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CONSTRUCTION AND USE OF THE SCHOOL SIMULATION VEHICLE.

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THE PLANS FOR A SIMULATION MODEL USING SYSTEMS ANALYSIS AND COMPUTER SIMULATION TECHNIQUES WERE PRESENTED. THE TECHNIQUES AND DESIGN RECOMMENDATIONS WERE INTENDED TO FIND NEW METHODS FOR IMPLEMENTING INSTRUCTIONAL MEDIA. FOUR MAJOR STEPS WERE INVOLVED IN THE PROJECT--(1) SURVEY AND SELECTION OF HIGH SCHOOLS, (2) SYSTEMS ANALYSIS OF FIVE HIGH SCHOOLS SELECTED, (3) CONSTRUCTION OF A COMPUTER-SIMULATION VEHICLE, AND (4) SIMULATION AND STUDY OF THE FIVE HIGH SCHOOLS WITH THE MODEL. THE REPORT CONCENTRATED ON DISCUSSION OF THE CONSTRUCTION OF THE MODEL AND THE SIMULATION STUDY. THE MODEL WAS CONSTRUCTED TO DESCRIBE A SCHOOL IN TERMS OF ITS CHARACTERISTICS AND STUDENT CHARACTERISTICS THAT BEAR ON THE INSTRUCTIONAL PLAN OF THE SCHOOL. PRELIMINARY STUDIES WITH THE MODEL WERE BEING CONDUCTED WHICH INVOLVE THE MODELING ASPECTS OF THE CONTINUOUS PROGRESS PLAN. THIS PLAN WAS DESIGNED TO PERMIT STUDENTS TO PROGRESS AT THEIR INDIVIDUAL RATES. THE REAL TEST OF THE MODEL'S VALIDITY WILL COME WHEN ITS PREDICTED EFFECTS ARE IN FACT CARRIED OUT IN THE SCHOOL ENVIRONMENT. RELATED REPORTS ARE ED 010 559 AND ED 010 577 THROUGH ED 010 581. (RS)

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TECHNICAL MEMORANDUM

(TM Series)

CONSTRUCTION AND USE OF THE SCHOOL SIMULATION VEHICLE

by

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Donald G. Marsh, and Frank A. Yett
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CONSTRUCTION AND USE OF THE SCHOOL SIMULATION VEHICLE

by

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This paper describes a project that is making use of techniques relatively new to educational research--systems analysis and computer simulation. The purpose of the research is to find new solutions to implementing instructional media through analysis and simulation of school organization. Although great strides have been made in the development of educational methodology and technology during the past twenty years, the formal organization or structure of education has remained relatively constant despite obvious weakness in its ability to adjust to instructional innovations.

A major reason for this lack of change is the complexity of designing school organizations that efficiently accommodate modern instructional media. An innovation such as programmed learning, for example, if used on a large scale in a school, has implications for the organization of the whole school. By providing a means of effective self-study, it may allow students to progress at their own rates. It provides a means, and even suggests the need, for breaking away from the lock-step system of advancing students once a year only. However, when the full range of factors involved in an organizational plan is considered--the spatial arrangements, the student-scheduling problems, the versatile and effective use of teachers and other resources--the problem of design becomes overwhelming.

At his present level of capability for designing school organizations, the educator formulates a relatively simple plan, tries it in a real school, observes the problems as they arise, and attempts solutions on a piecemeal basis. It is in this fashion that schools have been designed in the past,

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and it is the pattern that will be followed in the future unless new solutions can be found.

The SDC project, which studies the use of systems analysis and computer simulation, should yield techniques and provide design recommendations that are more carefully conceived, that involve more pervasive and integrated changes throughout the schools, and that employ instructional media more effectively than do current school-design methods.

The high school is the basic unit for investigation in the study. Four major steps or procedures are involved in the project: (1) survey and selection of high schools; (2) system analysis of five high schools selected for study; (3) construction of a computer-simulation vehicle that will provide the capability of building detailed, dynamic models of the schools and of hypothetical changes in the schools; and (4) simulation and study of the five high schools with the simulation vehicle.

Since this paper is concerned mainly with description of the latter two procedures--the construction of the simulation vehicle and its use as a modeling tool--only a brief account of the first two activities is provided.

SURVEY OF INNOVATING SCHOOLS

Questionnaries requesting a description of their activities and plans were sent to approximately 200 high schools identified by their State Departments of Education as significantly involved in innovation. These schools were asked what they were doing, or planning, in the way of using programmed learning, television, language laboratories, flexible scheduling, team teaching, ungraded classes, electronic data processing, and other innovations. Ninety questionnaires were returned. The twenty-eight schools most extensively and intensively involved in innovation were selected for site visits. Twenty-four visits have been completed. The survey is being used to provide a basis for selecting five schools for study and to identify significant trends and problems associated with innovation.

SYSTEM ANALYSIS AND DESIGN OF FIVE HIGH SCHOOLS

Five high schools, ranging from the fairly traditional to the highly innovative, are being selected for analysis and design studies. Three of the high schools have been selected--the Continuous Progress Plan School, being developed at the Brigham Young University Laboratory School; The Culver City High School in Los Angeles; and the Nova High School in Ft. Lauderdale, Florida.

The analysis consists of: (a) collecting data descriptive of the high schools; and (b) translating the descriptive data into detailed flow charts. Following from the analysis, recommendations are made for design changes in the organizational structure to facilitate the use of media.

The flow diagrams have the value of presenting a diagrammatic picture of a complex sequence of procedures. They tend to reveal inconsistencies, redundancies, and omissions in the organization much more readily than detailed verbal descriptions. They also force a contemplation of the logical possibilities to be considered in analyzing how the system could be improved. The representation of the sequence of events and the flow from event to event helps to emphasize the interaction between different activities in the analysis.

