An overview of the development of computer modeling for instructional and research purposes

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This paper presents an overview of the characteristics, pedagogy, and future prospectus of some widely used computer-based laboratory simulation systems in psychology. These systems were developed to augment undergraduate laboratory instruction by providing an experience which enables students to have considerable practice designing a series of experiments in an interesting and challenging context. The use of computer-based simulation makes possible the construction of a learning environment in which the laboratory class is converted into a research community engaged in scientific dialogue. The development of new simulation models is critical to the operation of this environment. A team approach for developing new models, requiring a programmer, content specialist, and instructional designer, is offered which has appropriate incentives built in to insure its success.

This paper could have just as easily been titled "*Dick Johnson, you sure have started something!*" In his review of the development of computer-based simulations and games, Kissler (1973) credits Johnson (Note 1) with developing the first computer-based laboratory simulation for teaching students about psychological research. Johnson's simulation game, *DATA CALL*, has since provided the basis for a number of simulation systems which model the research process. All of these systems have one thing in common. They are intended to enrich the teaching of courses which emphasize the use of a scientific methodology. These systems have been used primarily by psychologists to teach students about research methodology in psychology courses, but they can be applied to content areas in any discipline.

A general introduction to the characteristics of four widely used laboratory simulation systems will be followed by a discussion of the pedagogy involved in their implementation and an evaluation of their effectiveness. The development of new models is critical to the future viability of this educational innovation. A team approach which requires a programmer, content specialist, and instructional designer is discussed. This model, which addresses itself to both instructional and research needs, has incentives built in which are intended to insure its success.

GENERAL CONSIDERATIONS

Introductory laboratory courses take up a major portion of instructional time and departmental resources in most scientific disciplines. They are designed primarily to acquaint students with paradigms, equip-

ment, and techniques for data collection that are appropriate to the discipline. As such, the traditional laboratory course is often expensive to operate, cumbersome to administer, and relatively inflexible to individual student needs. These objections are often countered by pointing to the "real" aspects of the traditional laboratory experience. However, most of us are painfully aware that traditional lower division labs are seldom slices of reality, but rather demonstrations at best. The success of matching the data from labs to real-world phenomena is directly related to the instructor's ability to massage the student-derived results into some meaningful form. Under these conditions, the student becomes a relatively passive data collector, who discovers what he was supposed to do after he has already done it. Finally, the tight time and budget constraints of laboratory courses make it difficult to repeat labs. While some would argue that this experience builds character, it is clear that it does not teach students how to apply these tools to new contexts. If you believe in the logic behind "George Stoddard's famous remark that we learn not by doing but by thinking about what we are doing" (Cronbach, 1966, p. 239), then the traditional undergraduate laboratory experience leaves much to be desired.

Computer-based laboratory simulations were developed to help resolve the problems with undergraduate laboratory courses mentioned above. Specifically, they are intended to teach students to design, analyze, and report on a series of experiments in specific content areas within a reasonable time frame. In a typical laboratory simulation the student reads a scenario, which describes a problem and some published research related to it, and then he designs an experiment of his choice by specifying levels of instructor-provided independent variables. Uncontrolled variables are allowed to default to a program-specified value. The computer then calculates the appropriate value of the dependent variable

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for the number of subjects specified by the student. The algorithm which computes the individual subject's scores provides for sampling error so that the scores derived from replications of an experimental design differ according to a program-provided distribution function. Summary statistics are often calculated by the program, and the student evaluates his results according to his original hypothesis. Based on his findings, the student proceeds to design additional experiments which, hopefully, follow from previous ones. Each of the simulation systems discussed in this paper has the above mentioned characteristics, although the systems differ considerably in the way in which models are built and data is generated.

CHARACTERISTICS OF SPECIFIC SIMULATION SYSTEMS

DATACALL

The simulation game DATACALL, developed by Johnson (Note 1) to teach psychological research design, takes the student-specified parameter values for independent variables and generates scores for individual subjects. After each group of subjects' scores is printed, DATACALL calculates a *t* statistic for each set of two groups. A built-in point system, which charges students for the number of subjects and variables used, provides its gaming aspect. The point system was designed to make the simulation competitive. A student can regain points by writing up his report. A measure of success with this simulation game is the number of points retained at the end of a series of experiments.

Two clear positive results were obtained using DATACALL. First, the speed with which data could be collected enabled students to design a large number of experiments, encouraging them to think in terms of a program or sequence of experiments, rather than in terms of a single experiment, as is so characteristic of traditional laboratory experience. Second, students were more highly motivated to analyze and interpret their results, resulting in a more concrete understanding of the place of statistics in research design. Johnson's apparent success with this approach to teaching research design in psychology encouraged others to try variations of his model.

