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ABSTRACT This report describes Huntington simulations--computer programs and associated off-line materials for the teacher and for the students. Separate guidelines for choosing a simulation are presented for the curriculum planner and for the teacher. The Huntington simulation, POLUT, is the example which is used. Modifications to this program and its materials are described, and a role-playing game is outlined that will initiate consideration by the students of the value orientations that affect decisions about environmental issues. (DAG)

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The Illinois Series on Educational Applications of Computers

A STUDY OF COMPUTER SIMULATIONS FOR ENVIRONMENTAL SCIENCE EDUCATION

Douglas Dirks, Ted Singletary and Bruce Hicks

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A STUDY OF COMPUTER SIMULATIONS FOR  
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Preface

Teachers are finding that the computer is a new educational resource but one, like other educational resources, that must be properly understood and managed. Unfortunately, the computer is often an unfamiliar resource and often under- or over-appreciated.

The authors, in writing this paper sought to answer a rather specific question of teachers concerning computers as an educational resource. The question is "What must be done by the teacher or curriculum advisor in preparation for effective use of computer simulations by science and social studies classes?" The discussion in the paper applies directly to science education (and less directly to social studies education) and treats that open-ended, responsive instructional application of computers known as simulation. We believe that the question and much of the discussion of it is relevant also to other subjects and other modes of instructional application of computers.

We are indebted to the Institute of Environmental Studies at the University of Illinois for their financial support of our study of social and environmental science education and for technical advice by the staff of the Institute. We also wish to thank Professor Roger Brown for his advice and encouragement.

Summary

The Huntington simulations are one of the valuable instructional applications of computers. They include both computer programs and associated off-line materials for the teacher and for the students. These materials are therefore a good basis for a careful examination of the uses of simulations in environmental science classes.

Our examination goes beyond the Huntington materials in several respects. We develop detailed guidelines for the curriculum planner and (separately) for the teacher for them to use in choosing a simulation that is suitable for a given class and for utilizing the simulation effectively with the class.

The Huntington simulation POLUT is used as an example throughout the discussion. Many desirable modifications of the POLUT program and its associated materials are described, and a role-playing game is outlined that will initiate consideration by the students of the value orientations that affect decisions about water pollution or other environmental issues.

I. The Development of Environmental Computer Simulations  
For Classroom Use

From the time of its invention, men have tried to expand the uses for the "Analytic Engine" or computer. In particular, the computer's abilities to store and recall large amounts of information and to make many complex computations in a short period of time suited it to tasks which had formerly been done only through the efforts of large numbers of persons. Many schools were ready to incorporate new technological advances, and being endowed with both large amounts of information and short amounts of time, turned enthusiastically to the use of computers.

Initially computers were used for the mundane, but important, tasks like payrolls, inventories, student records and class scheduling. But soon the use of computers penetrated even into the classroom itself. At first also the instructional uses of computers were confined to the presentation, primarily, of drill type work. Computers became the "ultimate gimmick," to be used with students whose interests could not be won by more conventional educational methods. However, outside the mainstream of public education, two movements involving computers were developing which were to be combined into a new and more powerful use of computers for education.

The first of these movements was the use of computers to control simulators, originally for use in pilot flight training. A complex range of possible situations could be programmed to give students a feel of actual flight conditions, but without the expense or danger. The use of computer assisted simulators reached its peak in the American space program, as described by astronaut Edward Collins. He likens the process to that of preparing someone who has never ridden in a car before and will drive from Los Angeles to

San Diego, encountering various crises, such as high speed blowouts, along the way. The simulator for the Apollo crews cost millions of dollars and was maintained by hundreds of people working three shifts a day, seven days a week.<sup>3</sup>

The other movement was the development of computer models and simulations of other complex situations. A model is an analog of an existing or conceivable system. A simulation is the use of one process to model a second process.\* (A simulation is therefore a special type of model.) In computer simulations the first process is the operation of a suitable computer program, together with the interactions of a few people (students, scientists, economists, etc.) with the computer. The second process, the one that is modeled, may come from such areas as economics, population dynamics or ecology, for example. The second process often involves the interaction of many components, such as companies or groups of people, and therefore involve many factors and relationships. Computers have allowed the development of models and simulations, represented by the corresponding complex mathematical relationships describing such processes. These models allow theories to be tested or possible future outcomes to be predicted. These models are, of course, not perfect, for the areas involve too many variables to be handled with certainty. This point is made clear by the authors of one of the larger models, the World Simulation, used by the Club of Rome and discussed in the book, The Limits To Growth.<sup>9</sup> However, even though the simulations using these models are not perfect they can be used to give glimpses of developing trends or movements.<sup>14</sup>

Computer simulations have been particularly useful in the burgeoning field of ecology or environmental science. The multitude of factors present in any

\* Our definitions of model and simulation are based upon the discussion by Schultz and Sullivan (Chapter 1 in Reference 7.).

environment or ecosystem precluded any thought of modeling before the development of computers. Even now only a portion of the variables can be programmed into a model, but many models have been developed and are being used as devices for analysis and for prediction of possible ecological outcomes. The Metro Apex program developed at the University of Michigan and in use at the University of Illinois simulates the problems of urban air pollution.<sup>4</sup> Many programs have been developed to study water quality or changes in aquatic systems, and one of the simple ones, POLUT<sup>15</sup>, will be of special interest to us in this paper.

Medical schools were among the first to make use of digital computer simulations in education (See Reference 12. and several papers cited there.) The simulations give medical students practice in the development of diagnostic technique. While the use of simulations should not be considered a substitute for direct clinical experience by medical students, simulations can be useful where students in medicine or other fields are prevented from getting such experience by one circumstance or another.