In the design phase, hypothetical changes in the organization are made by constructing additional flow diagrams. Design recommendations may include any number of changes. Generally speaking, the intent is to suggest new combinations of media and personnel that will accomplish the task of education more efficiently. In addition to considering how instructional media and personnel may be used more effectively, the study is concerned with how space may be arranged more efficiently and how information-processing technology can be used to facilitate the implementation of media. For example, analysis of the Continuous Progress Plan School has resulted in the design of a centralized information-processing center. One of the major functions of this center is the Surveillance and Detection System, which automatically analyzes student performance data. If a student appears to be having trouble, appropriate school personnel are alerted by the System and can take action to remedy the problem.

As the design recommendations become more complex and involve more pervasive changes throughout the system, the uncertainty regarding the effects of these changes becomes greater. Well-thought-out extensive changes may have more positive effects on the total system, but the associated increase in the risk of negative effects increases resistance to their acceptance. A simulation vehicle that could be used for provisionally trying out design recommendations may not only help to decrease resistance, but also may provide a conceptual tool for working out more effective plans.

CONSTRUCTION OF THE SCHOOL SIMULATION VEHICLE

A first version of a vehicle has been designed that permits an experimenter or designer to construct on a computer a detailed dynamic model of a real or proposed school organization.

The simulation vehicle was designed to meet the following specifications:

1. The capability of building dynamic models of real or proposed high schools.

2. The capability of flexibly modifying the models to represent different design configurations.

3. Detailed recording of the events that take place during the simulation.

4. The production of detailed output data that reflect the effects of various design changes within the model.

5. The simulation of events occuring in relation to time.

The simulation vehicle has been constructed so that any high school can be described in terms of school characteristics (resources, organizations, procedures, etc.) and student characteristics that bear on the school's instructional plan; for example:

a. The curriculum and its organization.

b. The spatial arrangement of the instructional space.

c. The resources such as programmed learning materials, teaching machines, equipment, teachers, counselors.

d. The procedures for sequencing students through the instructional system.

e. The procedures for channeling students through the counseling system.

f. The procedures for admitting and terminating students.

g. The procedures for relating to external agencies directly concerned with helping students.

h. The information-processing procedures.

i. The characteristics of the students that relate to the instructional and counseling process.

j. The decision-making procedures.

The vehicle is programmed in the JOVIAL programming language for the Philco S2000 computer. It is constructed in modular form so that a model of an existing or proposed school can be constructed by assembling the modular parts into a particular configuration. The modules or parts exist in a hierarchical order with five levels.

At the most detailed level the basic unit is called an activity. Activities are combined to constitute procedures. Sets of procedures make up packages. Packages are combined to form modules. And finally, the assembly of modules defines the total system that is being simulated.

Figure 1 shows the Study Package. The Study Package comprises four procedures--the Assign, Do, Help, and Assess procedures.

Various sets of procedures can be simulated by varying the flow of students through the study package. Students, for example, may be assigned to work in a group mode. They can be simulated spending time doing the work. After a period of time they can be assigned to work again in a different mode or on a different course; or the flow can represent their getting help from some teaching resource; or the simulation can entail students being assessed in some fashion. Following the assessment, students may be given help or they may be assigned to work again.

Each of the procedures is defined in greater detail as a set of activities. Figure 2 shows the Assign procedure--the procedure used to indicate that students are to work in an individual or a group mode. Figure 3 represents the flow that can occur in the Do procedure. The rectangle labeled QS21 is a queue or waiting line. If the student is assigned to work in individual study and resources are available, he will spend no time in queue. But if the student is assigned to a group mode of study he will remain in queue until the group is assembled.

The alternative of getting help, being assessed, or going back to Assign following the simulation of work, is expressed by the XS22 split.

Each of the procedures in the Study Package is defined in terms of a set of activities. Figure 4 shows the representation of a total system. The system consists of three modules--a Control Module, an Outside Resource Module, and a Subject Alpha Module.

Subject Alpha is comprised of seven Study Packages and one Evaluate Package. The course, Subject Alpha, is shown as having four units of work and three projects. Each of the units and projects is described in the simulation model by varying the flow within the Study Package. Project one could be described as a group activity, whereas Unit One could be an activity conducted in an individual mode, or in a combination of individual and group modes. The Evaluate Package includes the decision rules that a teacher would usually use regarding the flow of students in the system.

The Control Module contains four packages--The Enter, Terminate, Counsel, and Diagnostic/Prognostic Packages. The Enter and Terminate Packages can be used to simulate such procedures as admission, registration, graduation, and withdrawal. The Counsel Package can be used to represent students spending time

