DOCUMENT RESUME

ED 104 376 IR 001 770

AUTHOR Braun, Ludwig
TITLE Learning through Computer Simulations.
PUB DATE Mar 75
NOTE 15p.; Paper presented at the Annual Meeting of the American Educational Research Association (Washington, D.C., March 30-April 3, 1975)

EDRS PRICE MF-$0.76 HC-$1.58 PLUS POSTAGE
DESCRIPTORS *Computers; *Computer Science; Enrichment Activities; Group Activities; Individual Activities; Laboratory Training; Large Group Instruction; Opaque Projectors; Overhead Projectors; *Simulated Environment; *Simulation; Small Group Instruction; Student Projects; Teaching Methods; Teaching Techniques
IDENTIFIERS *Computer Simulation

ABSTRACT

Prior to the relatively easy access to computers which began in the mid-1960's, simulation was a tool only of researchers. Even now, students are frequently excluded from direct laboratory experiences for many reasons. However, computer simulation can open up these experiences, providing a powerful teaching tool for individuals, for small and large groups, for laboratory experiments, for independent enrichment activity, or for classroom use. To be effective, classroom use requires a display of the computer output which can be viewed by the entire class through the use of video converters, cathode ray tube terminals, opaque projectors, or overhead projectors. As computers become easier for teachers to acquire and use, the potential of computer simulation can be realized. A number of computer simulations, along with their various applications, are presented. (KKC)

ED104376

LEARNING THROUGH COMPUTER SIMULATIONS

Ludwig Braun

State University of New York at Stony Brook

March, 1975

Learning Through Computer Simulations

I. Introduction

Until ten years ago simulation was a tool only of researchers, but in the mid 60's educators discovered that this was a valuable tool for them as well. One of the major stimuli for this was the introduction of the digital computer onto the educational scene. Prior to the relatively easy access to computers which has occurred, simulations were fairly trivial (a lå Monopoly), or they were difficult to execute. Because of this easy access, rather complex simulations now are available routinely to the teacher at all levels from elementary school to graduate school and in many disciplines from biology, chemistry, and physics to economics, sociology, and history.

There are two reasons for educators' interest in computer simulation. First, in the author's personal experience, the level of student excitement during a simulation experience is very high whether the students are fourth graders or fifty-year-old adults. Secondly, the direct and intimate involvement of the student in the activity provides a learning experience achievable otherwise only in the laboratory. Unfortunately, for a variety of reasons students frequently are excluded from direct laboratory experiences. Some of these reasons are:

1. The necessary equipment is not available because of expense, or it is too complex or delicate to permit students to use it (e.g., in high-energy physics).
2. The sample size available in the real world is too small to permit generalizations. (This is especially true in the training of medical students in the diagnosis of disease. Medical students in New York state, for example, run into very few cases of malaria and develop little experience with it.)

3. The experimental technique is difficult and must be developed over an extended period (e.g., in experiments in genetics and in titration).
4. There are serious dangers to the student (e.g., where radiation or high temperatures are involved, where there may be explosive mixtures of gases, or where highly toxic materials are required).
5. The time scale is too short or too long to permit the student to make observations (e.g., the study of the dynamics of a population or the runaway of a nuclear reactor--here, of course, there are other reasons for not permitting students to do the experiment).
6. The opportunity to experiment directly is not available (e.g., in studies of ecological, economic, political, or social systems, or in studies of human genetics, or spread of disease).
7. When it is desirable to measure variables which are difficult to access (e.g., the tension on a pendulum string or the differential effects of the gravitational forces of the earth and the moon on an orbiting satellite).
8. When measurement and other noise obscures the important phenomena (in the computer, we can create a world in which there is no noise and in which instruments are perfect and <u>then</u> show the student how noise and imperfect instruments obscure the data of interest).
9. There are times when it is useful to underscore the significance of natural laws by comparing their results with other laws (e.g., study of non-inverse-square-law gravitational systems* or non-Mendelian genetics).

---

* An excellent example of this is seen in the film, "Force, Mass, and Motion," by Dr. Frank Sinden of The Bell Telephone Laboratories, Murray Hill, New Jersey.

In such circumstances the student usually learns by listening to a lecture or by reading a textbook, both of which are relatively passive experiences.

For the foregoing reasons, the Huntington Computer Project* has focussed its energy, since 1970, on the development of computer simulationa and on their application in the classroom. The philosophy of the Huntington Computer Project is summarized in the Chinese proverb of Fig. 1.

In addition to his work in the Huntington Computer Project, the author has used simulations in his undergraduate and graduate courses. In what follows, various applications of simulation from the author's experience are described.

