inhibit other conventional uses of large computers for research or administration.[9]

It is possible that such time-sharing systems will spread through American institutions of higher learning. Alternately, smaller time-sharing systems--like the PDP-11--may proliferate for specialized CAI applications. In either case, teaching techniques in which the computer facilitates student-faculty interaction may be especially valuable in the future. For this reason, careful evaluation of the effects of computer applications in undergraduate education is particularly important. Although further assessment is necessary, preliminary evidence concerning the effects of the techniques described should therefore be of interest.

Effects of Computer Worksheets

It should go without saying that mere "information transfer" is not the primary objective of college instruction generally. But, as was argued above with respect to political theory, accurate learning of specific factual statements is a necessary prerequisite to understanding, analysis, and sound judgment. As such, there are two measures of effectiveness that need to be distinguished more clearly than usual: first, accurate recall (i.e., the probability of a "correct" answer); and second, avoiding error (i.e., the probability of "wrong" answers).

In the assessment that follows, it will be assumed that we seek not only to *increase* the former, but also to *reduce* the latter. Following the Socratic precept that ignorance is thinking one knows the answer when one does not,[10] avoiding an erroneous answer is considered a desirable outcome independent of--and complementary to--correct responses. While "Don't Know" is not as desirable as the correct answer, it is surely preferable to mistakes.[11]

Only one statistical analysis of the effects of the computer-programmed "Worksheets" has been completed. This study concerns a 50-question, true/false part of a final examination. The number of students taking this exam was only 16, and there is no way to compare the difficulty of questions rigorously. Nonetheless, the data give a tentative idea of the consequences of introducing computer exercises in courses dealing with what are usually called "soft" or qualitative materials.

Throughout the questionnaire, statements were included in their correct forms or were inverted to make false statements in roughly equivalent proportions. In Table 1, the percentage of correct and incorrect answers, as well as "Don't Know" responses, is tabulated separately for six different conditions under which the applicable quotation had been presented to the students in the course. The computer exercises described above appear to have had a positive impact, striking because they not only markedly increased the proportion of correct answers (to 82.6%), but also reduced the proportion of errors (to 9.5%). Hence, on the dual criteria set forth above, the use of programmed Worksheets seems to improve the cognitive learning of factual propositions without the side-effect of increasing errors.

TABLE 1

Effect of Computer Worksheets on True/False Final Examination

Source of Item on Final Exam	Answer: Correct	Answer: Incorrect	Answer: Don't Know	Number of Responses
Assigned reading only	63.7	14.3	21.8	160
Reading and lectures:				
Live	68.7	20.3	10.9	64
Taped	27.0	31.2	41.6	48
Reading and lecture with TV display of quote:				
Live lecture	53.1	13.5	33.3	96
Taped lecture	50.0	21.8	28.1	64
All of above (without computer Worksheet)	56.0	18.1	25.9	432
Any of above with computer Worksheet	82.6	9.5	7.9	368

Source: Final Examination, Government 96 (Fall, 1973).

Qualitative comments on the computer Worksheets by some of the best students, moreover, reinforce the admittedly provisional[12] statistical data. As one outstanding student said, in an unsolicited letter after computer exercises in political philosophy:

> I found the computerized worksheets an invaluable and innovative guide to some rather difficult reading; they brought out salient points in the material, provided immediate feedback, and gave additional important distinctions not immediately obvious in the material itself (in the form of your "Notes" [i.e., explanatory material programmed in the computer feedback]).

This is not to say that the use of computer Worksheets was considered desirable by all students. A few objected vigorously to the extent to which they were required, in reading philosophic texts, to structure their study in terms of the questions on the Worksheets. While these objections indicate that this technique effectively requires students to emphasize precise learning of specific propositions and concepts, they reflect an attitude of some students who bitterly resent the feeling of being "programmed" to do a specified assignment.

Needless to say, at the limit such a feeling reflects a highly "subjectivist" attitude toward study, often found in students who take courses in philosophy precisely because they are *not* scientific and allow the maximum play for personal interpretation. If the argument at the outset of this report is correct, such "subjectivism" is undesirable: just as one hopes that students will identify typographical or grammatical errors in their written work (which cannot be justified merely by the conventional excuse "you know what I meant"), so it is impossible to enter into coherent discussion of political thought before the objective facts of philosophical positions have been learned.

Even granting this justification, however, it could be asked whether the benefits of the programs for computer Worksheets are attributable to the Worksheets and Answers rather than to the computer exercises based on them. For example, students themselves seem to have found the Worksheets more valuable than the experience of answering them on the computer: in College Course 2 (Spring 1973), the hard-copy Worksheets and Answer Sheets, which after all could be administered as paper-and-pencil exercises, were rated an average of 6.9 (on the 0-10 scale), whereas the execution of the computer routines based on the Worksheets was only rated an average of 4.7.

This relatively low rating of the computer component of the exercise must be compared, however, to ratings for classroom quizzes. Students in College Course 2 rated quizzes given in class, also on a "pass-fail" basis, even lower (average 3.7) than the computer routines based on Worksheets. Moreover, the computer exercises in Government 96 were rated an average of 5.9 (on the 0-10 scale), whereas paper-and-pencil administration of similar multiple-choice or true/false items in another, more traditional political theory course (Government 64, "Modern Political Thought," Winter 1974) was rated an average of 6.

It would appear, therefore, that while many students do not *like* the experience of running computer exercises, these ratings reflect in part the distaste for required assignments which influence grades. Computer administration of the Worksheets compares relatively favorably with alternatives, and is preferable from the point of view of faculty time (since paper-and-pencil administration is extremely awkward and time-consuming).

Moreover, despite the difference between ratings of the Worksheets themselves and computer routines based on them, many students admitted that their experience with the computer was ultimately valuable. For example, in Government 96 (in which more than half of the students were science majors with considerable computer experience), 17 of 39 students said they had learned significantly by using the computer routines. In Government 97 this past year, when one of the computer routines did not function and students did the Worksheet with paper-and-pencil, several students complained, commenting that their interaction with the computer was "fun."

It follows that the use of the computer to administer programmed instruction in political theory could be considered a matter of convenience. If such materials are well designed, alternative methods of administering them would perhaps be equally valuable, provided they require an active response by students. Nonetheless, hostility to the use of the computer does not seem to vitiate the educational benefits of Worksheet exercises. And the computer does have manifest advantages, especially in large courses, which counterbalance the fact that students prefer more traditional classroom experience such as lectures, and assigned reading.

The complaint that Worksheets unduly "program" student work does, however, reflect a danger. It may be wondered whether these exercises reduce student reading to a rapid scanning of the assigned text in search for the "answers" to Worksheet questions. There is no question that some students have so responded to the technique. But here a balanced judgment is in order: many of those who quickly search the assigned reading for answers to the Worksheet would have superficially scanned the assignment anyway—or have skipped it altogether. And some who merely skimmed the reading for the "answers," because they were too busy to study the work carefully at the time, later *reread* the text more carefully in preparing written papers or examinations.

In general, comparison of scores on the computer exercises with final grades (based on traditional written examinations and papers) indicates that there are three rather clearly distinct groups of students. First, those who score highly on *both* the computer Worksheets *and* the graded written work (the outstanding, highly motivated students); second, those who score highly on the computer Worksheets, but did poorly in traditional graded work (those who did the computer exercises but little else); and third, those who scored low on the computer worksheets, but did well in traditional graded assignments.

Statistical analysis of this finding was not performed because the obvious result of a quick survey is sufficient for present purposes: the computer Worksheets should *not* be substituted for traditional written work. To do so would punish those students who effectively learn the material by other means (including "all-nighters" before the final examination), and would reward others who merely skimmed the assignment for the "correct" answers.

Moreover, counting grades in such exercises would invite attempts to cheat: while the computer Worksheets can be changed sufficiently to make results of a previous year irrelevant, it is virtually impossible to prevent sharing of the completed computer run being used in the course. By reducing the benefits of dishonesty as much as possible, the cost of being "caught"—e.g., for several students who always have identical scores—has been sufficient to deter most attempts to cheat.

If the Worksheets are not highly correlated with final grades and should probably not be graded, one might ask: "Why bother?" The answer corresponds to the three classes of students described above: first, the data and impressions summarized indicate that these exercises were extremely valuable for *good* students, who benefit from the structuring of their first reading of a philosophic text. Second, for the average or mediocre student, the computer exercise raises the floor of course work, since it decreases the probability of factual errors even when analysis of the material is weak. Third, students who dislike the computer exercises, but are willing to study hard in a traditional way, are not prevented from so doing by their mere existence.

The above considerations would seem to militate heavily in favor of utilizing such computer instruction *only* as a "pass-fail" adjunct to existing methods of teaching. As such, they seem to be useful, particularly in introducing students to a new work, without in any way serving as a panacea. One need not fear, in other words, that this technique will be subject to Rousseau's criticism of "vulgar authors":[13] insofar as American society has adopted the principle of democratizing higher education, the least one can say is that the teaching of political philosophy should minimize the tendency of students to make factual errors.