L. Braun lists a number of factors which make the use of simulations an acceptable substitute for or even preferable to more direct student experience.<sup>1</sup> These include such things as the cost of the necessary equipment, danger to the student, the difficulty of the techniques necessary, difficulties in obtaining reliable samples, time scales that are either too long or too short and the inability to experiment directly. Each of these could be an adequate reason for the use of environmental (as well as other) simulations for educational purposes.

Many environmental simulations for classroom use exist. Some of these are board games. EXTINCTION, THE POLLUTION GAME, THE PLANET MANAGEMENT GAME and ECO-ACRES are examples of these.\* Other simulations have been developed for

\* See Resources.



use on a specific, graphic display system. SURVIVAL by Steven Petak of the University of Illinois is a good example of this type of simulation.<sup>10</sup>

SURVIVAL is designed to make use of the exceptional display facilities of the PLATO system.\* Unfortunately this system is not generally available to school systems at this time.

A third class of simulation program is a more generally useful type. These simulations are usually written for use with a teletype (or similar) display system and in the BASIC language, both of which are more generally often available in schools than is PLATO. The computer programs for the simulations are modest in size and can be run on any modern mini-computer or time-sharing system that supports BASIC. The Huntington II project has developed several simulations of this type that are environmentally oriented. These include, among others; USPOP, which deals with population dynamics and demography in the United States; BUFFALO, which covers animal herd management; and POLUT, which deals with water pollution of lakes and rivers. Each of these simulations comes as a package which includes, in addition to the program itself, a Resource Manual, a Teacher's Guide and a Student Handbook. Yet, even though these simulations are well prepared and documented, there are still problems in using them in a classroom situation. The nature of these problems and of related questions can best be shown by using an example.

The POLUT simulation was one of the first programs developed by the Huntington II project.\*\* It is being used in many school systems throughout the country. Basically the program allows the student to vary five parameters.

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\* A large number of simulations have been developed on the current PLATO IV system and earlier PLATO systems in the Computer-Based Education Research Laboratory at the University of Illinois (Urbana).

\*\* Our past studies of POLUT are described in Appendix A.

(the type of body of water, the water temperature, the type of waste, the amount of waste and the type of treatment) to produce a given pollution situation, and the program determines how the waste level and dissolved oxygen levels change over a period of days. This information can be displayed to the student in the form of a table or a graph or both.

The Resource Manual gives, very briefly and generally, an introduction to water quality and the effects of each of the parameters that can be changed. It also includes examples of the environmental uses of simulations; a list of references dealing with water quality; some data from sample runs; a short discussion of the simulation model and the assumptions upon which it is based; and a listing of the program code.

The Teacher's Guide for the POLUT simulation includes a description of the POLUT program along with acceptable ranges for the parameters that can be input. It also includes a listing of the rationale and goals of the unit; some suggested activities to prepare the student to use the simulation effectively; some follow-up questions to be used for class discussion; and some suggestions for the actual use of the program in the class.

The Student Workbook contains questions that are designed to be answered by the student using the POLUT simulation and can give a student an idea of the effects of varying the five parameters. Also included are a few open-ended questions which require the student to make judgments concerning various alternatives.

We see that there is quite a range of materials for the teacher to cover before POLUT is used in the classroom. A teacher should plan regular use of such a computer simulation for a class only if such materials are already well-developed and available for use by himself and the class.\*.

\* Exploratory and experimental uses of simulations are often advantageous; however, if they are undertaken with a few students while the off-line materials and manuals are still being developed.

Even though the materials for POLUT or other simulations are well-developed, both the teacher and the curriculum supervisor need plans to guide them in the choice and the effective utilization of computer simulations by the students. Sections II and III of this paper discuss a method of planning that takes the form of one set of guidelines for the curriculum planner and a second set of guidelines for the teacher. These guidelines make it clear that a group effort is necessary, often involving several teachers and the curriculum planner, together with a few advanced students, if the choice and utilization of simulations are to be successful.

The POLUT materials, the off-line manuals and the program itself, could be used as they are with some degree of effectiveness. It is our feeling, however, that some modifications of the materials are necessary to maximize the effectiveness of the POLUT unit. Of course, the final decisions concerning modifications and modes of use of this or any other simulation should be left to the teacher and curriculum planner who take responsibility for specific classes. We hope that such decisions will be aided by the Guidelines discussed in Sections II and III.

One type of modification we suggest has to do with the technical content of the simulation. We reviewed the POLUT material with the help of experts in water quality, computer-assisted instruction and classroom teaching, and compiled a list of modifications which we think should be included by any users of the POLUT unit. A list of these modifications is given in Appendix B.

A second type of modification is suggested by the relevance of both social science and the environmental sciences to POLUT. The students' study of POLUT or, indeed, of many other simulations, are incomplete unless the students analyze social studies topics. (Who makes decisions? What values are the basis

of the decisions?, etc.) as well as those specifically derived from science and engineering. We therefore outlined a role-playing game (see Appendix C) that introduces one of the relevant social studies topics, that of values orientation.

## II. Guidelines for the Use of Computer Simulations

Many in education feel that computer simulations represent the single most exciting instructional application of computers. Nearly 100 computer simulations are already available commercially, and scores of others are being written for private use. As the number of classroom computer proliferates, and interest in simulations is maintained, the number of computer simulations will grow dramatically. With the dramatic increase in this medium comes the need for a plan that will help the teacher to exploit the potential of those computer simulations that, in his judgment, have instructional merit.