II. Examples of Simulations

Educational simulations may be designed for use by individuals, by small groups (two to six people), or by large groups (up to perhaps fifty). In the following paragraphs, we shall look at examples of simulations of each of these types.

A. Examples of Individual Simulation

In this section we shall look at two examples of simulations which were designed for use by individual students.

The first of these is a simulation of Millikan's Oil Drop Experiment called CHARGE. CHARGE is an example of a simulation motivated by the difficulty of the experimental technique. In this simulation, students discover the discrete character of electric charge without having to develop the manual dexterity required in the real-world experiment. In addition, individual data values are obtained much more rapidly in the simulation than is possible in the real world. This is important because of the necessity to obtain a large number of

---

* A curriculum development project supported in part by the National Science Foundation under Grants GW 2247, GE 5973, and GJ 79.

聽而忘之
視而記之
做而明之

I HEAR... AND I FORGET

I SEE... AND I REMEMBER

I DO... AND I UNDERSTAND

—ancient chinese proverb

Fig. 1: Philosophy of Huntington Computer Project

data values in order to achieve results with reasonable statisticsl significance. (In most cases, we are interested in having the student discover the property of discreteness of charge, rather than in having him develop a technique for making the measurements.)

A sample run of CHARGE is shown in Fig. 2. In this run we focus on particle 1 and adjust the applied voltage until the particle reaches zero velocity (i.e., it is suspended in space). At this point we ask the computer to calculate the charge on the suspended particle. In normal use the student will repeat this process for twenty or more particles until he sees a pattern of charge distributions emerging.

Another example of a simulation designed for individual use is MALAR, a simulation which permits the student to make a set of decisions about allocation of resources during an effort to control deaths due to malaria in a malarial region. A sample run of MALAR is shown in Fig. 3.

This simulation represents an area where there normally are one thousand malaria deaths each year. By intelligent allocation of his budget among field hospitals, mosquito control, preventive medication, and medication for malaria victims, the student can reduce the annual malaria deaths substantially below the normal one thousand.

B. An Example of a Small-Group Simulation

MARKET is an example of a small-group simulation. It represents a two-company, single-product market situation in which two companies, starting with equal total resources, compete for the market in bicycles. In each quarter both companies decide upon their advertising budget, bicycle production, and selling price for the forthcoming quarter. On the basis of these decisions, the computer determines the quarter sales, profit, and market share for each

```
                    MILLIKAN OIL DROP EXPERIMENT

INSTRUCTIONS (1=YES, 0=NO) ?1

INSTRUCTIONS -- AFTER EACH QUESTION MARK, (V=  ?), YOU MAY:

TYPE IN VOLTAGE BETWEEN -1000 AND 1000 (IN ORDER TO MAKE
THE VELOCITY PRINTED OUT AS CLOSE TO ZERO AS POSSIBLE),
REQUEST CALCULATION OF CHARGE FOR STOPPED DROP (TYPE IN 2000),REQUEST NE
W BATCH OF DROPS (TYPE IN 3000),
OR END THE PROGRAM (TYPE IN 4000).


                    NO ELECTRIC FIELD

DROP:               1              2              3              4
                   ---            ---            ---            ---
 VELOCITY
(METERS/SEC)
( X  10↑-6 )
                   -30.4          -30.3          -29.8          -30

V= 0     ?100
                    2.6           -2             -10.5          -30

V= 100    ?97
                    1.6           -2.8           -11.3          -30

V= 97    ?93
                    0.3           -3.9           -12.1          -30

V= 93    ?94
                    0.6           -3.7           -11.9          -30

V= 94    ?92
                   -0.1           -4.2           -12.3          -30

V= 92    ?92.1
                    0             -4.2           -12.3          -30

V= 92.1    ?2000


CALCULATION FOR WHICH DROP ?1

CHARGE ON DROP 1  IS 11.14  X 10↑-19 COULOMBS.
```