Effects of Computer Quotations on TV

The positive effects of the computer Worksheets were not equally evident in the use of computer generated quotations, exhibited on a TV screen. As Table 1 shows, along with this innovation the frequency of correct answers was reduced (from 68.7% to 53.1%). However, the use of TV display of quotations was also accompanied by a reduction in the frequency of *incorrect* answers (from 20.3% to 13.5%).

It will be noted that some of the items tested were related to lectures pre-recorded on audio-cassettes. While this experiment is not the focus of the present report, it seems that the live lecture is vastly superior to the prerecorded one: here is an innovation that is accompanied by a *reduced* frequency of correct answers (from 68.7% to 27.0%) AND an *increased* frequency of incorrect responses (from 20.3% to 31.2%). Although it had not been intended as such, therefore, these taped lectures are a model of the kind of technological innovation which should probably *not* be employed, if it has consistently negative consequences like those shown above when larger and randomized samples of items are used.

The potential of the computer-generated display of textual quotations is indicated, however, by its effect on the generally ineffective medium of pre-recorded lectures: compared to a proposition which was only conveyed on a pre-recorded tape, when such a tape was combined with TV display, the frequency of correct answers increased markedly (from 27.0% to 50%) and the proportion of errors declined (from 31.2% to 21.8%). Hence, whether for live or pre-recorded lectures, one finding seems to be that this technique does reduce erroneous judgments—though it also seems to interfere with correct information recall in live lectures.

These experiments were conducted *without* regularly distributing, before the class, a xerox copy of the quotation file to be displayed on the TV monitors. Subsequently, this has been done on several occasions. In fact, what happened in the first use of this technique was that students tried to copy the quotations being shown on the TV monitors. Thus their attention was divided between following the lecture and copying the quotation. By handing out the entire file in advance of the lecture, it may well be that one can overcome the reduced number of correct identifications under this method, without necessarily losing the advantageous reduction in erroneous answers. Only further research will say for sure, though the impressionistic response to the combination of the TV-generated signal and the distribution of hard-copy was highly favorable.

In any event, students in Government 96, in which several quotation files were listed or distributed in advance, rated this device on the average as 8.0 (on the 0-10 scale); and whereas those in College Course 2 had a lower rating for the TV display of quotations (average 6.7), they rated the hand-out of a few lecture outlines in that course much more favorably (average: 8.5). Hence it would appear that this technique is most effective when combined with advance distribution of a hard copy of the materials to be displayed on TV, so that these sheets can be used for note-taking.

Two Way Message System

The two-way message system was used in two courses (Government 96, and College Course 2 in 1974). In the former, a class of 42 students, the message system was frequently used by a large proportion of the class

TABLE 2

Use of Two-Way Message System

Week of Term	Student Messages: Total Number of Messages	Total Number of Students*	Number Anonymous	Faculty Messages (Total Number)
1	22	10	6	5
2	10	4	5	3
3	15	5	3	13
4	15	10	2	13
5	7	6	1	8
6	8	7	0	7
7	8	5	1	13
8	9	9	0	6
9	7	7	0	10
10	8	6	2	10
No date	2	2	0	0
Average per week	11.1	7.1	2.0	8.8

Source: Government 96 (Fall, 1973). Course lasted for a ten week term; 42 students enrolled.

*I.e., the number of different students who sent signed messages during the week. As will be noted, some students sent more than one mesasge a week, especially toward the beginning of the term.

(Table 2) and was highly rated (mean rating 8.39 on the 0-10 scale). In the latter, which had 33 students and 2 professors, the system was used by a smaller proportion of the class and was less highly rated (6.55 on the 0-10 scale). Nonetheless, even in the second case, the two-way message system provided extremely valuable feedback on a number of problems that arose in the course—and helped in many ways to "demystify" the computer.

Table 2 presents a detailed breakdown of the pattern of use of the two-way message system in the larger of the two courses described above. This pattern is perhaps even more instructive than the fact that there were an average of 11 student messages per week (approximately 1 per 4 students enrolled), and 8.8 faculty replies per week. It will be noted that the rate of student messages during the first four weeks of the term was approximately twice that of the last six weeks, and that the use of anonymous comments declined markedly after the first month. Both details suggest that the two-way message system served primarily to open channels of face-to-face communications rather than to substitute for them—which was also my impression in teaching the course.

The two-way message system was particularly effective in overcoming the lack of synchrony in the student and faculty work rhythms. Table 3 indicates the time of day when students used the message system. Only 43% of student messages were sent between the hours of 10 a.m. and 5 p.m., when students are most likely to contact their professors by

TABLE 3

Time of Day that Students Used Two-Way Message System

Time	Number of Messages Sent
Midnight to 3 a.m.	8
6 a.m. to 10 a.m.	5
10 a.m. to Noon	10
Noon to 5 p.m.	36
5 p.m. to 8 p.m.	23
8 p.m. to Midnight	25
No time recorded	4
Total	111

Source: Government 96 (Fall, 1973).

conventional means. The remaining 57% of student messages were initiated at times when communication between students and faculty is normally impossible, many during late evening hours when faculty are at home if not asleep.

Other Computer Applications

Of the other experimental uses of the computer, rather little need be said. The availability of computerized bibliographies was not *generally* considered of great utility in Government 96, where it was used most extensively (average rating 6.39 on 0-10 scale). Of seven such bibliographies, the average student listed 3.4. But for *some* students, these bibliographies were considered valuable—and, as will be recalled—the purpose of this device is to encourage more highly motivated students.

Comments on student papers entered in student message files were, in general, a failure. Students did not have occasion to list their message files routinely, and therefore did not profit greatly from this system; since it was necessary to announce in class that papers were finished, typed or handwritten comments could just as easily have been utilized. In this case, the use of the computer has been abandoned, though it might be successful in a college environment where all students regularly list many messages and announcements stored on line.

Summary and Conclusion

A range of computer applications, developed primarily for courses in political philosophy and also used in a course on "Politics and Biology," have been described. Most important are Worksheets based on major works in political theory. Students read the texts with the Worksheets as a guide to central issues, then run a computer program in which they answer multiple-choice or true/false questions; after each answer, the program indicates the reasons for the importance of the question, and the nature of the error if one has been made.

Other instructional applications of the computer included TV display of textual citations generated by the computer, a two-way message system for student-faculty communication, and computer storage of supplementary annotated bibliographies. While fragmentary data indicate that Worksheet exercises on the computer improved recognition of propositions encountered in reading and lectures, all of these experimental applications served to supplement and reinforce--rather than replace--the primary educational experiences of reading, lectures, written assignments, class discussion, and final examinations.

Indeed, one of the most impressive and useful consequences of *multiple* computer applications was a generalized familiarity with the Dartmouth computing facility for non-science majors. While only a few minutes at a terminal were needed to complete each Worksheet, when combined with other computer applications, students gained an awareness of the limitations and capacity of computer technology.

In a sense, the computer exercises were what Rousseau called "leçons des choses" (lessons by doing things).[14] For example, the inevitable difficulties arising from interaction with the computer system (occasional difficulties of access to a terminal [illegible] program which inexplicably malfunctioned, etc.) gave rise to useful, [illegible]*ncrete* understanding of the role of technology in modern society. Students who had never touched a computer terminal began the course by exhibiting great hostility to the experiment--and ended by feeling that they were no longer afraid of the computer as such.

It should go without saying that an understanding of the impact of technology on society is particularly important, not only for humanities or social science students, but also for the science major. This general consequence of using computers in teaching political philosophy may therefore be far more important than the detailed results discussed heretofore. All too often, the gap between the so-called "two cultures" is decried as a basic weakness in our educational system. Philosophers frequently condemn modern science and technology in words, while scientists blame philosophers and social scientists for an inability to specify ethical or legal standards for modern technology.

Ultimately, the fate of Western civilization may well depend on the ability of elites and citizens alike to come to grips with the awesome problems posed by contemporary scientific advances, particularly as they find practical applications. These problems will not disappear, and the student should be aware of them even when engaged in the sometimes comforting and ennobling study of political philosophy. Whatever the other consequences of using the computer when teaching theorists like Hobbes, Rousseau, and Aristotle, its primary benefit may well be a reminder that science and technology condition our attempts to realize the ends which preoccupied Western political philosophers: freedom, community, and, above all, justice.

FOOTNOTES

1. *Discourse on the Sciences and Arts* (1750), in *Rousseau's First and Second Discourses*, ed. Roger D. Masters (N.Y.: St. Martin's, 1964).

2. E.g., Roger D. Masters, *The Political Philosophy of Rousseau* (Princeton: Princeton University Press, 1968).

3. E.g., *The Political Writings of Jean Jacques Rousseau*, ed. C. E. Vaughan (Oxford: Basil Blackwell, 1962), I, 1-117.

4. Cf. Rousseau, *Emile*, III, in *Oeuvres Complètes de Rousseau* (Paris, Editions de la Pléiade), IV, 345 n.

5. *Emile*, III, p. 345 *et passim*.

6. Since I had never touched a computer terminal before beginning preparations for this course, Prof. Harris was of incalculable assistance in introducing me to the potentialities of the computer. Although he is in no way responsible for short-comings in the computer applications described below, their development would have been impossible without his help. In numerous instances, he was able to locate "bugs" which, to this non-initiate, had mysteriously afflicted my programs. Thanks for vital assistance in computer programming are also due to Seth Masters and Elliott Noma.