The authors of this paper propose that just as effective simulation writing involves a team effort, effective simulation use also requires a group effort. Subject matter specialists, who can evaluate the content validity of the simulation, are vital. Curriculum planners, who make curriculum and administrative decisions, are significant contributors. Teachers, who make instructional decisions, are important. Finally, students, who make hundreds of learning decisions during their use of simulations, contribute valuable input. The efforts of this team can help the teacher to realize the maximum educational benefit of the computer simulation.

The teacher is the central figure, since he not only serves on the team, but also orchestrates classroom activity. The authors affirm the autonomy of the teacher in his instructional decision-making role. We respect his right to select and sequence those media, materials and learning activities that to him seem most appropriate for his students. We accept the fact that the teacher, for a variety of reasons, may decide not to use a resource even though it may have been proven to be effective in classes other than his own. We further accept the fact that a teacher, out of ignorance and lack of planning, may

fail to exploit the instructional potential of a resource that he does decide to use. It is to this last problem, as it applies to computer simulations, that we address ourselves.

A computer simulation is an instructional tool. With any tool, the more the user knows about it, the better he is able to use it; the less he knows about its use, the less satisfactory his results. We contend that the more the teacher knows about the computer simulation--its design, recommended uses, intended outcomes, etc.--the better use he will make of it.

The guidelines described in Sections A and B are designed to help the team members collect information about a specific computer simulation. Some of the data may be found in the off-line materials. Other data must be provided by members of the team. In the authors' view, the guideline questions must necessarily be asked and answered for each simulation considered for instructional use.

Several systems are already in print which enable teachers and planners to evaluate and compare textbooks and other instructional media.<sup>6, 13</sup> The guidelines may be considered as a similar tool, specifically intended for the evaluation and comparison of computer simulations for environmental education.

Section A of the guide is to be used by the curriculum planner. The curriculum planner is one or more steps removed from the classroom (e.g., he is a department chairman, district coordinator or curriculum director). He is in a position to make administrative decisions about the curriculum, and to provide support services to his staff. One of his responsibilities is to recommend certain computer simulations to his staff. Another responsibility is to provide his staff with data about the computer simulation that they may be too busy to provide for themselves. One method of transmitting the information is through Section A of the guide.

Before completing Section A, however, the curriculum planner will want to be sure that his teachers actually intend to use the simulation. Otherwise his effort will be wasted. The curriculum planner can accomplish this by meeting with his teachers and viewing with them one or more computer simulations before he employs the guide. He can then invest his time in only those simulations to which his teachers commit themselves.

Section B of the guide is designed to be used by the teacher. The questions require him to call to mind important elements in the classroom setting. These data, together with the data prepared by the curriculum planner, enable the teacher to make reasonable decisions about the best use of the computer simulations for his students.

Briefly, the steps for effective use of a computer simulation are:

1. A team is formed of curriculum planners, subject matter specialists, teachers and students.
2. The team meets to view one or more computer simulations. Together they decide whether any of the simulations has potential for instruction in the area for which the teachers are responsible. Those with apparent potential are turned over to the subject matter specialist.
3. The subject matter specialists establish the content validity of the simulation.
4. The team decides how the computer simulation will fit into the curriculum.
5. The curriculum planner evaluates the computer simulation package, using Section A of the guide. The planner provides data that is not presently in the simulation package. Of course, the teacher may use Section A if he has the interest and time to do so, or if he has no team with which to work.

6. The curriculum planner passes the data he has gathered to the teacher. The teacher then completes Section B of the guide.
7. The teacher compares his response to Section B with the accompanying data from Section A. On the basis of this information he decides how to use the on- and off-line materials that comprise the computer simulation package.
8. At the conclusion of instruction, students provide feedback for the teacher who will modify his instructional strategy the next time he uses the computer simulation.
9. The teacher in turn provides feedback to the curriculum planner who may alter his response to the guide, or change the on- or off-line materials.

These guidelines, including Sections A and B, have been generalized from the authors' limited experience with a single computer simulation--POLUT. In addition, they have been generalized from the context of environmental science education. Some users of the guidelines may find the questions are specific only to POLUT, or to environmental science. Other users may sense that the guidelines are suited to a particular level of instruction, for we had high school teachers in mind when we wrote it. Still others may feel that vital questions are missing from our list.

At present the guidelines are intended to help educators maximize the effectiveness of a specific computer simulation. The writers envision a time, however, when a particular set of the teacher's classroom objectives might be attained with two or more highly polished computer simulations. The guidelines could then be used to make a comparative judgment about the relative quality of the simulations.



For these reasons this document should be considered to be a working paper. Users should feel free to adapt the guidelines to their own needs. The authors invite criticism of this work, and will be grateful for all suggestions.

Section A: For the Curriculum Planner

Section A is designed to be used by the curriculum planner to evaluate computer simulations that he and his teachers have agreed to use in an educational setting. When the teacher has the interest and time he may complete Section A himself. If the answers to the questions in Section A cannot be found in the materials accompanying the computer simulation, the curriculum planner or teacher must provide them.

The objective is to provide the teachers who use the computer simulation with one part of the information they need to maximize the effectiveness of its use. In every case the questions should be considered by one who has in mind a specific teacher in a specific course who is working with a specific group of learners.

1. How does the computer simulation fit into the instructional setting?
  - 1.1 In what class or setting will the computer simulation be used?
  - 1.2 How will the computer simulation be used in this setting?
    - 1.2.1 As a learning activity in a pre-existing unit?
    - 1.2.2 As a supplementary or enrichment activity?
    - 1.2.3 As a unit complete in itself?
    - 1.2.4 As one of a series of learning activities included in its own special unit?
  - 1.3 Does the intended use of the computer simulation indicate user decisions based on a single set of results, or does it necessitate comparison of two or more sets of results?
2. Is the simulation itself adequate and appropriate?
  - 2.1 Is there a reasonable agreement between the simulation and reality? (How has this judgment been made--and by whom?) Will the simulation then allow you to carry out the intentions stated in 1.3?
  - 2.2 Is the logic and conceptual complexity of the simulation appropriately matched to the users?