Fig. 2. Sample Run of CHARGE

```
YOUR OBJECTIVE IS TO MINIMIZE MALARIA FOR THE NEXT
5 YEARS, WITH A TOTAL FUND OF  500  THOUSAND DOLLARS

..............................................................  (HOSPITALS)

HOW MANY FIELD HOSPITALS DO YOU INTEND TO USE ?0

..............................................................  (DRUGS FOR SICK)

HOW MANY FULL TREATMENTS OF DRUGS
FOR THE ILL, SHOULD BE ORDERED PER YEAR ?5000

FOR THIS TREATMENT:
INDICATE YEARS TO BE USED BY TYPING, AFTER THE YEAR,
1=YES OR 0=NO
 ?1
 ?1
 ?1
 ?1
 ?1
COST OF THIS TREATMENT: $ 50000
THIS LEAVES A BALANCE OF  450000  DOLLARS

..............................................................  (MOSQUITOES)

WHAT PERCENTAGE OF MOSQUITOES DO YOU WANT TO ELIMINATE ?100
WHAT PESTICIDE WILL YOU USE
1=DDT        2=MALATHION       3=PROPOXUR
 ?1

FOR THIS TREATMENT:
 ?1
 ?1
 ?1
 ?1
 ?1
COST OF THIS TREATMENT: $ 375000
THIS LEAVES A BALANCE OF  75000  DOLLARS
..............................................................  (PREVENTIVE DRUGS)

HOW MANY DOSES OF PREVENTIVE DRUGS, FOR THOSE
HEALTHY, DO YOU WANT TO ORDER PER YEAR ?20000

FOR THIS TREATMENT:
 ?1
 ?1
 ?1
 ?1
 ?1
COST OF THIS TREATMENT: $ 72000
THIS LEAVES A BALANCE OF  3000  DOLLARS


USING YOUR PLAN:
YEAR         NO. SICK       NO. DEATHS DUE TO MALARIA
....         ........       .........................
 0           24954          977
 1           668            8
 2           658            6
 3           657            5
 4           670            9
 5           665            8

OVER YOUR  5  YEAR TREATMENT PROGRAM
 36  DEATHS DUE TO MALARIA HAVE BEEN RECORDED

DO YOU WISH AN EVALUATION (1=YES, 0=NO) ?1


TOTAL COST  497000  DOLLARS
PROGRAM       COST         YEARS       EFFECTIVENESS (PCT.)
.......       ....         .....       ....................
DRUG TREAT    50000         5           85
MOSQ SPRAY    375000        5           80
PREVENT DRUG  72000         5           12
```

Fig. 3. Sample Run of MALAR

company. After several quarters a number of possible disasters occur at random. They include a wage-price freeze, embezzlement of funds, a warehouse fire, and a transportation strike.

A sample run of MARKET is shown in Fig. 4.

This simulation may be run effectively with two students or with two groups of two or three students each. Groups of more than one usually are more effective than one-person companies because of the opportunity for discussion before reaching a decision.

C. An Example of a Large-Group Simulation

POLICY is an example of a large-group simulation, which simulates the effect of special-interest-group pressures on the federal legislature.

In POLICY there are six special-interest groups: business, labor, civil rights, militarists, nationalists, and internationalists. Each special-interest group is assigned one hundred influence units each year which it can use to attempt to influence the legislature. The legislature has fourteen policies under consideration ranging from provision of medical care to low-income families to support for supersonic transports.

No special-interest group has enough influence units to cause a policy to be enacted without help from other groups. This forces groups to trade off votes on a policy in which they may have only mild interest or even mild opposition in order to get votes for their policies from others. It also is possible for a group to cast some of its votes <u>against</u> a policy in an effort to prevent its adoption.

POLICY requires six groups with each group consisting of from one to six (or even eight) people. The simulation is executed most effectively when there are several people in each group since this provides for the possibility of multiple negotiating teams.

```
DO YOU WANT INSTRUCTIONS(TYPE 1 FOR YES, 0 FOR NO) ?1

MARKET SIMULATES THE COMPETITION BETWEEN TWO COMPANIES
SELLING A PRODUCT DIFFERENTIATED BY BRAND ADVERTISING.
THE QUANTITY EACH COMPANY SELLS IS DEPENDENT UPON PRICE
AND ADVERTISING BUDGET. THE GAME ENDS WHEN ONE
COMPANY GOES BANKRUPT OR REACHES  12  MILLION IN
TOTAL ASSETS.

ARE YOU BEGINNING THE GAME OR CONTINUING
(TYPE 1 FOR BEGINNING, 2 FOR CONTINUING) ?1


FIXED PRODUCTION COST= 250000  DOLLARS/QUARTER
VARIABLE PRODUCTION COST= 20  DOLLARS/UNIT
WITH NO ADVERTISING AND A SELLING PRICE OF 50 DOLLARS/UNIT
A COMPANY WILL SELL  25000  UNITS (PRINTED AS  25 )
WAREHOUSE CHARGE FOR INVENTORY= 5  PER CENT
INTEREST CHARGE ON BORROWED MONEY= 5  PER CENT



UNITS AND DOLLARS BELOW ARE IN THOUSANDS

QUARTER  0

PROFIT   MARKET SHARE   CASH ON HAND   NUMBER SOLD   INVENT.   ASSETS
 0        0              5000           0             100       7000
 0        0              5000           0             100       7000


COMPANY  1
PRODUCTION LEVEL ?10
ADVERTISING BUDGET ?500
UNIT PRICE ?55

COMPANY  2
PRODUCTION LEVEL ?10
ADVERTISING BUDGET ?0
UNIT PRICE ?50

QUARTER  1

PROFIT   MARKET SHARE   CASH ON HAND   NUMBER SOLD   INVENT.   ASSETS
 760      64.28          6460           45            65        7760
-415      35.71          5715           25            85        7415
```