7. It is perhaps fitting that the first use of computers in teaching political philosophy concerned *modern* theorists. Nonetheless, the technique can be applied equally well to the classics, especially since Plato emphasized so clearly the necessity of clear memory in the education of the philosopher-king. Cf. *Republic*, III, 413c-d: "So we must watch them straight from childhood by setting them at tasks in which a man would most likely forget. . . . And the man who has a memory and is hard to deceive must be chosen, and the one who's not must be rejected mustn't he?" Trans. Allan Bloom (N.Y.: Basic Books, 1968), p. 92.

8. The rationale for the choice of Antiphon the Sophist, Aristotle, Hobbes, and Marx as "modal" political philosophers, whose writings elaborate characteristic alternatives in the tradition of Western political thought, is spelled out in Roger D. Masters, "Nature, Human Nature, and Political Thought," in *Human Nature and Politics*, ed. Roland Pennock and John Chapman, *Nomos XVII* (N.Y.: Lieber-Atherton, in press).

9. Arthur W. Luehrmann and John M. Nevison, "Computer Use under a Free-Access Policy," *Science*, 184 (31 May, 1974), 957-61.

10. *Apology*, 21c-23b; Rousseau, *First Discourse*, pp. 43-44.

11. Rousseau, *Emile*, III, p. 485.

12. The chi-square for the last two rows of Table 1 is only 2.54, with $p \approx .3$, if each item is treated as a unit and no measurement error or item allocation bias is assumed.

13. *First Discourse*, p. 62.
14. *Emile*, II (pp. 317, 393-96); III (p. 446); *et passim*.

Figure 1. A Worksheet

College Course 2 **73S Masters**

WORKSHEET NO. 2

ONE: The question posed by the Academy of Dijon, which served as the occasion of Rousseau's *First Discourse*, was:

1. "What good is it to seek our happiness in the opinion of another if we can find it within ourselves?"
2. "Has the restoration of the sciences and arts tended to purify or corrupt morals?"
3. "What is the origin of inequality among men; and is it authorized by natural law?"
4. "Has the restoration of the sciences and arts tended to purify morals?"
5. "What is the origin and Foundation of Inequality among men?"

TWO: Rousseau claims that:

1. It is a grand and noble sight to see man emerge from obscurity somehow by his own efforts.
2. That he will easily be forgiven for the side he takes.
3. Academies are always concerned with metaphysical subtleties.
4. Erudition is even dearer to the scholarly than integrity to good men.
5. Our reasoning does not coincide with historical inductions.

THREE: For Rousseau, the simplicity, innocence, and virtue of peoples who have been preserved from the contamination of vain knowledge are exemplified by:

1. The Moslems or Arabs.
2. Athens.
3. The Tartars.
4. The first Persians.
5. The Kingdom of Naples.

FOUR: For Rousseau, children should:

1. Learn how to write verses, as Voltaire (Arouet) advised.
2. Avoid idleness—e.g., by playing tennis, as Montaigne suggested.
3. Be educated by women, like the Persian kings' education described by Plato.
4. Be taught by professors like Cicero and Bacon.
5. Study the writings of the best known philosophers, like Hobbes and Spinoza, rather than the works of "elementary authors."

FIVE: Rousseau argues that:

1. Newton was a preceptor of the human race.
2. Paganism perpetuated the extravagances of the human mind to a degree unique in human history.
3. All of our vices owe their birth to the sciences and arts.
4. Montaigne erroneously preferred the Laws of Plato to the simple and natural regulations of the savages in America.
5. All of the above.

Figure 2. A Computer Worksheet Exercise

```
2) WORKS    17 JUN 74   14:21

YOUR NAME? ROGER MASTERS
THIS IS A MULTIPLE CHOICE TEST. ANSWER THE FIRST THREE
QUESTIONS EITHER 1,2,3,4,5, OR DK. ANSWER QUESTION FOUR
EITHER 1,2,3,4,5,6, OR DK. YOUR NAME, USER NUMBER, RESPONSES
DATE, AND TIME ARE BEING RECORDED.
QUESTION ONE. YOUR ANSWER?
? 4
CORRECT. SEE P. 80. NOTE THE IMPLICIT CRITICISM
OF GENEVA: WHILE ROUSSEAU SAYS HE WOULD HAVE CHOSEN
TO LIVE IN A CITY LIKE GENEVA. THE 'TRUE' MODEL IS
REPUBLICAN ROME. IN FACT, ROUSSEAU'S PRAISE OF
GENEVA INCLUDES A GREAT DEAL OF CONSCIOUS IRONY,
ESPECIALLY PP. 84-6 (WHICH IGNORE THE CONTINUED
POLIT'CAL CONFLICTS IN GENEVA DUE TO THE REFUSAL
OF THE MAGISTRATES TO CONFORM STRICTLY TO THE
CONSTITUTION--SEE PP. 229-30).

QUESTION TWO. YOUR ANSWER?
? 2
NO. SEE P. 92: 'THE MDRE NEW KNOWLEDGE WE ACCUMULATE,
THE MORE WE DEPRIVE OURSELVES OF THE MEANS OF
ACQUIRING THE MOST IMPORTANT KNOWLEDGE OF ALL.'
NOTE HOW ROUSSEAU QUESTIONS THE POSSIBILITY OF
BENEFICIAL PROGRESS.

QUESTION THREE. YOUR ANSWER?
? 5
CORRECT. SEE P. 129. HOBBES WAS CORRECT TO
REJECT THE TRADITIONAL NATURAL LAW TEACHING,
ACCORDING TO WHICH VIRTUR DEPENDS SOLELY ON
REASONING. 'HOBBES DID NOT SEE THAT THE SAME
CAUSE THAT PREVENTS SAVAGES FROM USING THEIR
REASON, AS OUR JURISTS CLAIM, PREVENTS THEM
AT THE SAME TIME FROM ABUSING THEIR FACULTIES,
AS HE HIMSELF CLAIMS.' (P. 129). MEN IN THE
PURE STATE OF NATURE ARE TOO STUPID TO BEHAVE
IN THE MANNER HOBBES DESCRIBES AS THE 'NATURAL
CONDITION OF MANKIND'-AND, IN ADDITION,
HOBBES REJECTS THE SENTIMENT OF PITY AS A NATURAL
CHECK ON THE DESIRE FOR SELF-PRESERVATION.

QUESTION FOUR. YOUR ANSWER?
? 2
CORRECT. NOTE THAT, ON THIS POINT, ROUSSEAU'S
POSITION IS IDENTICAL TO THAT OF HOBBES (CF.
QUESTION TWO, E.)

END OF WDRKSHEET
YOUR SCORE WAS:
  3 CORRECT   1 INCORRECT   0 DK
            = 2 OUT OF 4

2.622 SEC. 86 I/O
2) READY
```

Figure 3. Answer Sheet for a Worksheet

College Course 2 **74S Masters**

ANSWERS TO WORKSHEET NO. 2

Question ONE:

1. No. This is a question posed by Rousseau himself at the end of the *First Discourse* (p. 64). Note that, in terms of Rousseau's conclusion, "virtue"—i.e., the standard of good "morals"—is a "sublime science of *simple* souls" whose principles are "engraved in all hearts": it is *not* necessary to study science or philosophy in order to be virtuous.

2. No. This is the question of the *First Discourse* as it is RESTATED by Rousseau (p. 34). Note that in restating the Academy of Dijon's question, Rousseau changes it by adding the alternative that the "restoration of the sciences and arts" may have tended to "corrupt morals" rather than "purify" them; tacitly, he accuses the Academy of having biased the issue by the way it posed the question.

3. No. This is the question posed by the Academy of Dijon in 1754, which became the subject of Rousseau's *Second Discourse* (see p. 99).

4. CORRECT. See p. 31 (title page of *First Discourse*).

5. No. Compare the title of Rousseau's *Second Discourse* (p. 101), which—like the *First Discourse*—involves a subtle change in the question posed by the Academy of Dijon; in this case, Rousseau adds a reference to the "foundation" of inequality, and deletes the question relating to the possibility that inequality is "authorized by natural law."

Question TWO:

1. CORRECT. See p. 35. Rousseau never denies that, in a sense, the process of scientific and artistic development in the West since the Renaissance is superior to the superstition and barbarism of the Middle Ages. Indeed, Rousseau asserts that "the peoples of that part of the world which is today so enlightened lived, a few centuries ago, in a *condition worse than ignorance*" (p. 35). The moral corruption produced by science is *not* the only source of a "condition worse than ignorance."

2. No. See p. 33: Rousseau says explicitly the reverse ("I foresee that I will *not* easily be forgiven for the side I have dared to take.") Indeed, many critics in Rousseau's day—and since—have confirmed this prediction; as Rousseau well understood, he was attacking a central belief in Western culture.

3. No. See p. 33: according to the Preface, "This discourse is *not* concerned with those metaphysical subtleties that have prevailed in all parts of learning and from which the announcements of Academic competitions are not always exempt. . . ." Apparently, the Prize Competition of the Academy of Dijon is an exception to a trend "in all parts of learning" (though of course one could read the above sentence to mean that the "Academic Competitions" are *not* "parts of learning"). In any event, Rousseau goes on to add at once that, in this case, the Academy of Dijon has raised the issue of "one of those truths that concern the happiness of mankind."