- 2.3 Is the reading style and reading level appropriate for the users?
- 2.4 Does the simulation create a context for the discussion of values and decision making?
3. Does the computer simulation package contain off-line materials addressed primarily to the teacher?  
If so, do the authors:
  - 3.1 Carefully state the intended outcomes of the computer simulation used as a learning activity?
  - 3.2 Clearly state the basic background skills and knowledge required of each student who will use the computer simulation?
  - 3.3 Clearly explain the model upon which the computer simulation is based and provide evidence that the factual materials addressed to the teacher are true and complete?
  - 3.4 State the amount of student time needed to complete a typical run, or series of runs?
  - 3.5 Suggest the optimum student use of the program? Should the student have free access to the terminal?
  - 3.6 Describe the amount of computer time required on a typical system to make a run, or series of runs, and estimate its dollar cost?
  - 3.7 Provide an annotated bibliography arranged topically?
  - 3.8 (When appropriate): Suggest where to find data to make the computer simulation locally relevant?
  - 3.9 Provide performance data on previous use of the simulation?
  - 3.10 (When the computer simulation is to be used as part of a special unit): Offer a suggested unit plan?
    - 3.10.1 State the objectives of the unit?
    - 3.10.2 Describe what the teacher should know before teaching the unit?
    - 3.10.3 Suggest a lesson plan for the unit, including an extensive list of possible films, speakers, field trip sites and other resources?
4. Does the computer simulation package contain off-line materials addressed primarily to the student?  
If so, do the authors:
  - 4.1 Provide the student with the necessary background knowledge and skills he needs to fully understand the computer simulation?

- 4.2 State and clearly explain the assumptions upon which the model is built?
- 4.3 Explain the simulation parameters, and discuss the constraints on input?
- 4.4 Show a step-by-step sample computer run, and include an interpretation of results?
- 4.5 Suggest appropriate problems to solve and questions to answer? Are these provided in satisfactory quantity? Are there some problems every student should solve? Are the problems appropriately open-ended? Do these problems sometimes cause students to make value judgments?
- 4.6 Suggest additional resources (grouped topically) a student can obtain for further study?
- 4.7 (In an appendix): Discuss the limitations of simulations in general, and this one in particular?
- 4.8 Finally, is the reading level of these materials appropriate for those who will use them?

Section B: For the Classroom Teacher

This section is to be completed by the teacher who will use the computer simulation with students. The questions he answers may serve only to formalize what he already intuitively knows about his students, school and community. But this data, together with the information provided by the curriculum planner, will help the teacher decide how to maximize the learning he seeks to achieve with the help of the computer simulation.

1. What is the class setting in which the computer simulation will be used?
  - 1.1 How many students are in the class?
  - 1.2 What is the length of the instructional period?
  - 1.3 How much time has been allocated for instruction?
  - 1.4 How many terminals are available?
  - 1.5 How much computer time is available?
  - 1.6 Are there schoolwide constraints that limit the range of possible student activities?
  - 1.7 Does each student have access to off-line materials?
2. What are the group characteristics of the learners?
  - 2.1 What is their reading level?
  - 2.2 What is their background in science? In social studies?
  - 2.3 Do they have experience on the computer system?
  - 2.4 Are they already thoroughly familiar with the content of the computer simulation?
  - 2.5 What is the level of the group's maturity and social attitude?
  - 2.6 Do the learners have the ability to interpret data?
  - 2.7 Do the learners have a fundamental comprehension of the experimental method?
  - 2.8 Do the learners have the ability to synthesize?

3. How much time will be reserved for values education related to the simulation? What kinds of issues will be raised?
4. How will the students' performance be evaluated?
5. How will the students provide feedback about their experience with the simulation?
6. (When the computer simulation is to be used as part of a special unit): What kinds of community resources and materials are available?
  - 6.1 Field trip sites?
  - 6.2 Audio-visual materials?
  - 6.3 Materials and speakers from local groups?
  - 6.4 Library resources?

### III. Examples of the Use of the Guidelines

The following pages give examples of the use of section A of the Guidelines. Specific responses are given to specific questions, and concern the proposed use of the computer simulation POLUT. The examples are included because they show how the Guideline questions can serve to generate data that may be helpful to the curriculum planner and the teacher. We have confined our examples solely to Section A because the responses to Section B would be of a narrower scope suited to a particular teacher in a particular classroom setting.

All of the examples given are responses to SECTION A, Question 3 ("Does the computer simulation package contain off-line materials addressed primarily to the teacher?"). That question, and Question 4 ("Does the computer simulation package contain off-line materials addressed primarily to the student?") are prescriptive. They reflect the authors' concept of adequate off-line materials.

When the off-line materials are inadequate, considerable time will be required to upgrade them. In fact, if no off-line materials accompany the simulation, the majority of the planning team's time will probably be spent writing them.

A team may be satisfied with an incomplete analysis of a computer simulation prior to its first use in the classroom. The ideal method would be to complete a thorough analysis of the simulation before its initial use. But time constraints could force the team to complete the guidelines in stages, over a period of two or three uses.

The use of the guidelines requires a team effort. The team is comprised of curriculum planners, subject specialists, teachers and students, and each may be expected to shoulder some responsibility. Shared responsibilities reduce the effort demanded of any one individual.

The examples included required about two to three hours to complete. While the time investment is admittedly large, potential users should find that the use of the guidelines need not require an inordinate time commitment of any one individual.