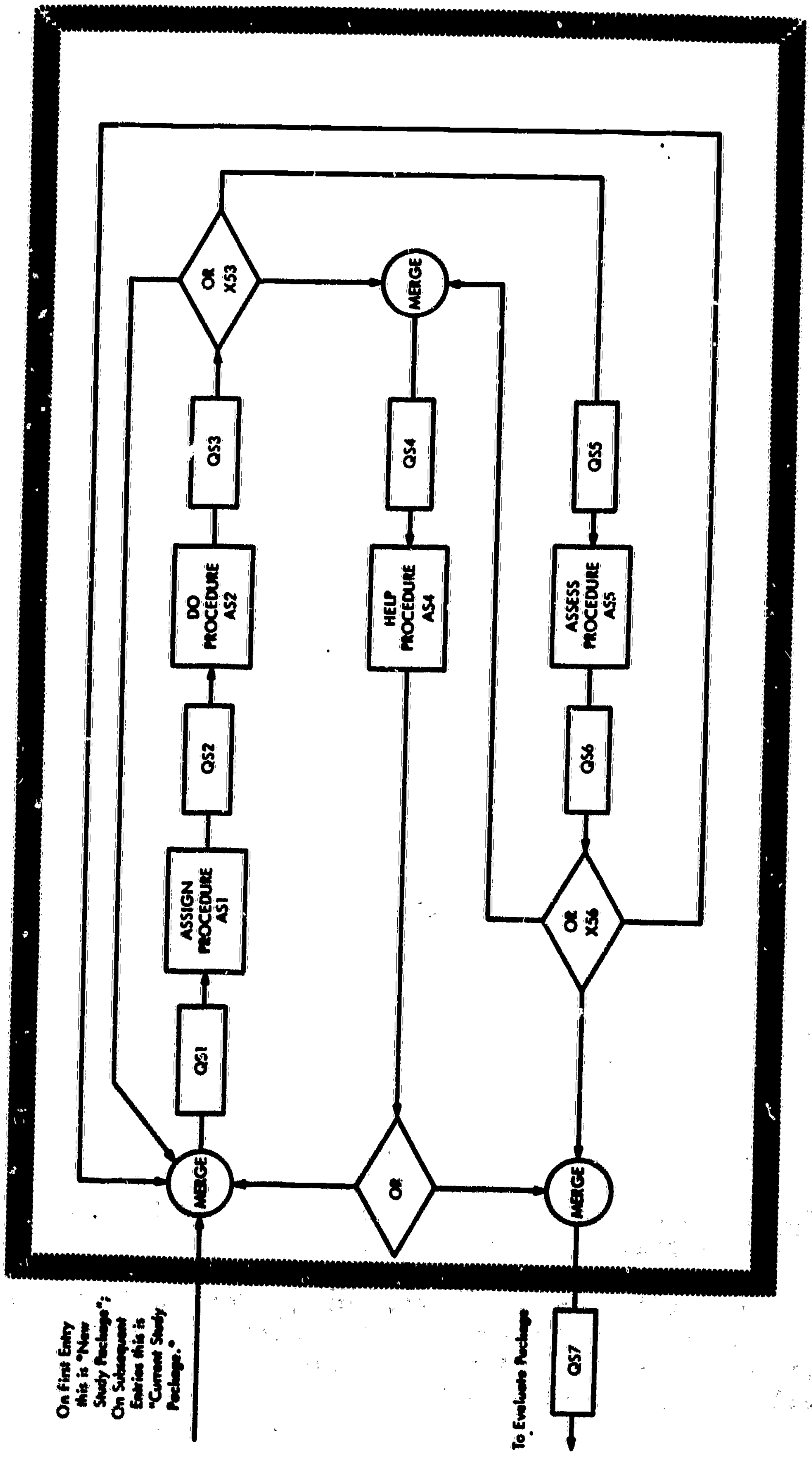

Figure 1. Flow Diagram of Procedures in Study Package

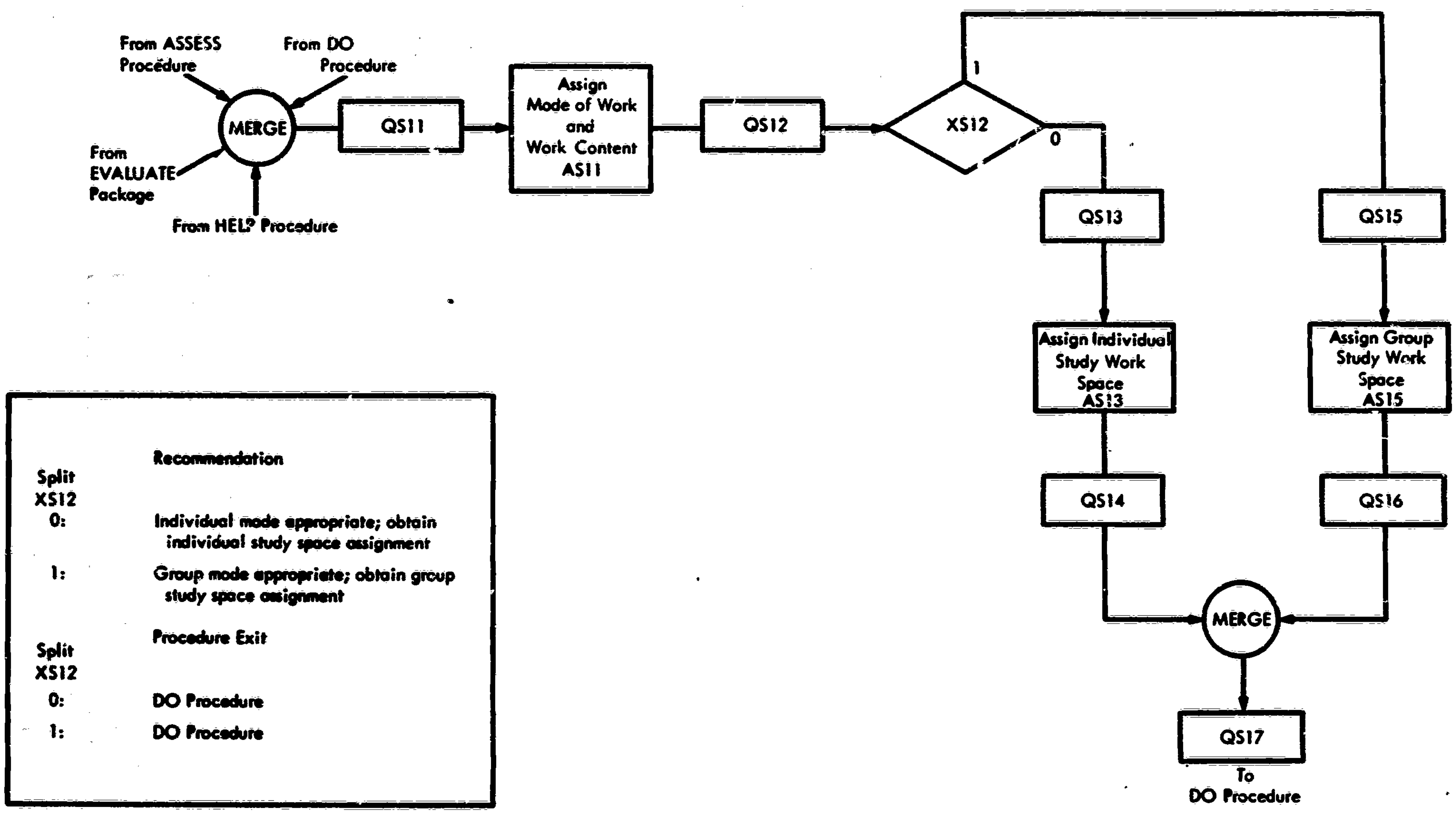

Figure 2. Flow Diagram of the Assign Activities in the Assign Procedure of the Study Package