Figure 4. Computer Listing of Student Records

```
.OLD LISTER.RUN
2) LISTER    17 JUN 74    14:02
NAME OF RECORDS FILE? RECORDS
                                   1  2  3  4       MINUTES    SCORE
HDU99001                                      EXERCISE NOT DONE
HDU99002 JACK BARRETT              1  1  1  1          4          4
HDU99003 ELLEN M. BERES            1  1  1  1          3          4
HDU99004 JEFF BOLTON               1  1  1  1          3          4
HDU99005 CRAIG BROWN              -1  1  1 -1          7          0
HDU99006                                      EXERCISE NOT DONE
HDU99007 DAVE FARMER               1 -1  1  1          5          2
HDU99008                                      EXERCISE NOT DONE
HDU99009 PAMELA GERVER            -1  1  1 -1          3          0
HDU99010                                      EXERCISE NOT DONE
HDU99011                                      EXERCISE NOT DONE
HDU99012                                      EXERCISE NOT DONE
HDU99013                                      EXERCISE NOT DONE
HDU99014                                      EXERCISE NOT DONE
HDU99015 GEORGE C. JEPSEN          1  1  1  1          4          4
HDU99016 DAVID KEPES               1  1  1  1          3          4
HDU99017 BRIAN KINGSBURY           1  1  1  1          4          4
HDU99018 DWIGHT KINGSBURY          1  1  1  1          4          4
HDU99019 KEVIN MCGILLICUDDY        1  1  1  1          3          4
HDU99020 JIM MIERS                -1  1  1  1          4          2
HDU99021 THOMAS N. NICHOLSON      -1  1  1  1          3          2
HDU99022 HEATHER PETERSON          1  1  1  1          4          4
HDU99023 MARK RHODES              -1  1 -1  1          4          0
HDU99024 MICHAEL ROITMAN           1  1  1  1          3          4
HDU99025 LG ROSENSHEIN            -1  1  1  1          3          2
HDU99026                                      EXERCISE NOT DONE
HDU99027                                      EXERCISE NOT DONE
HDU99028                                      EXERCISE NOT DONE
HDU99029 REGINALD L. THOMAS        1 -1  1  1          4          2
HDU99030 STUART WEEKS              1  1  1  1          4          4
HDU99031                                      EXERCISE NOT DONE
HDU99032 NEIL KORSEN               1 -1  1  1          4          2
HDU99033 DAVID LOCKARD             1  1 -1  1          4          2
HDU99034                                      EXERCISE NOT DONE
HDU99035                                      EXERCISE NOT DONE
HDU99036                                      EXERCISE NOT DONE
HDU99037 IRIS                      1  1  1  1          3          4
HDU99038 JOE HOFFMAN              -1  1  1  1          5          2
HDU99039                                      EXERCISE NOT DONE
HDU99040                                      EXERCISE NOT DONE
HDU99041 ROGER MASTERS             0  0  0  0          4          0
HDU99042                                      EXERCISE NOT DONE
HDU99043                                      EXERCISE NOT DONE
HDU99044                                      EXERCISE NOT DONE
HDU99045                                      EXERCISE NOT DONE
TOTAL CORRECT                     16 20 21 21

                        MEAN = 2.66667
                        S.D.  = 1 52277
1.197 SEC. 37 I/O
2) READY
```

Figure 5. Computer-Generated Quotations

JEAN-JACQUES ROUSSEAU

DISCOURSE ON THE
SCIENCES & ARTS

CLAUDE LEVI-STRAUSS

"A WRITING LESSON"
TRISTES TROPIQUES, CH. 28

@ ROUSSEAU'S CRITIQUE OF

CIVILIZED SOCIETIES

@

IF I WERE THE CHIEF OF ONE OF THE PEOPLES OF AFRICA, I DECLARE THAT I WOULD HAVE A GALLOWS RAISED ON THE FRON-TIER OF THE COUNTRY, WHERE I WOULD HAVE HANGED WITHOUT REPRIEVE THE FIRST EUROPEAN WHO DARED ENTER AND THE FIRST CITIZEN WHO WOULD TRY TO LEAVE.

ROUSSEAU, DERNIERE REPONSE
(1752)

@

THE EXAMPLE OF SAVAGES, WHO HAVE ALMOST ALL BEEN FOUND AT THIS POINT, SEEMS TO CONFIRM . . . THAT THIS STATE IS THE VERI-TABLE PRIME OF THE WORLD; AND THAT ALL SUBSEQUENT PROGRESS HAS BEEN IN APPEARANCE SO MANY STEPS TOWARD THE PERFECTION OF THE INDIVIDUAL, AND IN FACT TOWARD THE DECREPITUDE OF THE SPECIES.

ROUSSEAU, SECOND DISCOURSE

@

LEVI-STRAUSS' STUDY OF
PRE-LITERATE SOCIETIES

@

IT WAS NOT A QUESTION OF KNOW-ING SPECIFIC THINGS, OR UNDER-STANDING THEM, OR KEEPING THEM IN MIND, BUT MERELY OF ENHANCING THE PRESTIGE AND AUTHORITY OF ONE INDIVIDUAL—OR FUNCTION—AT THE EXPENSE OF THE REST OF THE PARTY.

LEVI-STRAUSS,
A WRITING LESSON

@

THE EFFECTS OF THE

DEVELOPMENT OF THE

SCIENCES AND ARTS

@

NEED RAISED THRONES; THE SCIENCES AND ARTS HAVE STRENGTHENED THEM.

ROUSSEAU, FIRST DISCOURSE

@

THE DEFECT OF WRITING

@

THIS DISCOVERY . . . WILL CREATE FORGETFULNESS IN THE LEARN-ERS' SOULS, BECAUSE THEY WILL NOT USE THEIR MEMORIES.

PLATO, PHAEDRUS

Figure 6. Part of Course Assessment Form for Students

DARTMOUTH COLLEGE

Government 96 **74F: Masters**

COURSE ASSESSMENT QUESTIONNAIRE

Please answer each of the following questions by writing in the blanks a number between "0" and "10," representing your measure of the effectiveness of the aspects of Government 96 listed below. (0 meaning useless or harmful, 10 meaning the best educational approach imaginable). To provide a base-line for comparison, you are asked to rate—on the same scale—the best and worst courses you have ever taken at Dartmouth (without naming them of course). If you have no opinion on a question, answer *"11."*

For the "Yes-No" or "More-Same-Less" subquestions just check the appropriate box. If you have no opinion on THESE questions, leave blank.

ANSWERS WILL *NOT* BE READ OR ANALYZED UNTIL AFTER COURSE GRADING IS COMPLETED.

Course User Number ______________

RATE THE FOLLOWING ASPECTS OF CLASS MEETINGS:

______ 1. Music played before class starts.

______ 2. Use of Computer quote files, projected on screen DURING Professor Masters' lecture presentations.

(Note: Your rating here should deal solely with the experience of seeing headings of lecture outline and quotations during the class—do not confuse this rating with item 14.)

______ 3. Slides chosen to illustrate lectures.

______ 4. Audio-visual lecture-presentations by Professor Masters (as a whole).

______ 5. Traditional lectures by Professor Masters

a. Would you have preferred a straight lecture course? Yes ______ No ______

Figure 7. Computer Analysis of Student Course Assessments

VARIABLE	TYPE	MEAN	MEDIAN	NO ANS	
1	0-10	7.22	7	2	Music before class
2	0-10	6.96	7	1	Use of Computer Display
3	0-10	8.06	8	0	Choice of Slides
4	0-10	7.76	8	0	Audio-visual presentations
5	0-10	5.83	6	1	Traditional lectures
85	0-10	8.52	8	1	Best course at Dartmouth
86	0-10	6.25	6	21	Best course elsewhere
87	0-10	2.19	2	4	Worst course at Dartmouth
88	0-10	1.75	2	21	Worst couise elsewhere
89	0-10	7.46	8	1	Rating Government 96

VARIABLE 85 (Rating of "Best Course taken at Dartmouth")

VARIABLE 89 (Rating of Government 96)

VARIABLE 89 \ VARIABLE 85	0	1	2	3	4	5	6	7	8	9	10	NA
0												
1												
2												
3												
4												
5										2	1	
6								1	3			
7								1	2	2	1	
8									4	2	1	
9								1			1	
10								1			1	
NA												1

Note: Diagonal represents ratings of students for whom Government 96 was equally rated with "best course" taken at Dartmouth. Ratings below the diagonal thus reflect judgments that Government 96 was better than any other course taken by the student completing the assessment.