The following is one curriculum planner's response to SECTION A, question 3.2.

The question asks: "Do the authors clearly state the basic background skills and knowledge required of each student who will use the computer simulation?"

The planner is helping a teacher who intends to use the HUNTINGTON II simulation POLUT as part of a comprehensive unit on water pollution. The unit will be taught to a senior high school biology class. Since the planner could not find applicable data in the off-line materials, his answer to the question was "no", and he formulated the following statement of prerequisite skills and knowledge of the student.

1. The student understands all of the terms and units used in the simulation (and knows local examples of waterways, temperatures, etc.).
2. The student knows examples of wastes discharged by various industry groups and treatment plants.
3. The student understands the processes of waste treatment.
4. The student understands the effectiveness of primary and secondary waste treatment in terms of reduction of BOD.\*
5. The student understands the waste decomposition process.

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\* BOD - Biochemical Oxygen Demand. "A measure of organic waste load...which indicates the amount of oxygen drawn upon in the process of decomposition of waste." The amount of oxygen demanded is partly dependent on the type and quantity of the waste. The characteristic BOD value of a degradable waste is established by careful experimentation under controlled laboratory conditions.<sup>8</sup>



6. The student understands the role of dissolved oxygen in waste decomposition.
7. The student understands the BOD/Oxygen sag model.\*
8. The student knows the relationship between oxygen concentration and the activity of fish.
9. The student understands water chemistry.
10. The student knows the effects of water on various pollutants.
11. The student knows the effect of water temperature on the amount of dissolved oxygen, and the rate of waste decomposition.
12. The student can construct graphs from tabular data, and can read and understand simple line graphs.
13. The student understands experimental method and the advantages of controlling variables.
14. The student's required level of understanding must in each instance be set either intuitively or more formally by the teacher.

The same curriculum planner responded to SECTION A, question 3.11.1. The question asks: "Do the authors state the objectives of the unit?"

The planner found several objectives, which he felt were well stated, in the off-line materials accompanying the computer simulation. These objectives are listed below as citations from the Teacher's Guide. However, he felt that the given list of objectives should be supplemented. The supplementary objectives are fully written out below as items 2.1, 2.2...5.1,5.2...etc..

1. (Teacher's Guide; page 3; Objective #1)<sup>16</sup>.

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\* BOD/Oxygen Sag Model. A model of the dynamic relationship between BOD and Dissolved Oxygen (DO) in a stream, first proposed by Streeter and Phelps in 1925. After a degradable waste is discharged at a specific location in flowing water, decomposition and reaeration produce first a decrease and then an increase in DO (over time) as the waste is carried downstream. The model prescribes a quantitative relationship between BOD and DO.<sup>8</sup>

2. Describe the effects of each of the following variables on the water's ability to handle wastes:
  - 2.1. the type of body of water;
  - 2.2. the water temperature;
  - 2.3. the type of waste released into the water;
  - 2.4. the rate of dumping of waste;
  - 2.5. the type of waste treatment.
3. (Teacher's Guide; page 3; Objective #3) 16.
4. (Teacher's Guide; page 3; Objective #4) 16.
5. Given an instance of water pollution, the student can do the following:
  - 5.1. provide a crisp statement of the problem;
  - 5.2. list some areas where more data is needed;
  - 5.3. describe some alternative courses of action;
  - 5.4. describe impediments to the implementation of the solutions;
  - 5.5. select a single alternative, then:
    - 5.5.1. provide a justification of its selection (perhaps using data generated by POLUT);
    - 5.5.2. identify several interested parties and describe their feelings and attitudes toward the problem and proposed solution.

The same curriculum planner responded to SECTION A, question 3.11.2.

The question asks: "Do the authors describe what the teacher should know before teaching the unit?" Since the planner could not find applicable data in the off-line materials, he wrote the response included below.

1. The teacher should have a complete understanding of the things the student is expected to learn. The teacher should be especially knowledgeable about the following topics:
  - 1.1 the effects of dissolved oxygen on fish activity;
  - 1.2 the BOD/Oxygen sag model;\*
  - 1.3 the processes of waste treatment;
  - 1.4 the characteristics of various types of waterways;
  - 1.5 the effects of water on wastes;
  - 1.6 the properties of water.
2. The teacher should be familiar with the POLUT simulation and with the use of the computer terminals. He should be able to anticipate and solve minor problems in using the terminals and the computer-based simulation.
3. The teacher should have a knowledge of local waste treatment and water pollution problems and situations to use as examples during instruction.
4. The teacher should understand the limitations of both the simulation and his students.
5. The teacher should have a clear idea of the desired outcomes of instruction.

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\* See footnote on page 22.

The same curriculum planner responded to SECTION A, question 3.11.3. The question asks: "Do the authors suggest a lesson plan for the unit, including an extensive list of possible films, speakers, field trip sites and other resources?" Since the planner could not find applicable data in the off-line materials, he has written the sample lesson plan included below. The individual teacher may reject the plan in its entirety, or may select those parts of it that he chooses.