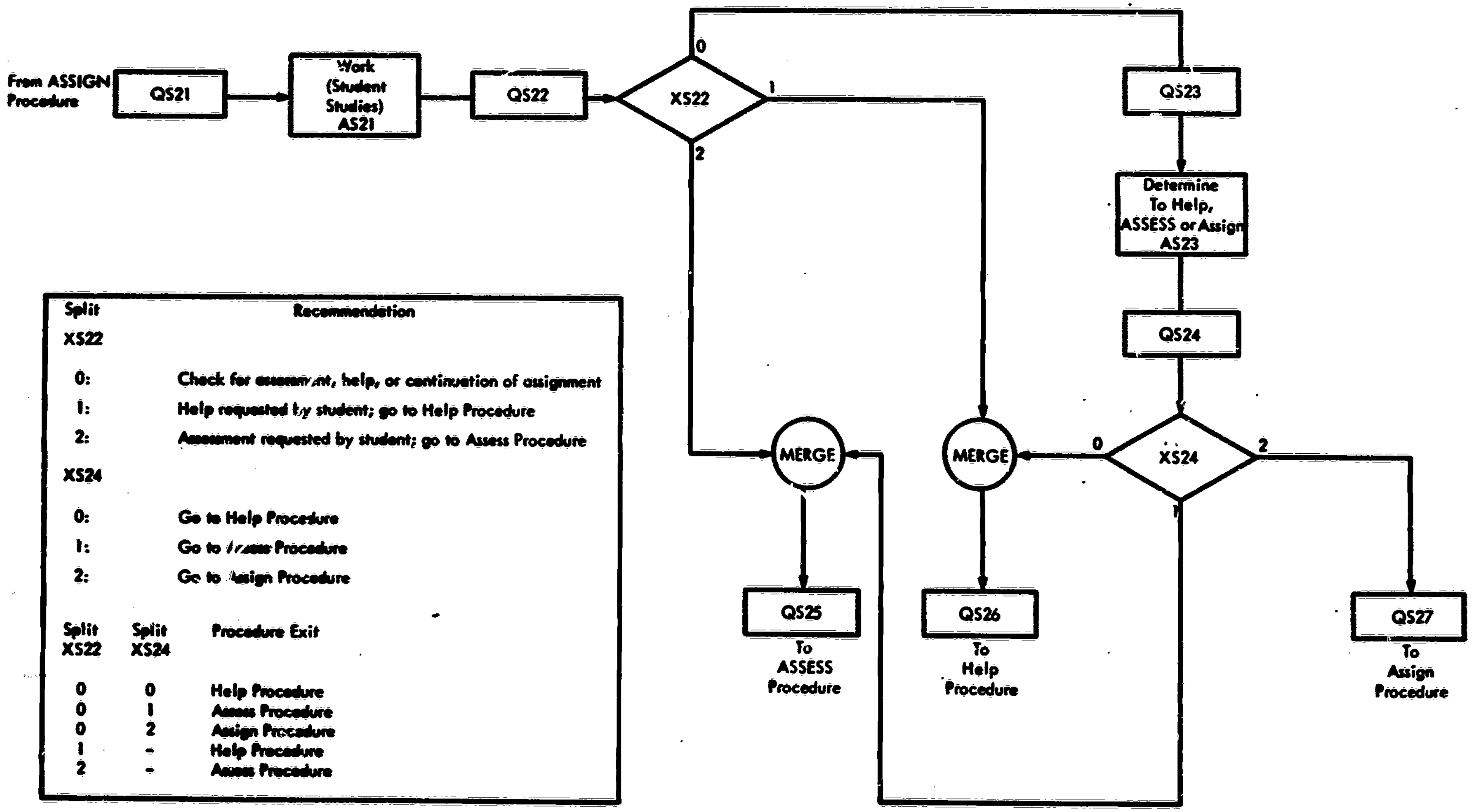

Figure 3. Flow Diagram of the Do Activities in the Do Procedure of the Study Package