EXPER SIM

The best known and most widely used modification and elaboration of Johnson's (Note 1) DATACALL is the EXPER SIM system. The term EXPER SIM is an acronym for *experimental simulation* by digital computer. It embodies an innovative pedagogical philosophy, and to date includes three different software packages: the Michigan Experimental Simulation Supervisor (MESS), the Louisville Experimental Simulation System (LESS), and a modification of LESS, the Wabash Research Investigation Teacher (WRIST).

From the student's point of view, the EXPER SIM systems and DATACALL are similar in that they read a scenario, specify certain independent variables, and receive scores for their subjects. The EXPER SIM systems differ in the complexity of experimental design features available to the student and instructor. These "bells and whistles" were provided so that students could work their way through a sequence of four modes of interaction with the systems. To date, over 100 institutions have tried the EXPER SIM systems and thousands of students have gotten their initial exposure to research design via this type of simulation. With the aid of the computer-based simulation systems, the instructor can create a miniature scientific community engaged in scientific dialogue. The reported reactions of students, instructors, and administrators to this innovative approach to laboratory education is very positive, even enthusiastic (Miller, 1976).

MESS. The MESS programs were written by Robert Stout; their development and characteristics are discussed in a paper by Main and Head (Note 2). The system is a large FORTRAN IV program designed as an interface between students and data-generating models. It is simple to use, requiring little programming knowledge. It manages the individual models in the program library through prompts in English and a set of error messages. There is no general type of experimental design that is impossible to do. Once a student learns the protocol for using one data-generating model in the library, transfer to any other model is easy.

The MESS programs are the largest and most complex of the EXPER SIM systems, and as such they provide the most features. The present system can correct student's spelling errors, adjust for column entry errors, and is generally able to give students the benefit of the doubt. A major drawback of the MESS system is that it requires considerable programming skill to develop new models. The latter problem is being resolved by the development of an interactive program called SWIP (Stout, 1975), which when completed will translate models written in English by nonprogrammers into FORTRAN IV. SWIP will eventually interface with the MESS program library.

LESS. The development of the LESS system as a modification of the MESS system for smaller computers is discussed in a paper by the developers, Thurmond and Cromer (Note 3). LESS was originally written in BASIC for a Hewlett-Packard 2000c computer. Because of its smaller size, LESS does not have as many features available as the MESS system. Its interactive nature and the availability of a wider selection of models makes it particularly suitable for introductory-level classes. An additional feature is an already available system similar to SWIP. This program is called general model builder (GMB); it questions the modeler interactively to build a multiple regression model which is passed to the main program and becomes the

algorithm that generates subjects' scores. A liability of this system is that only the simplest of design types can easily be accommodated and that large factorial designs must be specified by the user one at a time. For comparison, the MESS system allows the student to specify a complex design in one statement and then proceeds to process the entire experiment without further prompting from the student. This difference is, of course, the price one pays in converting the programs to a smaller machine.

WRIST. The programs which comprise the WRIST system were translated from the LESS system into BASIC-PLUS by Spelt and Schafer (Note 4). All of the models available on the LESS system can be used with the WRIST system, and the resource-sharing capabilities of RSTS V4 or RSTS/E have permitted Spelt to include features not available in the LESS system. The WRIST system allows for research designs that are more complex than those available in the LESS system. In addition, Spelt has written a simulation which provides for multiple specification of groups.

Since the development of each of these systems was supported by the EXXON Educational Foundation, programs and documentation are available for the cost of reproducing materials. For information about these systems, contact the following: CONDUIT¹ (MESS), John Thurmond² (LESS), and Philip Spelt³ (WRIST).

PEDAGOGY

The laboratory simulation systems briefly described above should be thought of as tools to facilitate simulation. They are not *the* simulation. At first reading this may seem contradictory, but Main (Note 5) considers the laboratory simulation to be concerned with the total structure of the classroom and the organization of activities that may or may not involve the use of the computer. To this end, the structuring of a learning environment in which students are encouraged and permitted to model the activities of researchers involved in the dialogue of science is recommended. Main's position is well developed in the paper and the notion of converting traditional laboratory classes into a model scientific community is an important contribution to teaching of laboratory classes. Main presents concrete examples of how this scientific community can develop, and has empirical proof of its viability. The development of this community is enhanced immeasurably when computer-based simulations are incorporated into the activities of the class.

Building on this fundamental notion of a scientific community, Main, Stout, and Rajecki (Note 6) present four modes of interaction for the student researcher using computer simulation.