Chapter 6. Teaching Principles and Methods with CAI

Jonathan Pool

"Why do you want to teach political science with CAI?" This is the first question that the staff of the SUNY at Stony Brook CAI Laboratory put to three political scientists in 1970, when they asked about the possibility of using the lab to teach "Introduction to Political Analysis," the basic course in methodology and philosophy of political science. Why CAI? To be truthful, the reasons for our interest in CAI were not very well thought out at the time. In retrospect, they were:

1. Stony Brook had a CAI lab.
2. The lab was not yet operating at capacity.
3. The course had not been offered before and had no crystallized syllabus.
4. The three instructors were committed to designing a fresh approach to the teaching of the subject.
5. There was a general ethos of experimentation and innovation in the department under its new chairman.
6. The three instructors were interested in CAI and its potential for individualized, interactive instruction.
7. The subject of philosophy of social science and basic methodology seemed suitable for CAI, because of the prevalence of definitions, procedures, and quantitative problems, which could be the bases for questions with correct and incorrect answers subject to automatic, objective diagnosis.

The last reason was enough to elicit guarded sympathy from the director of the campus CAI lab. She was aware that faculty demand for the facility would soon outrun the available terminal-hours, and she wanted to make sure that the lab would be put to the best possible use. So she put question number two: "What are you going to do with CAI that you can't do with conventional methods? After all, we can't waste expensive computer time doing what a programmed textbook could do as well."

Our answers to this question were based more on hope than on experience. First, we could route the student in more complex ways by computer than in a programmed textbook or workbook. Second, we could program the computer to analyze students' answers, rather than just compare them with a single correct answer. And, third, we could use the computer to keep records of how the students were doing, so the faults in our instructional programs could be corrected. This would be too expensive if piles of workbooks had to be collected after use, and every student entry coded and punched for analysis.

Tentatively convinced, the lab director said we could begin and offered the full cooperation of the staff. By the time we began to use CAI the course had been taught one semester, and the instructors had some ideas about the role the computer might play. At the outset, a decision was made to give CAI one particular job in the course: making sure that the students really knew and understood what they *supposedly* knew and understood. CAI was consciously built in as the "third force," after (1) class discussions and (2) textbook reading. Students came to the lab for one of their three weekly class sessions, and everything they were taught in CAI had already been discussed in class and in the assigned reading. These three components of the course were fully integrated, in part because the textbook was being written simultaneously with the CAI lessons by the instructors themselves. If, instead, we had selected an existing textbook for the course, we still could have produced a coordinated set of CAI lessons for that book in agreement with its author and publisher.

The need for a "third force" in our methodology and philosophy-of-science course was clear. Like our colleagues, we had great difficulty teaching abstractions. And even when students did successfully memorize, in words, the definition of "definition" or the distinction between a row and a column percentage, there was no certainty that they had learned anything meaningful or useable.

Thus motivated, the author of this chapter took on the job of producing some CAI material that would help students master the content of the course. With no prior programming experience other than an ability to use DATA-TEXT and SPSS, he was happy to hear that a CAI author's package was available on campus to make his job easier. The package contained a primitive version of the CLUEGEN procedure described in Chapter 3, and this is what was used. Since that chapter discusses what it is like to write CAI material with such a package, the present chapter will focus on the material that resulted.

Four Kinds of Tasks

Our use of CAI to make sure students knew and understood the subject involved four approaches. At the first and simplest level, we tested the students' ability to *reproduce* something which they were supposed to know. A typical case was a definition, which appeared on the screen with a blank in place of the term that was being defined. The student, who had already seen this definition in the textbook, had to supply the missing term. Multiple choice questions were also given at this level, where one of the answers reproduced what had been read in the textbook. This approach corresponds to the basic one described by Masters, oriented toward correct factual knowledge.

An example of a reproduction question as it appeared on the screen was the following:

> A(n) ______________ relational property is one that (y,x) has whenever (x,y) has it.
>
> □

The rectangle, called the "cursor," indicates that the computer is waiting for the student to type an answer. As (s)he does, each letter appears inside the cursor, which moves one position to the right. In this example the student is expected to type in the word "symmetrical"; this definition has appeared in the textbook, so this CAI item is merely checking to see whether the student remembers which term is defined this way—if not, the student will be reminded.

The second kind of material was *recognition* exercises. Here students might be asked to observe a series of items, while keeping a particular distinction in mind. When an item appeared, they had to indicate which of the distinguished concepts the item was an example of. Alternatively, they might be given a set of things and asked to pick the one that exemplified a particular concept. A set of generalizations might be presented, for example, with the instruction to indicate which was the probabilistic one. Or two statements containing partly similar wording were given, and the student was asked whether they referred to different objects, different properties (attributes), or both.

An example of a recognition item was the following:

"Last year most countries in the world experienced inflation."

☐

u,s,d

This was one item of a series, whose instructions were to decide whether each generalization that appeared on the screen was "universal" (u), "semi-universal" (s), or "descriptive" (d). Students typed the letter standing for the answer they thought was correct. The verbal definitions of these three types of generalization had been given in the textbook, and the students had already shown (in exercises of the previous type) that they remembered these definitions, but now for the first time they were asked to recognize actual cases as falling into one of the three types.

Thirdly, there were *practice* components that gave the student the chance to ask for things fitting certain descriptions. Whenever a conceptual distinction was being taught, there were practice opportunities in which the student could choose one of the concepts and see an instance of it. For example, logical relationships among sets were taught in part by a sequence which began as follows:

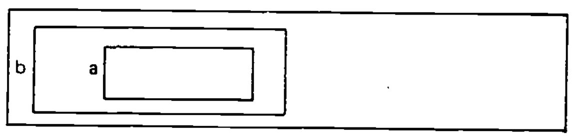
1. All objects with *a* have ***b***.
2. Most objects with *a* have ***b***.
3. Some objects with *a* have ***b***.
4. No objects with *a* have ***b***.

☐

Whichever number the student typed in, the corresponding (modified Venn) diagram appeared immediately below. Typing "1" would transform the screen into:

1. All objects with *a* have *b*.
2. Most objects with *a* have *b*.
3. Some objects with *a* have *b*.
4. No objects with *a* have *b*.

1



Students were also given chances to "change" what they saw on the screen. A generalization appeared, for example, and students were asked whether they would like to change its "domain," its "force," or both:

"No U.S. Senator today favors abolishing the Senate."

☐

•d,f,b,go•

If the student typed "d," asking that the domain be changed, the original generalization was crossed out and another appeared underneath, dealing with a different domain (set of objects) but otherwise identical:

~~"No U.S. Senator today favors abolishing the Senate."~~

d

"No legislator favors abolishing his legislature."

The screen then returned to its former display, and students could continue typing change commands, repeating the same ones if they wished. When ready to go on to the next item, they typed "go."

Finally, we used CAI lessons to teach the *application* of principles. This is clearly the most demanding test, not only for the student, but also for the author of CAI lessons. It is here that the capacity of CAI as a medium has its limit. But we have far to go before we as authors reach that limit. An archtypical application question might be: "Give an example of an ordinal variable." No machine can be programmed to recognize all the right answers and reject all the wrong answers to this question. But some less creative application skills can be taught via CAI. Table reading is one of the hardest skills to acquire, even though the possession of this skill is often erroneously taken for granted. Since we hypothesized that the skill could be developed only through extensive practice rather than explication, CAI was an important component in our strategy for teaching this skill. Our application exercises with tables involved the continued display of a table, accompanied by a series of questions or descriptive generalizations. The student's task was to inspect the table and infer from it two things: (1) whether it was possible, on the basis of the information in the table, to answer the question or determine the truth or falsity of the generalization on the screen; (2) if so, what the question's answer was or whether the generalization was true or false. An example is provided by the following display:

	Race of Executed			
Period	White	Black	Other	Total
1930-39	827	816	24	1667
1940-49	490	781	13	1284
1950-59	336	376	5	717
1960-69	98	93	0	191

☐

Was anyone executed in 1969?

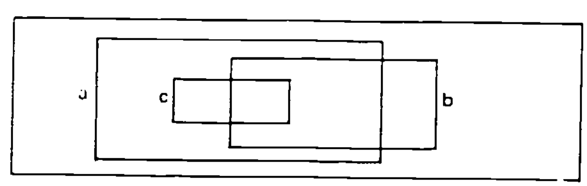
The instructions were to give the answer if the answer could be determined, and otherwise to type in "?." The question shown above was one of 16 consecutive questions all based on the same table.

Beyond this paradigm, considerably more creative exercises involving tables could have been written. A table with labeled row and column variables but with blank cells could be presented, and students asked to fill in the cells and margins with absolute numbers and row, column, and total percentages. The computer could be programmed to check the figures for internal consistency. Students could be required to make necessary adjustments and then be asked some questions calling for use of their own figures and requiring that they know whether row, column, or total percentages were called for.

Elsewhere in the course the computer presented items each containing two generalizations dealing with the same subject, and asked students to determine whether these were just different formulations of the same generalization or were substantively different. We found that this was by no means a trivial exercise. Students were often initially stumped by items like the following:

> More Communist than Democratic Party members are FBI agents.
>
> •y,n•
>
> ☐
>
> If X and Y are the sets of Communist and Democratic Party members, respectively, then the proportion of elements being FBI agents is greater for X than for Y.

Another example of CAI in the teaching of application skills was the presentation of a Venn diagram and a generalization, with the problem of determining whether the diagram could or could not represent the generalization. These problems, too, could be difficult. In the following example, one of the lettered boundaries encloses the set of gun-owners, one the set of liberals, and one the set of suburbanites. Students first indicated whether this diagram could possibly represent the generalization shown, and, if so, they specified which boundary bounded which set.