- DAY ONE: Trip to sewage treatment plant.
- DAY TWO: Class discussion: (1) processes of waste treatment; (2) role of oxygen; (3) BOD and BOD/Oxygen sag model;\* (4) types of waste; (5) types of water bodies; (6) water temperature vs. oxygen concentration; (7) oxygen concentration vs. fish activity.
- DAY THREE: Trip to water treatment plant.
- DAY FOUR: Class discussion: (1) finish topics not covered on Day Two; (2) introduce students to computer system; (3) introduce POLUT to students. Hand out specific problems to be solved with POLUT.
- DAY FIVE: Students work with POLUT.
- DAY SIX: Class discussion: (1) help students graph data; (2) help students interpret individual graphs; (3) students share data-- teacher helps students synthesize results. Hand out open-ended problems to be solved with POLUT.
- DAY SEVEN: Students work with POLUT.
- DAY EIGHT: Class discussion: (1) results of yesterday's work; (2) experimental methodology; (3) assumptions of the simulation.
- DAY NINE: Trip to local polluting industry.
- DAY TEN: Class discussion: (1) impressions from yesterday's trip; (2) prepare for role playing game.\*\*
- DAY ELEVEN: Role playing game.\*\*
- DAY TWELVE: Role playing game.\*\*
- DAY THIRTEEN: Evaluation.

\* See footnote on page 22.

\*\* Given in Appendix C.

The following is another curriculum planner's response to SECTION A, question 3.11.3. The question asks: "Do the authors suggest a lesson plan for the unit, including an extensive list of possible films, speakers, field trip sites and other resources?"

The planner is helping a teacher who intends to use the HUNTINGTON II simulation POLUT as part of a comprehensive unit on water quality. The unit will be taught to a senior high school environmental science class. Since the planner could not find applicable data in the off-line materials, he has written the sample lesson plan included below. The plan is merely a topical outline, and does not include actual teaching methods and materials.

FIRST WEEK:

- Water lab: An investigation of samples of local waters. The samples are tested for turbidity, pH, dissolved solids and microscopic life.
- Discussion of the chemistry of water. This would include the chemical formula of water, its specific heat, the process and role of dissolved oxygen, typical aquatic organisms and a food web and man's uses and proposed needs for water in the future. Appropriate audio-visual material should be used.
- Field trip to a water treatment plant or a model of a plant in class.

SECOND WEEK:

- Discussion of waste degradation in water; BOD;\* types of waste and their effects on natural systems.
- Discuss sewage treatment.
- Field trip to local sewage treatment plant and/or major water using industry.
- Introduction to and discussion of POLUT simulation.

THIRD WEEK:

- Work with POLUT simulation: Students will be given specific tasks (individually or in groups) to determine the effects of the parameters available for change.
- Discussion and comparison of results of changing variables in POLUT.
- Work with POLUT simulation: Students will be given (individually or in small groups) open-ended projects dealing with water quality and report to the class as to their solution for a particular problem including their reasons for the choice.

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\* See footnote on page 21.

FOURTH WEEK:

Discussion or outside speaker on water quality laws and/or local pollution problems and possible solutions.  
Role playing\* and/or designing ad campaigns against water pollution.

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\* Given in Appendix C.

Appendix A: A Review of Past Work on POLUT

The work of the authors on POLUT extends the efforts of others that began in 1972 at the University of Illinois. At that time the original programming and writing of POLUT had just been completed by Ludwig Braun and others at the Polytechnic Institute of Brooklyn.

The original version of POLUT was programmed in BASIC, but in 1972 BASIC was not available on an interactive system at the University. However, PLATO was available. Consequently, a team of students, working under the supervision of one of the authors, adapted the BASIC version of POLUT for PLATO III.<sup>5</sup>

By the fall of 1973, PLATO III had been discarded in favor of the more powerful PLATO IV system. At that time a second team of students, George Carter and Kathy Rubsam, worked with one of the authors to reprogram POLUT for PLATO IV.<sup>11</sup> Their goal was to combine the BASIC POLUT logic with many of the off-line materials in order to produce a PLATO lesson. Kent Richardson later evaluated the PLATO POLUT with respect to the learning objectives printed in the BASIC Teacher's Guide. He subsequently suggested changes to be made in the PLATO POLUT to upgrade its effectiveness.

Carter and Rubsam were the first to compare the PLATO POLUT with the original BASIC POLUT. Their report favored PLATO because of its dialogue capabilities; its fast output capability which allowed textual material to be included with the simulation; its graphical display capabilities; and its capability of collecting student performance data.

During the fall of 1973 BASIC was added to an interactive system (PLORTS) at the University of Illinois. This development allowed a working version of the BASIC POLUT to be compared with the PLATO version.

Angela Buske and Greg Lyons<sup>2</sup>, a third team working with one of the authors compared an improved version of the PLATO POLUT with the BASIC version. Their report again favored PLATO over the interactive BASIC system (FLORTS). Briefly, their reasons were that PLATO was faster, more flexible and had better and more attractive display capabilities. The hard copy output feature was cited as an advantage for FLORTS.

Buske and Lyons also proposed numerous changes for both the BASIC and PLATO versions of POLUT. Some of their suggestions might be loosely termed "lesson design" changes. These included, for example, a proposal to extend the time scale of the graph of results. The remaining suggestions might be classified as "pedagogical" changes. Briefly, these included:

- (1) expanded lesson guidance for students;
- (2) more clearly stated objectives;
- (3) explanation of assumptions and model during instruction;
- (4) extension of the simulation into the political and economic arenas;
- (5) better explanation of the parameters;
- and (6) tying the parameters to local conditions.

Each of these pedagogical changes has influenced the changes the authors advocate elsewhere in this paper.

The authors of the present paper favor the FLORTS version of POLUT for high school students. First, and most importantly, we feel that a permanent record of the parameter choices and results, available from the FLORTS hard copy output, is a necessary and convenient reference for high school students.\* Secondly, we favor the adaptability of the FLORTS system. A portable teletype, taken into the public school, can be coupled to the computer via the telephone. Students can enjoy the simulation in their own classroom. The nature of the PLATO system requires high school students at present to travel to the University campus to use one of the PLATO labs.

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\* Hard copy is available from a few PLATO terminals.