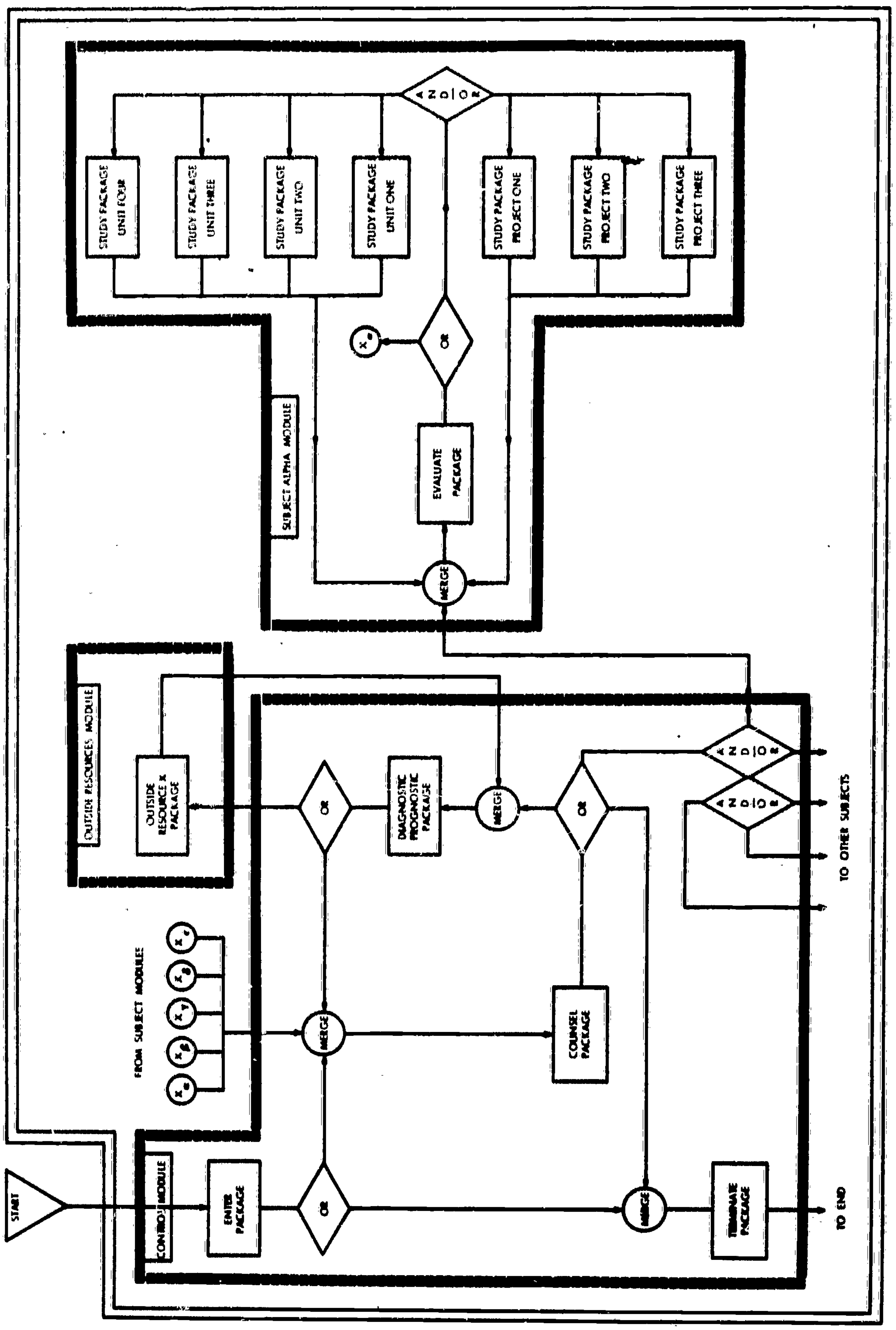

Figure 4. Flow Diagram of the Total System--Version One

with the counselors. Students can be referred to counseling by the teacher from the course work. The decision box following the Evaluate Package in Subject Alpha, shows the alternative (Xa) which feeds into the Counsel Package of the Control Module. The Diagnostic/Prognostic Package contains a set of decision procedures for referring students to outside agencies such as a Child Guidance Clinic. In the figure, the outside agency is represented by the Outside Resources Module. Although the total system in the example does not represent a whole school with all the courses and procedures, it does show the way that a system can be modeled by assembling packages into modules and modules into a system.

Figure 5 illustrates the logic for simulating the dynamic occurrence of events through time. Time duration in the simulation vehicle is expressed on two time scales. The one for the Activity Processor is a series of time units, (i, i+ 1) logically connected end-to-end ad infinitum. All activities begin at the start of a time unit and terminate at the end of a time unit. From its beginning to its end, an activity is said to be underway. During the time in which the activity is being performed, the resources engaged by the activity undergo no change. All changes in resources take place at the completion of the activity.

The program that changes resources and redistributes resources to activities operates on a time scale considered as a series of "suspended" or "null" periods interspersed between successive time units of the Activity Processor. In other words, the clock is stopped before resources are reallocated to activities and before activities are discontinued. When all of the required changes have been made the clock is turned on again, and time is simulated as if there had been no interruption in the flow of events through time.

Another computer program has been developed that permits the experimenter or designer to construct student populations. Since the simulation of school organization will frequently involve the modeling of system processes that respond differently to characteristics of members of the population, the distribution of trait-descriptions in the population must be defined. Individuals within the population can be described in terms of a number of measures and the distribution of traits within the population can be determined. In addition, data from real samples of students can be used to describe the students in the simulation.

When a model of a school organization and a student population has been defined with the vehicle, the simulation is conducted on the Philco S2000 computer. A recording tape is generated by the simulation run. The recording contains a detailed account of the events that occurred within the simulation. A record is made of every step that each student went through and the time that each event occurred.