> ☐
>
> "Every liberal who is not a suburbanite is also not a gun-owner."

Venn diagrams like those shown above turned out to be challenging not only to our students, but also to us. We were using a small computer, an IBM 1800, with hard-wired IBM 1510 terminals. Our CLUEGEN packaged procedure was generating code in a CAI language called COURSEWRITER II. This system *allowed* the author to display diagrams, but certainly did not *facilitate* such displays. Each diagram had to be decomposed into vertical or horizontal dashes, which had to be punched on cards in succession together with information about their locations. Vertical lines required specifying a backspace and a line change after each (vertical) dash. Rounded corners required devising new characters, with the shapes of portions of circles, and adding them to the catalog of characters, since the whole system was oriented toward producing strings of letters, numbers, and punctuation marks, rather than diagrams. All this took many hours. Had we been writing on the PLATO system instead, for example, we could have used the "draw" and "circle" commands in its TUTOR language to produce the desired diagrams in a fraction of the time.[1]

Responding to the Student's Response

Up to now, just about all of what has been described could have been in a workbook rather than in a set of CAI lessons. What distinguishes and justifies CAI most is what happens after a student has given an answer to the question or problem appearing on the screen. In our course, the computer's response to the student's response—i.e. the feedback—mainly took the form of clues that were displayed after the student gave a wrong answer.

Suppose the purpose of our sample item is to make sure the student remembers one technical term used in the textbook, such as "dictionary definition." In this case the initial display might be:

> A(n) ______________ is a statement giving the meanings a term ordinarily has in various contexts.
>
> ☐

A variety of clues might come to mind, such as:

> Remember what kinds of statements give the meanings of terms.
>
> We find such statements in a particular kind of book.
>
> d __________ d __________

These or other clues could, in the desired order, be displayed if the student continues to give wrong answers.

But one possible type of clue consists in a modification of the original problem itself. By making a clue appear in the same place as the problem, the author can, in effect, erase and replace the problem. Such a clue could be:

> A(n) ____________ definition is a statement giving the meanings a term ordinarily has in various contexts.

This gives part of the answer and hence narrows the question. As soon as this clue has replaced the heading on the screen, the previously specified right answer is, of course, no longer adequate. "Dictionary definition" should still be allowed as a right answer, in case the student has not noticed or appreciated the change at the top of the screen; but from now on the single word "dictionary" must also be accepted as the (main) correct answer. For this purpose, CLUEGEN's "temporary correct answer" routine is used. Subsequent clues may again appear underneath the answer zone, leaving the new question intact, e.g.:

> A(n) ____________ definition is a statement giving the meanings a term ordinarily has in various contexts.
>
> ☐
>
> One of these: dictionary
stipulative
prescriptive

But what do we do about the student who at the very beginning recognizes that a definition is being described, and without bothering to be more specific types "definition" as the answer? The author must anticipate this, for otherwise students who give this partially correct answer might be greeted with a general clue like:

> Remember what kinds of statements give the meanings of terms.

This is intended to remind the student of precisely that part of the correct answer which (s)he in this case has just provided. Here the unintended effect would be to make the student question whether there was any correctness at all in an answer of "definition." A way out is to provide a response-specific clue, keyed to a response of "definition."

> Yes, but can you be more precise?

might do the trick. If the author is providing for scorekeeping and believes that no points should be taken off for responding with "definition" alone, (s)he simply assigns a "0" to this response-specific clue as its contribution to the score.

Items of this type (reproduction) are only the beginning of an effort to make sure that the student understands the different types of definitions. A series of recognition items can be provided, each of which gives an example of a definition and asks the student what kind it is. The initial display of such an item might look like this.

> "By 'law' I shall mean a governmentally adopted and promulgated normative rule with or without sanctions."
>
> ☐
>
> •d,s,p,x•

The conventions

> d = dictionary definition
> s = stipulative definition
> p = prescriptive definition
> x = not a definition
> • . . . • = response alternatives

would have been explicated in prior instructions, as would the task for this set of items: determining which type of definition each statement is, if it is a definition at all.

Items of this sort can make good use of response-specific clues. One type of such clue would give an example of the kind of definition the student erroneously specified, for comparison. Thus, if in response to the above stimulus the student typed "d," (s)he might see the following clue:

> Sorry, a dictionary definition might be:
>
> "A *law* is a factual regularity in science, but a governmentally adopted norm in politics."

Practice items could provide terms and ask which kinds of definitions of those terms students would like to see. By typing "d," they would bring forth a dictionary definition, and so on, and they could repeat these requests in any order, receiving new examples from the bank, until they felt they understood the differences.

Finally, a more complicated exercise to test the ability to apply these concepts could present a set of three definitions together in a single item. The student could be asked to identify the two definitions belonging to the same type. Some of the items could be so written that the definitions that were identical in type were quite different in content, while those definitions different in type were similar in content. Students could thus be trained to look for the less obvious aspect of each definition that determined its logical type, and appropriate clues could be fashioned for this purpose.

What CAI Taught Us

Our experience at Stony Brook was that a multi-faceted approach to a topic like the different kinds of definitions yielded quite satisfactory results. The bulk of the students emerged with at least a temporary mastery of an important conceptual distinction which otherwise would have been a dim recollection of just another professor talking at them (or even to himself) from the front of a room. The students themselves appeared to appreciate the help they got from CAI: in a confidential questionnaire at the end of each semester they almost all said that the hours allocated to CAI should be either maintained or increased, but not reduced. They compared CAI quite favorably with the other modes of instruction used in the course.

With a subject such as methodology and philosophy of science, student abilities vary greatly within the same class. This fact provides an important justification for an instructional medium like CAI that gives each student personal attention and lets each proceed at a different pace. We, like Coombs, observed that the fastest students finished the CAI lessons about three or four times as quickly as the slowest students. This was natural, considering that an item that was immediately answered correctly would terminate and never appear again, while one that was consistently answered wrong continued through the whole batch of clues and then was repeated two more times, again with clues. The slow students could keep up with the class if they spent more hours per week in the lab, and in this sense a CAI component helped counterbalance the speed bias of other evaluation techniques. But after a couple of semesters the CAI lab had become so heavily booked that in practice there was almost no time available for catch-up sessions. Thus the slowest students simply didn't finish.

CAI in our course seemed to provide a strong motivation for doing the assigned reading on time. Students attempting a CAI lesson without having read the corresponding chapter found the lesson embarrassing and meaningless and appeared conscious of their ignorance. Those who had done the reading found the lessons rewarding, both in the sense of receiving one perfect score after another and in the sense of building perceptibly on top of their textbook knowledge.

The size of our class at Stony Brook forced us one semester to double students up at terminals, and the result was so positive that we never tried to return to a singles-only policy. Seating two students to a terminal and allowing them to discuss the questions and answers appeared to provide companionship, a teamwork spirit, and a convention-floor rather than outer-space atmosphere. Teams tended to get the right answer more often, although their discussions made them take longer than singles. For the author, pairing the students had the irreplaceable advantage of letting him actually hear the students think. He did not merely have to guess why they made the errors that turned up on the performance tape. Walking around the room, he heard them explain to each other the rationales for the (right or wrong) answers they were contemplating. Students also explained to each other the meanings of the clues as they appeared, helping the author discover where he was being misunderstood.

As a CAI sequence goes through more semesters of testing and revision, the importance of listening to this student cogitation declines. It also becomes increasingly likely that the instructor will have enough confidence in the CAI lessons to begin using CAI scores as a component of the course grade, if this is deemed desirable in the first place. But when this is done, the risk of student complaints against pairing on the grounds of grade damage ("You assigned me a dumb partner.") rises. Thus, a return to single work might be best after the developmental stage, if grading will be partly based on CAI scores.

On the other hand, the decision to grade students on CAI work, and how to do so, should not be made lightly. If those making the fewest errors get the best grades, exploratory answers will be discouraged and the all's-well-that-ends-well aspect of CAI, which allows some students to make up in perseverance what others have in brilliance, will be vitiated. Further, instructors may find themselves arguing defensively with students over the justice of a particular score, when instead they ought to be welcoming student suggestions for improvements in the CAI material.

In the long run, it is important to regard any set of CAI lessons as always under development. The number of instructional experiments that can be conducted in a single course is limited only by the number of semesters it is taught. Packages like the one we used at Stony Brook, which collect all performance data for computerized analysis and allow alternative versions of a lesson to be prepared with ease, make a strategy of perpetual testing and refinement not only desirable, but eminently feasible as well.

A strategy of continual development depends, of course, on continuity in the computer facilities that are available. This, however, is not a common feature of the contemporary university. At Stony Brook, at a point when the political analysis CAI lessons had been revised to eliminate their most obvious faults, and when serious experimentation on alternative versions was beginning to be sensible, a budget crisis forced the university administration to announce, two weeks before the end of the semester, that the CAI laboratory would be abolished when the semester ended. CAI-dependent courses that had already been scheduled for the subsequent semester, for which students had already pre-registered, had to be canceled or hurriedly revamped. The staff of the lab, told to prepare for dismissal within a few months, began trying to convert the most commonly used CAI procedures to reproduce the suddenly useless library of course materials for the new central campus computer, which hadn't even been installed yet, and about which little could be learned. At the time this book went to press, the outcome of this race against time was still unknown. Even if the hasty conversion succeeds and the new central computer provides a better basis for CAI than the small one in the lab (and in principle this ought to be the case), the experience will have reminded us that computer-assisted instruction, for all its advantages, is peculiarly vulnerable to shocks in the affairs of educational politics, finance, and technology.