Thirdly, POLUT does not require any of the high-speed number crunching and versatile graphic displays that PLATO offers. We are suggesting elsewhere that POLUT's graphical display of results is ambiguous and unnecessary.

Our conclusion, should be tempered, however, by the observation that different users have different needs. Probably no absolute decision as to the desirability of a single system can be made. A decision must be reached on the basis of intended use, user characteristics, cost, etc., and will vary from one school situation to another.

Appendix B: Proposed Modifications of the POLUT Simulation Materials

The changes we shall suggest here are numerous and also varied in character, coming as they do from a review both of the technical content and the computer-assisted pedagogy of the simulation. This number and variety of worthwhile modifications of an already well-developed simulation should remind us of several facts about computer simulations; first, experts in the relevant science or branch of engineering or other specialty must work with teachers and simulation designers in continuing efforts to perfect a simulation; second, the criticisms and successive improvements developed for one simulation may often suggest criticisms and subsequent improvements for other simulations; and third, as mentioned earlier, the decision as to the final form of a simulation and its off-line materials that is most suitable for a given class should ideally be made by the teachers or the curriculum supervisor responsible for that class. (We say "ideally" because limitations of time, energy and expertise may prevent the staff of a school from molding a simulation to its best fit to a given class.)

Proposed Modifications of the POLUT Simulation Program

1. Include an option which would allow the user to request that only the data for a steady state simulated situation conditions be printed out. The display of time-dependence is interesting and may have subsidiary value as a method of teaching graph analysis, but water quality experts are interested primarily in what the final, steady-state conditions will be.
2. Include a test for steady-state conditions in the table print out similar to the test in use at present in the graphing routine, which stops printing when constant levels have been reached.

3. Clarify or change the unit for the waste concentration parameter. The unit "parts per million per day" is ambiguous, confusing and cannot be easily compared with data from other sources. Changing the unit to "milligrams/liter", a standard measurement of waste concentration would alleviate this.
4. Allow a greater range of input parameters, which would make the program more flexible. For example, flow rates (in cubic feet per second) or amounts of water (the area of a lake) could be used to define bodies of water instead of the rather vague terms used now (large, small, fast flowing,...).
5. There also seems to be a need to check the model itself for errors or inconsistencies. Several of the water quality experts who reviewed the program had serious questions concerning the assumptions and equations involved in the model. For example, the mathematical model in POLUT does not represent transient conditions adequately.

#### Proposed Modifications of the POLUT Simulation Off-Line Materials

These modifications are made with the existing program in mind. Any program modifications may require further changes in the off-line materials.

##### I. Modifications of the Resource Manual:

1. Generally improve the readability of the text. The unit is designed for use at the secondary level but many of the informative passages are taken almost verbatim from the original sources and are exceedingly dry. A greater use of examples and anecdotes would help to alleviate this problem.
2. Include some discussion of the values involved in water quality decisions and the types of trade-offs typically made in real world situations.

3. Define and explain the input parameters more clearly. This would include giving acceptable ranges for their values and relating these values to local water bodies, effluent discharges, etc., as examples.
4. Include a range of approximate costs and effectiveness of the various waste treatments.
5. Provide information as to where and how measurements of waste, concentration and dissolved oxygen levels would be taken in a real, analogous situation.
6. Discuss the general nature of simulations, stressing that they are just that, simulations, and not exact models.
7. Explain the assumptions in the simulation and what factors have not been taken into account that do affect water quality.
8. Give better explanations of the computer output with special emphasis on the analysis of the graph and relating the read-out data to local water bodies.
9. Provide a topically arranged or annotated listing of references so that help on specific topics can be more easily found.

A possible revision of pages 2 - 3 of the POLUT Resource Manual, which includes some of the above modifications is included here: <sup>15</sup>.

#### Bodies of Water

Fresh water occurs in many forms. Some of these are:

1. A lake is an inland body of water. A large lake is one with a surface area of more than 25 acres. Lake Shelbyville would be classified as a large lake.
2. A pond is an inland body of water that is smaller than a lake. A large pond has a surface area of between 5 and 10 acres. Kauffmann's Clear Lake, west of town, is an example of a large pond.

3. A river is a moving body of water which empties into a lake, another river or an ocean. Most rivers in Illinois, because of the level terrain, are considered slow moving rivers.
4. A stream is a small river.
5. An estuary is an inlet or arm of the sea, especially the wide mouth of a river, where the tide meets the river current.

The type of body of water is very important when considering the dumping of wastes. The larger the body of water the more water there is to dilute the waste and minimize any bad effects. Small bodies of water will become polluted more quickly because they contain less water and also change temperature more easily (since there is less water to heat or cool) and therefore have greater seasonal variations of temperature than do larger or deeper bodies of water.

One of the most important differences among various bodies of water is the speed with which they absorb oxygen from the air and the amounts of dissolved oxygen available for fish or other organisms. Generally, the larger the body of water, that is the greater the surface area of the body, the higher it's oxygen content. Thus, if all other factors (temperature, waste level, etc.) are the same, a large lake will have about 2-1/2 times as much dissolved oxygen as a large pond. Moving bodies generally have higher dissolved oxygen levels than still bodies of water. This is because the surface is more turbulent or rough and more water can come into contact with the air. The rougher the surface of the water the more easily it will "aerate" or take in oxygen. Thus, if all other factors are equal, a slow moving river will have 50 percent more dissolved oxygen than a large lake, and a fast moving river will have twice as much dissolved oxygen as a slow moving river.

II. Modifications of the Teacher's Guide:

1. Provide greater detail and listing of supplementary activities to the POLUT simulation with particular emphasis on laboratory experiences and values education.