a) Instructions and Quarter 1

Fig. 4. Sample Run of MARKET

COMPANY 1
PRODUCTION LEVEL ?10
ADVERTISING BUDGET ?500
UNIT PRICE ?52.50

COMPANY 2
PRODUCTION LEVEL ?30
ADVERTISING BUDGET ?400
UNIT PRICE ?53

QUARTER 5

PROFIT	MARKET SHARE	CASH ON HAND	NUMBER SOLD	INVENT.	ASSETS
700	53.57	9356	45	41	10217
603	46.42	8550	39	64	9894

THE PRESIDENT HAS JUST IMPOSED A WAGE-PRICE FREEZE ON THE ECONOMY, AND YOU MAY NOT RAISE THE PRICE OF YOUR PRODUCT OVER THE NEXT 2 QUARTERS.

COMPANY 1
PRODUCTION LEVEL ?30
ADVERTISING BUDGET ?400
UNIT PRICE ?55

COMPANY 2
PRODUCTION LEVEL ?60
ADVERTISING BUDGET ?500
UNIT PRICE ?53

QUARTER 8

PROFIT	MARKET SHARE	CASH ON HAND	NUMBER SOLD	INVENT.	ASSETS
570	45.67	11080	37	36	11836
606	54.32	10898	44	42	11837

COMPANY 2 HAS SUFFERED FIRE DAMAGE IN ITS WAREHOUSE
ALL UNITS WERE DESTROYED. YOUR INSURANCE WILL REIMBURSE YOU
IN THE AMOUNT OF 771 DOLLARS FOR THESE UNITS

NEW LABOR CONTRACT - VARIABLE PRODUCTION COST NOW= 22 DOLLARS/UNIT

b) Quarters 5 and 8

Fig. 4 (cont.). Sample Run of MARKET

This simulation has been utilized with groups of high school students and with groups of adults in a variety of settings. It has proven to be very exciting to groups of all ages and has been an excellent introduction to the concept of simulation because each participant becomes immersed in it.

III. Modes of Utilization

Teachers may utilize simulations in a variety of ways to provide useful learning environments for their students. Several of these ways are outlined below:

A. Laboratory Experiments

Many science teachers intermix computer simulations with conventional experiments in the laboratory programs for their students. In this way the students' learning experiences are much richer than they might be otherwise.

Because students usually work in groups of two to four, any simulation which is designed for individuals or small groups is suitable for this mode of utilization.

B. Enrichment Projects

Teachers frequently either permit or assign students to carry out independent research projects to broaden their experience beyond the curriculum boundaries. If such students have access to appropriate computer simulations, the range and complexity of projects from which they may choose is substantially larger than it is otherwise.

C. Classroom Use

One excellent way of enhancing the classroom presentation of a wide variety of concepts and simultaneously to increase student interest and motivation is to bring computer simulations into the classroom. In this way the students can debate the choice of parameter values and the plan of action as a group before decisions are made. Such applications are equally useful in social science courses and in science courses.

To be most effective, classroom use requires a display of the computer output which can be viewed by the entire class. This may be accomplished in a variety of ways. Among these are:

1. Video converters* which convert the ASCII code from the computer to a video signal which may be displayed on conventional television receivers or video monitors. Such receivers frequently are available in classrooms.
2. CRT terminals which frequently have video outputs. These video outputs may be used to drive video monitors.
3. If an opaque projector is available in the classroom, the paper may be removed from the terminal when the result is printed and displayed in the opaque projector for classroom viewing.
4. In a teletypewriter or other printing terminal, Mylar film may be used in place of paper. This film accepts ink readily and is transparent. When a result is obtained, the film may be taken off and placed on an overhead projector for relatively rapid viewing by the students.

---

* Two companies which offer such devices are Ann Arbor Terminals, Inc. and Digilog Corp.

IV. Conclusion

In the preceding paragraphs, some of the author's experiences with computer simulations have been related. These experiences have occurred in a wide variety of disciplines with students from high-school to graduate-school level. It is clear from these experiences that computer simulation has a great deal to offer to the teacher. This potential will be realized more and more as computers become easier for teachers to acquire and to use.