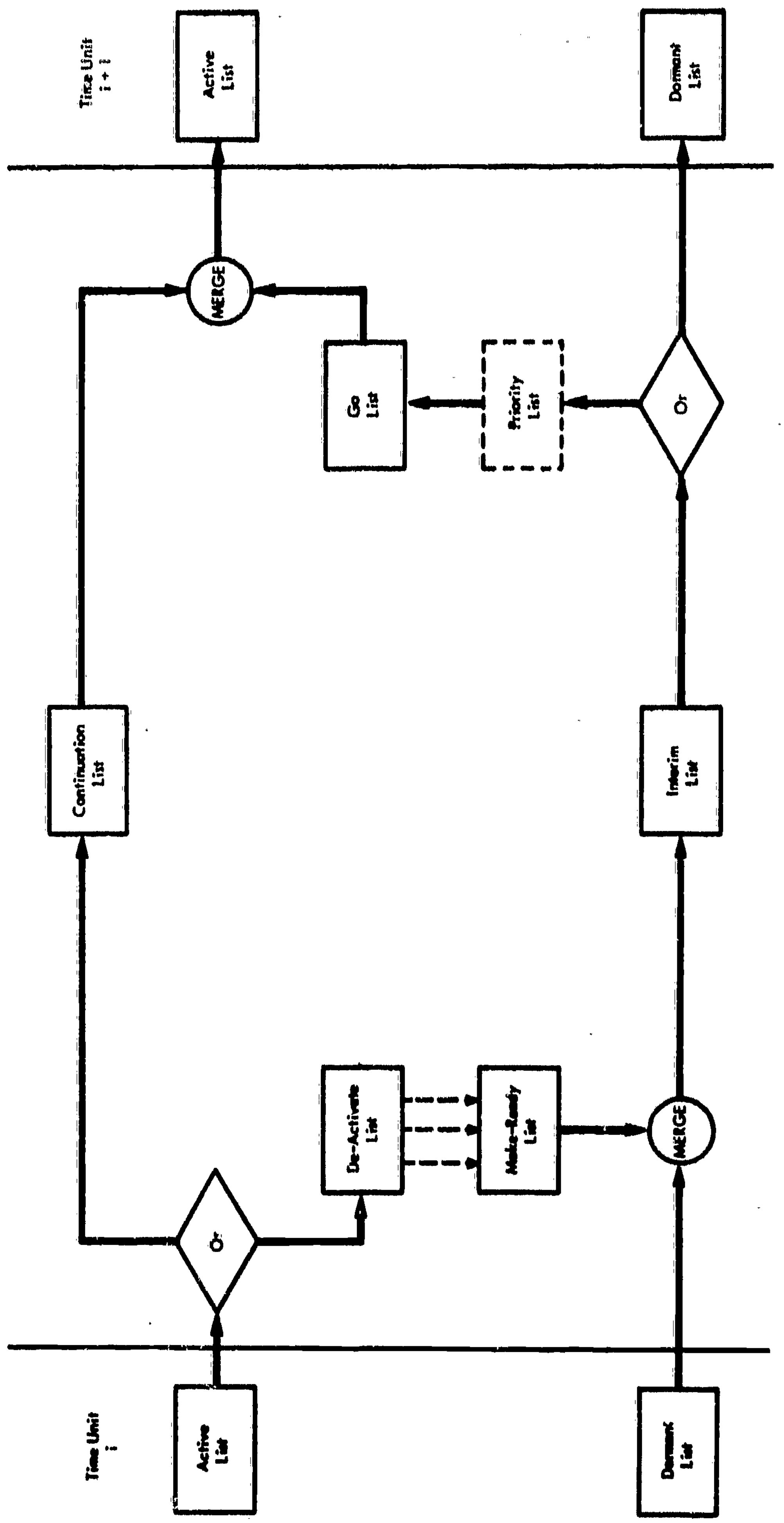

Figure 5. Resource Allocation Processor Pilot Version Mod 3--Logical Flow of Activities

A set of output or information-processing programs has been written to provide summarized displays of the events that occurred in the simulation. The output displays are the most critical part of the simulation.

The utility of the model for suggesting insights into the dynamic events that occur in the simulation is dependent upon the number and kinds of output displays that can be obtained.

At the present time the set of output displays is fairly limited. It is expected that this portion of the vehicle will be greatly enlarged before the study is completed. The present output displays provide the capability of obtaining a detailed account of the history of any specified students in the sample. Distributions of the spread of students on any activities can be printed out for any set of specified time periods. These displays contain the student numbers of the students within each of the frequencies. Another output routine provides a summary of the number of students of each type who have passed through each queue and each activity during the simulation. Means, medians, and ranges are provided for each of the variables that are summarized in the output displays.

The programs for the processing and recording of school resources such as teachers, space, and equipment have yet to be developed for the vehicle.

USE OF THE SCHOOL SIMULATION VEHICLE

Preliminary studies with the vehicle are currently being conducted. These studies involve the modeling of aspects of the Continuous Progress Plan School.

The Continuous Progress Plan is designed to permit students to progress at their individual rates through the curricula.

Students are assigned to courses whenever they are ready for them and spend from 40 percent to 90 percent of their time working by themselves. They work in a study booth or carrel where teaching assistants are available to help them if they are having difficulty. If they need help from the teacher they file a request, and within the next day or two they are called in to the teaching studio for help with other students experiencing the same difficulty. They take tests when they are ready and receive knowledge of results within 24 hours. Their work may be with programmed learning materials or with a study guide and conventional texts. When they have completed the course they may begin a new course. They are not kept together with a group in a lock-step system.

The first model with the simulation vehicle was of students going through an algebra course on a Continuous Progress Plan. A population consisting of 19 fast students, 19 slow students, and 62 medium students was defined. The fast students were characterized as doing the work in the course in 80 hours. The medium students were characterized as doing the work in 100 hours and the slow students were characterized as doing the work in 120 hours. It was assumed that all students had the same amount of work to do in the course. Different rules of treatment or procedures were defined for each of the three groups. For example, within the Do procedure (Figure 3) students are distributed as follows whenever they come to split XS22: 80% of the fast students take branch zero, which sends them back to the Assign procedure; 5% of them take branch 1, which means that they are given help by the teacher; and 15% go through branch 2, which means that they go through an assessment step before continuing to work.

The results of this particular decision rule are that a small portion of the fast students are simulated as receiving help from the teacher.

The actual assignment of each student to one of the three alternative branches in the decision rule is handled by a random-number-generator program that assigns the students in accordance with the prescribed proportions on a random basis.

The slow students are distributed in accordance with a different set of proportions at the XS22 decision point or split. A third of the slow students are branched to Help, a third are branched to Assess, and a third go back to work on the course. Differences for the treatment of the groups are defined throughout the simulation.

Figure 6 shows a comparison of data obtained from the simulated run with data obtained from real students in a Continuous Progress Plan course. The subject was Algebra I; the students used the TEMAC programmed course in Algebra for their individual study. They were free to do homework in the course. The data shows the distribution for the slow group. The slow students from the real course were defined as the lowest 20% in terms of their rate of progress through the course.