Note: Outlines of possible lesson plans for units involving the POLUT simulation are included on pages 25 and 26 of this paper.

III. Modifications of the Student Workbook:

1. Provide a wider range of open-ended, value orientation type questions.

Note: The preceding proposed modifications are intended to be general.

Any individual teacher using the methodology provided in this paper may develop other modifications, deletions or additions to the existing material. The most important consideration is that the materials finally developed are well suited for the particular classroom situation in which they are to be used.

Appendix C: Outline of a Role Playing Game on Values Orientation

The following is an outline for a role-playing game originally intended for use in a unit involving the HUNTINGTON II POLUT simulation, but it may be applied in any environmental decision-making situations.

The objective of the game is to allow students to clarify the values involved in a water quality situation and to see how the decision making process works when questions of water quality are involved. Particular emphasis is placed on trade-offs involved in any analogous real-life situation.

It is assumed that the students participating in this exercise have a adequate knowledge of water pollution, the factors that affect it, laws governing water quality and technological solutions to water pollution.

The Roles are:

Members of the Board of Directors:

Their objectives are: To produce a product at minimum cost and sell large amounts of a product in order to realize large profits and stock dividends.

Members of Local Environment Group:

Their objectives are: To maintain water and land quality as nearly as possible in their natural conditions.

General Public:

Their objectives are: To have a high standard of living (a good job and low prices) and maintain local recreational facilities.

News Media:

Their objectives are: To publicize the issues and stands of the conflicting parties and conduct informal polls of the public.

The Game:

To begin the game a situation must be developed in advance by the teacher, preferably one with local significance. The situation may include, for example, the building of a new addition to a local food processing plant or the bond issue necessary for a new sewage treatment plant.

Approximately three students, depending on the class size, are chosen as Members of the Board of Directors of the company and are in favor of the move. They will be given information concerning the cost of the building, the cost of treating any waste products, the amount of waste expected and the type of waste and the economic impact of the building on the community (the number of jobs created, per capita income increases, etc.).

A like group of students will be chosen as Environmentalists. These will be given information regarding the environmental impact of the building and the costs of maintaining the area in question in its natural state or modifying it for recreational uses.

A similar group will be chosen as representatives of the media, who will report on any information given by the two factions and survey the public. It may be desirable to work out some sort of credit system whereby the groups may "buy" time on the media.

The remainder of the class is the general public, who will vote at the end of the session to decide the issue. They may be acting as themselves, as if judging a debate, or be given specific roles to play. For example, one student could play the part of a 47-year old worker who is employed by the company in question, who has an annual income of \$14,000, has four children and whose favorite hobby is fishing. The student would then be expected to vote as if he was the person described and could be asked to give his reasons for the way he voted.



The Directors and Environmentalists should be given the necessary information in advance of the first session so they will have time to prepare presentations. These presentations might include posters, slides, films or other means of information dissemination.

The game itself has five separate sections which may vary in length of time depending on the size of the class, the complexity of the issue and the time available.

**Part I: Setting the Problem**

A short announcement by the Board of Directors outlining the proposed project and the benefits the community will secure.

A short announcement by the Environmentalists outlining their position.

**Part II: Campaigning**

Each faction tries using whatever means they choose to influence the public to support their view. The newspeople can post news 'leaks' on the black board as they occur and conduct an informal survey of public opinion.

**Part III: Clarification**

The Newsmedia produce the results of their survey and analyze the positions of the opposing sides.

**Part IV: Final Arguments**

The Environmentalists present further data supporting their position. They do not necessarily have to be directly opposed to the move by the company but could just be pushing for some modification of the existing plan. The Directors make their final statement.

**Part V: Voting**

A general show of hands determines the outcome of the discussion. Several situations may be invented so that each student has a chance

to play several of the roles.

Note: This is intended to be merely a working outline or idea sheet. It is expected that the classroom teacher will make whatever modifications he or she deems necessary.

The types of situations which may be used as the focal point of the discussions is also purposely left vague so that the teacher, perhaps with the help of a group or groups of students, can prepare situations that are locally relevant.

In conjunction with this exercise it might be possible to visit a city council meeting where environmental issues are being discussed or to have members of the community who participate in the decision making process of the community come to address the class.

#### Alternatives:

Should the teacher find that role playing is inappropriate for his or her class there are other methods useful in clarifying decision making and environmental values.

Some of these alternative exercises include:

Having the students, individually or in groups, design advertising campaigns in support of some environmental principle. These may include posters, news releases, scripts for panel discussion or any other method of communication that is aimed primarily at the affective rather than the cognitive domain.

Having the students write poems or even plays which deal with some environmental issues.

There are other materials which allow the student to gain a feel for the decision making process in government and an appreciation of some of the

values inherent in environmental questions. These include the HUNTINGTON II simulation, POLSYS, and such board games as ECO-ACRES and THE POLLUTION GAME among others. The section on these (see Resources) may, of course, be used in any combination with both POLUT and/or the role playing scheme. The most important point is that the teacher feels the activities fulfill the classroom objective he or she has set for the class.

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Resources

These board games, which may be of use, are obtainable from the following places:

ECO-ACRES, Educational Services Division of the Maine Public Broadcasting Network.

EXTINCTION, University of Michigan, School of Life Sciences.

THE PLANET MANAGEMENT GAME, Educational Research Council of America; published by Houghton Mifflin Company, Boston, Massachusetts.

THE POLLUTION GAME, Educational Research Council of America; published by Houghton Mifflin Company, Boston, Massachusetts.

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\* Student Project Report of work done in a course (Sec Ed 357) on the instructional applications of computers offered at the Urbana campus of the University of Illinois.