Mode 1

In this mode the student develops hypotheses, designs experiments to test them, and analyzes the

results as a prelude to further experiments. Designing programs of research is emphasized and students are encouraged to share their findings with other members of the class. It is in this way that the dialogue begins. At this level, groups of students can be brought together and report their findings to one another in a mock convention format. This level of interaction is appropriate for all levels of undergraduate courses.

Mode 2

The second mode differs from the first in that the student is made aware of only a subset of the variables effecting the scores of subjects in the simulation. These "x" variables were first developed in the LESS system (Thurmond & Cromer, Note 3) and the instructor has the option of revealing them to the student initially or allowing the student to infer their presence based on the results of his research. In Mode 2 the student does everything he does in Mode 1, but, in addition, "he must operationalize concepts and particularize values of variables. He must generate hypotheses on how mechanisms work and must articulate manipulable variables" (Main, Stout, & Rajecki, Note 6).

Mode 2 clearly requires a more systematic approach to designing experiments and more sophistication with research design principles. It is most appropriate for upper division content courses, but has been used successfully with advanced lower division students. The specific models available in the EXPER SIM system allow the instructor to use either Mode 1 or Mode 2 in his teaching. Both modes can be used effectively with students at a higher level of sophistication, but caution should be exercised in using Mode 2 at lower levels.

Mode 3

In Mode 3 the student is permitted to modify the algorithms he has been using in the two previous modes. The student could also be encouraged to help develop new models or, perhaps, conflicting models which predict similar data. A proposal for independent research might include the traditional review of the literature but, in addition, a model designed to accommodate the data. This sounds like an activity beyond the sophistication of most undergraduates, and it is. However, the development of programs like GMB and SWIP will make Mode 3 available to undergraduate students in the near future. At present this mode is appropriate for graduate-level design courses and independent research projects for more sophisticated undergraduates.

Mode 4

The final stage in the sequence is designed to link the simulation experience with the real world by having the student compare the results obtained from his model, developed in Mode 3, with the results of empirical research conducted in real laboratory experiments. Activities at Levels 3 and 4 could generate models for activities at Levels 1 and 2. Over a period

of time, Main envisions the accumulation of data-generating models representing a wide range of content areas in psychology. Students would be able to select an area of research to interact with in much the same way as they presently are able to select a book from the library. Graduate students and faculty, operating at Levels 3 and 4, would generate the models for the library. It should be apparent that with this system the role of the instructor would change dramatically. He would become a manager and consultant. Less time would be spent repairing equipment and more time discussing research tactics. The key to this approach is the continual development of new models. How can this best be achieved? The final section addresses itself to one approach that may be useful for the development of simulation models in the future.

TEAM APPROACH

Present models available in the MESS system were developed for the most part by graduate students at the University of Michigan (Miller, 1976). Each model required hundreds of hours of programming time to develop, at a time when the MESS system was new. The development of new models should be easier, but where will they come from? Individual instructors are usually too busy with class loads and committee assignments to take on the construction of a major modeling project without some form of support—either in the form of release time or summer research funds.

This past summer a group of psychologists⁴ interested in simulation models met and discussed the problems involved in developing simulation models for instructional and research purposes. In addition to the obvious problem of time commitments, there is the problem of the wide range of skills necessary to develop models to the point that they are useful for research and instruction. Borrowing a model developed by instructional designers (Edwards, 1975), we organized a group of people who had skills in programming, instructional design, and the specific content area we would model. Using this approach, we felt it would be possible to pool our resources to develop models that explained the phenomena we were interested in, write programs to add these models to the EXPER SIM simulation systems, and provide the proper support materials needed to implement these models in the classroom.

We chose as our content area the transitivity problem in children (see Riley, 1976, for a review). This area of research satisfied our criteria and appeared to provide us with the information necessary to satisfy Abelson's (1968) six criteria for a modelable simulation. Our intention was to divide the work in committee-like fashion and to meet for a work meeting at the end of the summer. Our objectives were to develop a series of process and predictive models that could explain the data. We then planned to develop these models into teaching simulations using the EXPER SIM systems.

Just as we were preparing to organize, an opportunity to communicate with each other via computer conferencing was made available. Our original objectives now included the evaluation of computer conferencing as an aid to solving this type of group problem, that is, a project within a project.

The results of this team approach to developing simulation models, and the added value of computer conferencing, are discussed in the other papers in this symposium. The process we have been involved in should provide others with some guidelines to aid in developing a way of promoting Level 4 activity in their disciplines.

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NOTES

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2. John Thurmond, Department of Psychology, University of Louisville, Louisville, Kentucky.

3. Philip F. Spelt, Department of Psychology, Wabash College, Crawfordsville, Indiana.

4. This project and subsequent meetings were an outgrowth of the Summer Simulation Conference held at the Denison Simulation Center, Denison University, Granville, Ohio, June 1976.