FOOTNOTE

1. Bruce Arne Sherwood, *The TUTOR Language* (Urbana, Ill.: Computer-based Education Research Laboratory, University of Illinois, 1974), pp. I-8, II-2.

APPENDIX
Guide to Selected Continuing Sources of Information on CAI

Betty Weneser

Introduction

This monograph will for the first time provide political scientists with a helpful reference source about instructional uses of the computer specifically geared toward their interests. A search of the existing literature on computer-assisted instruction (CAI) reveals little information on applications to the teaching of political science, but a vast amount of material on CAI in other disciplines and in general. These include reviews of problems and accomplishments in CAI; analyses of trends and prospects for the future (already proven wrong in many cases); research reports on computer-based learning and instruction; and technical papers about hardware configurations, programming systems and languages relevant to CAI. One also learns that the literature in this new and fast developing field can become out of date very quickly.

In this appendix, therefore, we will attempt to provide the reader not with a bibliography of currently relevant literature, but rather with some *sources* of information which may be useful and *remain* current for a longer period of time. We hope that in this way the serviceable life of this volume can be extended and that the reader will have a means for keeping up with new information in the future.

Guide to Sources

Preface

A limited number of references have appeared in footnotes throughout this monograph. Additional books and journal articles can be found via the usual routes; to help, some specialized bibliographies are listed in the last section of this appendix. Most of this guide, however, will deal with sources not so readily available to the new or casual investigator. These should be particularly useful to those who wish to get started in *doing* something but do not have an active CAI group at their institutions. The sources of information provided here will lead the reader to others. For example, attendance at a meeting of one of the more active societies will provide sources of information difficult to obtain in other ways; relevant conference and workshop calendars are included in several of the journals and newsletters cited. Information on costs of materials and their availability, subscription rates, and organization membership is omitted here because these data do not remain constant. Current addresses of the sources are given; though these may also change, they should help to locate information when needed.

Professional Organizations and Journals

Developments in CAI come from people with diverse backgrounds and expertise. As a result, their published works have appeared in a wide variety of journals (and often only in internal reports), and their papers delivered at conferences of assorted organizations. Attempts to gain more consistent forums have been made and are still in progress. Some of the organizations and journals which are most likely to offer information on instructional uses of the computer are cited in this section.

Association for the Development of Computer-based Instructional Systems (ADCIS), formerly called Association for the Development of Instructional Systems (ADIS), is an international organization whose purposes are to "1) advance the investigation and utilization of computer-based instruction (CAI) and/or management (CMI); 2) promote and facilitate the interchange of information, programs and materials in the best professional and scientific tradition; 3) reduce redundant effort among developers; and 4) . . . specify requirements and priorities for hardware and software development, and encourage and facilitate their realization."

Although the organization was begun (in 1967) by a small group of users of a common computing system, it has grown into *the* CAI professional society, catering to a membership with an ever-widening range of interests in the use of computers for instructional purposes.

ADCIS sponsors semi-annual conferences (soon to be changed to annual), and publishes a bimonthly *Newsletter*, which contains informal reports of activities of member organizations, information about relevant conferences, and other timely news, and the quarterly *Journal of Computer-Based Instruction* (JCBI). JCBI, published since August 1974, is intended to be a scholarly journal serving the interests of ADCIS members.

At this time there is no permanent office of ADCIS. The current president is Dr. G. Ronald Christopher, Airforce Institute of Technology, 1230 Rona Parkway, Fairborn, Ohio 45234; the current secretary-treasurer is Dr. Peter M. Dean, IBM Corp., P.O. Box 70189, Los Angeles, Calif. 90070.

Association for Computing Machinery (ACM), with national headquarters at 1133 Avenue of the Americas, New York, N.Y. 10036, is a professional organization dedicated to the further development of the discipline of information processing and to the responsible use of computers in a wide variety of applications.

Occasional articles concerning instructional uses of computers appear in the monthly publication, *Communications of the ACM*, less often in the quarterly *Journal of the ACM. Computing Reviews* at times contain abstracts and reviews of books and papers on CAI (note their *Comprehensive Annotated Bibliography on Computer Assisted Instruction* cited in the section below on "Bibliographies").

More than 30 Special Interest Groups (SIGs), with membership not restricted to ACM membership, provide contacts and information geared to more specific interests, via their individual bulletins and special sessions at ACM and other conferences. Of particular interest is the group on Computer Uses in Education, SIGCUE. Its quarterly bulletin, *Interface*, includes news items of activities of this and related groups. The following groups may also be of interest to some readers: SIGSOC (Social & Behavioral Science Computing), bulletin issued quarterly; SIGCAS (Computers and Society), newsletter issued quarterly; SIGSIM (Simulation), *SIMULETTER* issued quarterly; SIGPLAN/STAPL (Technical Committee on APL), bulletin issued quarterly.

American Educational Research Association (AERA), 1201 16th Street, N.W., Washington, D.C. 20036, is a large professional organization for educational researchers. One of its eight divisions--Division C: Instruction and Learning--and the special interest group, SIGCAI (Computer Aids to Instruction), often schedule sessions at the annual AERA meetings concerning instructional uses of computers. The quarterly publications, *American Educational Research Journal* and *Review of Educational Research*, include papers on studies of computer-based education.

EDUCOM, Interuniversity Communications Council, Inc., Box 364, Rosedale Road, Princeton, N.J. 08540, is a consortium of more than 100 colleges, universities and non-profit organizations that serve higher education. Its purpose is to promote the effective use of computers and communications technology by sharing the combined expertise and facilities of its member organizations, by conducting appropriate studies and conferences, and by providing a center for information exchange.

It publishes the quarterly *EDUCOM* bulletin, which frequently contains articles and news briefs concerning instructional uses of computers, often in the broader sense. For example, included in the Fall, 1975, issue (vol. 10, No. 3) is an article by Sheilah R. Koeppen about a project aimed at the development, use and evaluation of computer-related teaching methods and instructional materials in political science.

Special Conferences and Symposia: A number of important conferences are held under the auspices of other organizations; their conference proceedings frequently contain interesting papers not always published elsewhere.

The Conference on Computers in the University Curricula (CCUC), with partial support from NSF, has been held annually, at different locations, since 1970. It serves as a national forum for the study of computer use in undergraduate curricula. Information can be obtained from the CCUC Steering Committee, 124B Lindquist Center for Measurement, University of Iowa, Iowa City, Iowa 52242.

The International Federation for Information Processing (IFIP) has sponsored two World Conferences on Computer Education, the first in 1970 in Amsterdam, and the second in 1975 in Marseilles. Several publications were issued in connection with the 1970 conference. (See, for example, the van der Aa book listed below under "Bibliographies.") The proceedings of the more recent conference have been published in *Computers in Education*, edited by O. Lecarme and R. Lewis (New York: American Elsevier, 1975).

The American Federation of Information Processing Societies (AFIPS) holds joint conferences with ACM and IEEE. The proceedings of the "Spring Joint Conference" of 1972, vol. 40, contains many papers on computer-based instruction.

Education Resources Information Center (ERIC), supported by the National Institute of Education, through its central office at NIE and a network of 16 clearinghouses located at universities and professional organizations throughout the country, each with responsibility for a particular educational area, acquires, evaluates, abstracts, indexes, and disseminates "the most significant and timely education-related reports." The clearinghouse most likely to review documents related to CAI is "Information Resources," a combination of the former two groups: "Educational Media and Technology" and "Libraries and Information Sciences." It is located at Stanford Center for Research and Development in Teaching, Stanford University, Stanford, Calif. 94305. The clearinghouse on "Social Studies/Social Science Education," located at Social Sciences Education Consortium, Inc., 855 Broadway, Boulder, Colo. 80302, may at times review reports on computer-based political science instruction if the focus is on course content.

The two major ERIC publications, *Resources in Education* and *Current Index to Journals in Education*, are annotated in the section below on bibliographic guides. The clearinghouses, in addition to providing the entries for the two indexes, also prepare bibliographies and summary reports. (See, for example, *The Best of ERIC* under "Bibliographic Guides" below.) "Information Resources" Clearinghouse publishes a quarterly "ERIC at Stanford Newsletter," *Library/Media Report*, available on request.

Educational Technology is a monthly publication of Educational Technology Publications, Inc., 140 Sylvan Avenue, Englewood Cliffs, N.J. 07632, which also publishes books and monographs on educational uses of technology. Articles in many issues of the magazine deal with CAI--the March, 1970, issue was entirely devoted to "The Computer and Education." The *Educational Technology Review Series*, composed of collections of articles on a single topic which have appeared in *Educational Technology* within the previous five years, covered "The Computer and Education" in no. 9, January 1973.