Each line shows the distribution of the students in terms of the hours of work that they have completed in the course at particular times during the course. The total TEMAC course takes approximately 120 hours for the average student to finish. The base line shows the number of hours from zero to 120. Four distributions were obtained for each of the groups. The second line shows the distribution for the real students on October 2. The fourth line shows their distribution on December 1, the sixth line is the distribution on February 1, and the eighth line shows the spread on April 1.

The first, third, fifth, and seventh lines show the distribution of the students from the simulated run at comparable time periods.

Two hypotheses suggested by the comparison are of interest. The rate of progress that was modeled for the simulated group appears to be in error. The real students progress at a slower rate through the course.

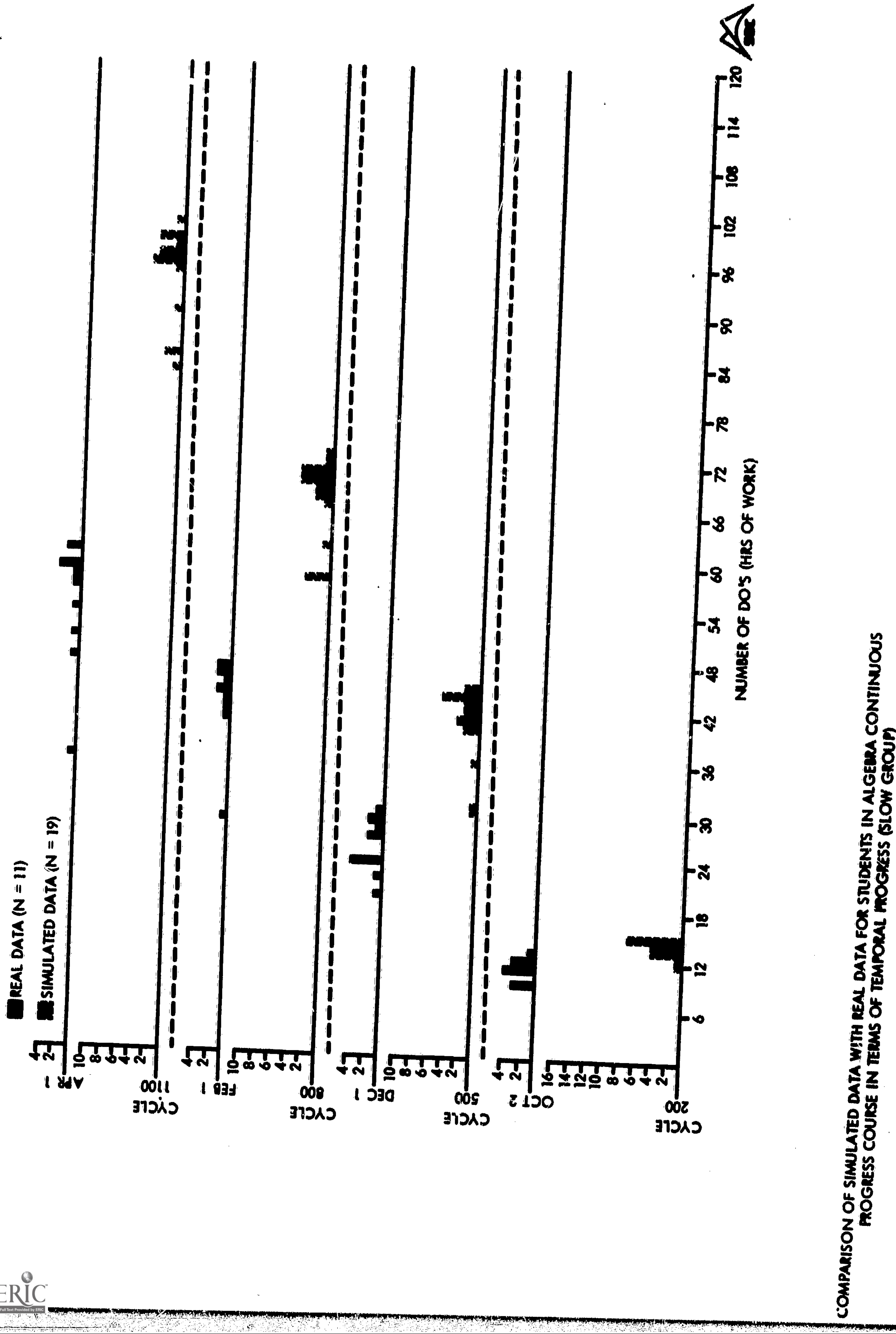

Figure 6. Comparison of Simulated Data with Real Data for Students in Algebra Continuous Progress Course in Terms of Temporal Progress (Slow Group)

The model should be changed to conform more accurately to the real data. However, the question of how the model should be changed is not as simple as it may first appear. The simulation did not involve the scheduling of students into groups for help, whereas in the real situation such grouping did occur.

When the waiting or queueing for the scheduled help is defined in the simulation, the rate of progress of the simulated group may correspond more closely to the progress of the real students. A simple adjustment of the rate of progress in the model would provide the same rate, but possibly for the wrong reason.

The second hypothesis of interest is related to the shapes of the distributions for the two groups. The shapes are very similar. Both the real and simulated data change from a normal distribution to a rectangular shape, and the spread of the two distributions increases rapidly over time. This data led to the prediction that the stress on the system imposed by the slow students would become increasingly severe as time progresses. Since it was assumed that the slow students would require more help, and since the data indicates that the spread becomes greater through time, the number of groups to be scheduled for the slow students also would become greater as time progresses. These hypotheses have been corroborated by the events in the real situation. Almost all of the available teacher time is being spent with the slow students. In addition, the number of groups has increased considerably and the number of students in each group has decreased. The average size of the groups is two students.

Two schools in two different parts of the country have independently been experimenting with the Continuous Progress Plan for the past four years. Both schools have independently decided to place their slower students back in a lock-step group plan. The analysis of the simulated data indicates that the change in procedure was required as an adjustment to the increased stress on the system. Although the administrative decision may be justified by the explanation that the slow students are not suited to the plan, the dynamics suggested by the simulated data indicate that the resources and the organizational plan have become increasingly unsuited to the students.

Figure 7 shows the comparison between the simulated fast group and the real fast group (the fastest 20% in the real Algebra course). The rates of the two groups are comparable, but the distributions are entirely wrong. The simulated data indicates much greater homogeneity in spread than actually occurred. Although the fast students spent minimal time with the teachers, they did vary markedly in their rate of progress.

The distribution of the total group of students on February 1 (including the so-called fast, medium, and slow) was correlated with a number of measures to provide some hypotheses regarding the reasons for the distribution. The measures included the STEP math, reading, and listening scores; an IQ measure; and the average number of frames of homework reported daily. For the total group of 55 students a significant portion of the variance was accounted for

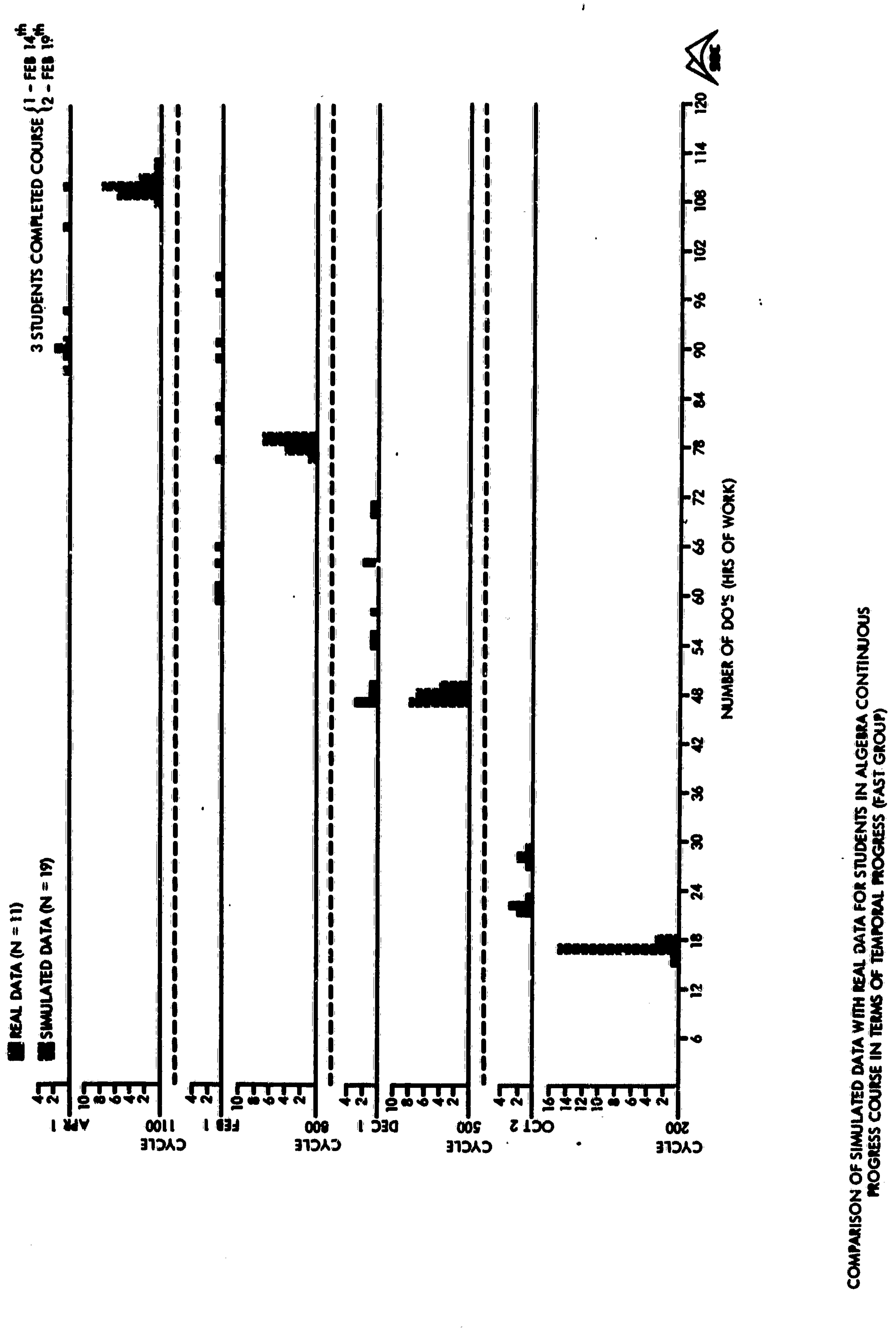

Figure 7. Comparison of Simulated Data with Real Data for Students in Algebra Continuous Progress Course in Terms of Temporal Progress (Fast Group)

by the combination of intelligence, homework, and STEP listening. Of the three variables, intelligence and homework contributed most heavily to the variance. Analysis of the slow group-although of questionable reliability because of the small sample size--suggests the hypothesis that reading contributes heavily to the variance within the slow group, but that it does not contribute to the variance within the medium and fast groups.

As a result of the analysis of these data, the simulation model will be modified to include time being spent in homework and greater spread among the fast students, which will be correlated with the student's intelligence.

The procedure to be followed in the development of the modeling study will be to work back and forth between simulated data and data obtained from the real environment. In this manner, the model serves the function of a theoretical model. It represents an explicit statement of the modelers' understanding of what takes place in the environment. The computer simulation technique both permits and encourages more detailed and dynamic explication of the experimenters' understanding. Logically, it is predicted that the correspondence between the data obtained from a model developed in this way and the data obtained from the environment will increase with continued study. When the experimenter becomes fairly confident of the validity of the model, it can be used to predict the effects of design changes. The real test of validity is successfully met when the experimenter can change the organization within the model and obtain predicted effects that later are substantiated by the same sequence of events in the real environment. It is toward this end that the simulation is directed.

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