THE Journal (Technological Horizons in Education) is a new monthly magazine (charter issue was May 1974) published by Information Synergy, Inc., P.O. Box 992, Acton, Mass. 01720. It attempts to provide a forum for the exchange of information by the educational and industrial communities. Included are articles concerning educators' experiences with the use of technology, calendars of pertinent conferences, information about and advertisements of technical products for education. For certain "qualified" readers the magazine is circulated free of charge, and in other ways resembles a trade journal.

Datamation is a monthly magazine published by Technical Publishing Company, whose circulation office is at 35 Mason Street, Greenwich, Conn. 06830. Though it serves as a trade journal broadly covering the computer industry, articles and news reports on instructional applications are included at irregular intervals. The September, 1968, issue (Vol. 14, no. 9) was entirely devoted to "Computer Assisted Instruction."

Institutional Publications: A number of universities and private and government organizations publish their own journals and bulletins which often contain information of interest to the CAI user or developer. For example, *Viewpoints*, the bimonthly bulletin of the School of Education, Indiana University, Bloomington, Indiana, devoted its July, 1974, issue (vol. 50, no. 4) to "Computer Assisted Instruction--Current Approaches and Trends."

Information on Computer Equipment: There is no uniformity in the use of computer equipment or programming systems for instructional purposes at this time. Information about new developments in computer hardware and associated equipment (terminals, for example) is provided by some of the sources already cited; further information can be obtained from the equipment vendors, and the following additional sources are sometimes useful:

Association for Educational Data Systems (AEDS), 1201 16th Street, N.W., Washington, D.C. 20036, sponsors conventions featuring demonstrations of equipment and workshops on educational data processing. It publishes the magazine *AEDS Monitor* and the *Journal of the Association of Educational Data Systems.*

Computerworld is a "Newsweekly for the computer community" published by Computerworld, Newton, Mass. 02158. Both advertisements and articles in this trade newspaper provide information on the state-of-the-art in hardware developments.

Computer Decisions is a monthly trade magazine published by Hayden Publishing Company, New York. Hardware and software developments are included in the articles and advertisements.

CAI Program Sources

Personal contacts are useful for learning about and acquiring access to CAI programs, but often more formal approaches are needed. Institutions active in developing CAI programs usually prepare indices of their own "courseware" (e.g., University of Illinois CERL report X41, "PLATO IV—Curriculum Materials," SUNY at Stony Brook's index "CAI Materials Available at SUNYSB," etc.). Computer manufacturers and users groups of common equipment also compile inventories of available programs. Three sources with broader scope are listed below.

Index to Computer Based Learning, to date the most comprehensive listing of CAI programs, is compiled by the Instructional Media Laboratory, University of Wisconsin-Milwaukee, Milwaukee, Wisc. 53201. The most recent edition (fourth), published in 1973 by Educational Technology Publications, Inc., is presently being updated. Previous editions, since the first issue in 1969, were titled "Index to Computer Assisted Instruction."

Formally annotated listings of CAI programs (the fourth edition contains 1766 entries) are organized by subject area (23 political science programs are listed). A useful appendix cross-references the programs by subject area, computer, programming language, instructional strategy, and source (institution where developed).

CIRCUIT (Catalog of Instructional Resources for Computer Utilization in Teaching) is a more recently begun effort operated by SECOS (Shared Educational Computer Systems, Inc.), 420 Main Street, Poughkeepsie, N.Y. 12601.

The catalog contains documentation for any program submitted to it, but CIRCUIT acts as a distribution center for programs written in only a limited set of languages (Coursewriter and APL).

CONDUIT, a project supported by NSF and currently housed at the University of Iowa (P.O. Box 388, Iowa City, Iowa 52240), began as a consortium of five regional university computer centers to study the problems in transfer (between computer networks) of computer-based instructional materials and to seek ways of eliminating barriers to their dissemination.

During this current fourth year of operation, CONDUIT is attempting to collect, evaluate, convert, maintain and distribute a limited group of instructional packages for undergraduate education. Social sciences, one of the areas of "courseware" being sought, has a review committee which includes a political scientist. Three times a year, CONDUIT publishes *Pipeline*, an informative report of its activities.

Bibliographic Guides

Knowledge of the specialized sources of information contained in the previous sections is not easily acquired via familiar routes. Guides to the published literature, however, are more generally known and available. In this section some special-purpose bibliographic sources are cited—cumulative guides to periodic literature in educational research and development, available in most libraries, and a few specialized bibliographies.

Cumulative **Indexes:** A number of standard cumulative indexes to the literature in education-related topics are generally available in libraries. Unfortunately, none of these is sufficiently comprehensive to eliminate the need for the others, and, indeed, many relevant documents do not appear in any of them. They can, however, serve a useful purpose, and three of the more helpful are cited here.

Resources in Education, which before January, 1975, had the title *Research in Education*, is one of the two major compilations prepared by the Educational Resources Information Center (ERIC), the national information network listed previously in the section on professional organizations and journals. This guide indexes and abstracts "selected documents of educational significance," attempting particularly to cover unpublished technical and research reports, conference proceedings, etc. The abstracts are cross-referenced by subject, author, and institution. It is issued monthly; a cumulative index without abstracts is issued semi-annually. The change in the title to *Resources in Education* reflects a wider scope of materials reviewed than before.

Current Index to Journals in Education, the other major ERIC guide, is a monthly index to current "important educational periodic literature." Semiannual and annual cumulated indices are also issued. Articles selected from over 700 journals are cited, with brief annotations for most, and indexed by subject, author, and journal.

The information collected for both of these ERIC indexes is also stored on magnetic tape in a computer-accessed data base; a topical key-word search (from a large set of descriptors, continually augmented) can very efficiently yield useful references. This facility is available in many libraries.

Education Index is a cumulative author-subject index to "educational materials in the English language." It is published ten times a year by H.W. Wilson Company, Bronx, N.Y. 10452. In addition to periodicals, some conference proceedings, yearbooks, bulletins, monographs, and governmer publications are included. Because the coverage of the education field is broad, and the list of publications reviewed for indexing is limited, this guide is not always strong on references to computer-based instruction.

Bibliographies: As previously noted, some of the journals and other documents which include articles of interest concerning instructional uses of computers are not indexed in the standard cumulative guides. Perhaps as a result of this, bibliographies of relevant articles and books appear at frequent intervals. A sample of some of these specialized bibliographies follows.

Clark, Richard E. *The Best of ERIC: Recent Trends in Computer Assisted Instruction*, ERIC Clearinghouse on Media and Technology, April, 1973.

This ERIC paper reviews trends in CAI through an annotated bibliography of relevant reports indexed in the ERIC system, arranged according to CAI problems dealt with. An updated version of this summary is in progress and is expected to be published by the "Information Resources" Clearinghouse at Stanford in August, 1976. An earlier summary was done in 1970 by Karl L. Zinn and Susan McClintock, "A Guide to the Literature on Interactive Use of Computers for Instruction," 2nd edn.

Testerman, J. D., and Jackson, J. "Bibliography 33. A Comprehensive Annotated Bibliography on Computer Assisted Instruction," *Computing Reviews*, October and November, 1973.

The articles, books and pamphlets included in this bibliography cover the period from 1967 to March, 1973. The annotated citations are classified by topic. *Computing Reviews* is a publication of ACM, listed in the section on professional organizations and journals.

Barnes, O. Dennis, and Schrieber, Deborah B. *Computer-Assisted Instruction—A Selected Bibliography*, Assn. for Educational Communications and Technology, Washington, March, 1972.

Each citation is followed by a list of topical keywords selected from the content of the article. A keyword index and author index are included.

van der Aa, H. J., et. al. (eds.), *Computers and Education—An International Bibliography on Computers and Education*, Science Associates-/International, 1970.

This "special publication on the occasion of the IFIP World Conference on Computer Education" is an annotated bibliography of books, articles, and bibliographies on education about computers as well as the use of computers in education. It is a very good reference for those interested in pre-1970 documents.

Stolurow, Lawrence M., and Peterson, Theodore I. *Computers in Education—Selected Bibliography 1969-1972,* IBM Application Bibliography.

This bibliography lists journal articles and books alphabetically by author, uncategorized and without annotation. A list of journals referenced is included.

Cantwell, Z. M., and Doyle, H. A. *Instructional Technology: An Annotated Bibliography,* Scarecrow Press, 1974.

The major section of this book consists of a carefully annotated bibliography of selected journal articles, research reports and government documents published between 1969 and 1973 which report results of research studies in which use of some instructional technology is made. Following this is a cross-referenced listing by category of instructional technology and student level, and, finally, an index, by discipline.

Razik, T. A., and Ramroth, D. M. *Bibliography of Research in Instructional Media,* Educational Technology Publications, 1974.

The intent of the compilers of this bibliography, volume two of the *Educational Technology Bibliography Series,* is to cover research reports in this broad field from 1915 to 1973. The entries are unannotated, but are indexed by topic. Computer-assisted instruction, one of the topic headings, has 16 categories under it.

As a final note, a small collection with the curious title of *Free and Inexpensive Materials on Computing in Teaching and Learning Activities,* compiled by Karl L. Zinn, is available from the Center for Research on Learning and Teaching, 109 E. Madison, Ann Arbor, Michigan 48104—single copy "free," multiple copies "inexpensive."

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