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THE ORGANIZATION OF A COURSE FOR INDIVIDUAL PROGRESS AT THEODORE HIGH SCHOOL--SYSTEM ANALYSIS AND SIMULATION.

BY- BRATTEN, JACK E.
SYSTEM DEVELOPMENT CORP., SANTA MONICA, CALIF.

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THE BIOLOGY COURSE OF THEODORE HIGH SCHOOL AT THEODORE, ALABAMA, WAS STUDIED AS A SYSTEM FOR "PROCESSING" STUDENTS AND WAS SIMULATED ON A COMPUTER. AN EXPERIMENTAL VERSION OF THE COURSE WAS SIMULATED AND COMPARED WITH THE ACTUAL COURSE. THE PURPOSES OF THIS STUDY WERE (1) TO EXAMINE THE CONCEPT OF INDIVIDUAL PROGRESS AS IT RELATED TO THE ORGANIZATION OF COURSES IN GENERAL AND THE BIOLOGY COURSE IN PARTICULAR, (2) TO DRAW IMPLICATIONS FROM THE RESULTS AS THEY RELATED TO DEFINING NEW ROLES FOR SCHOOL PERSONNEL, PROVIDING INFORMATION ON THE USE OF MEDIA AS IT AFFECTS INTERACTIONS OF STUDENTS AND OF STUDENTS AND TEACHERS, DESCRIBING NEW APPLICATIONS FOR DATA PROCESSING, PROVIDING INFORMATION ON AMOUNT AND ARRANGEMENT OF SPACE, AND PROVIDING ESTIMATES OF CHARACTERISTICS OF GRADUATING STUDENTS, AND (3) TO DRAW CONCLUSIONS ABOUT THE USE OF SYSTEMS ANALYSIS AND COMPUTER SIMULATION AS RESEARCH TECHNIQUES. THE USE OF SYSTEMS ANALYSIS AND SIMULATION TO STUDY POSSIBLE BEHAVIORS OF AN EXISTING SCHOOL ORGANIZATION WAS FOUND TO BE FEASIBLE AND VALUABLE. SIMULATION OF THE OPERATION OF A THEORETICAL ORGANIZATION PROVIDED PREDICTIONS OF THE RESULTS TO BE EXPECTED FROM USE OF THE PLANNED ORGANIZATION. DATA GATHERED FROM THIS STUDY COULD BE OF POSSIBLE VALUE TO COURSE DESIGNERS WHO DESIRE A THEORETICAL MODEL TO GUIDE THEIR EFFORTS. RELATED REPORTS ARE ED 010 565 AND ED 010 566. (AL)

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AUTHOR Jack E. Bratten
TECHNICAL
RELEASE H. F. Silberman
for J. I. Schwartz

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TECH MEMO a working paper

System Development Corporation/2500 Colorado Ave./Santa Monica, California 90406

The Organization of a Course for Individual Progress at Theodore High School: System Analysis and Simulation

ABSTRACT

This Tech Memo is the third in a series reporting the work done at Theodore High School in connection with the study New Solutions to Implementing Instructional Media Through Analysis and Simulation of School Organization. The biology course at Theodore High School is described as a system for processing students; the results obtained through simulating this system on a computer are reported. In addition, a computer simulation of an experimental version of the course is reported and compared with data from the actual course.

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I. INTRODUCTION

While conducting this study, project personnel have analyzed questionnaire data from 89 high schools, visited 25 schools, and made a detailed study of five of them. In examining this experience for trends in organizational innovation as it pertains to instruction, two major ideas emerge. One is team teaching and the other is individualization. The definition of both of these approaches varies from school to school. Of the two, individualization appears to be particularly vague. Schools claiming to have individualized courses may actually be referring to traditional independent study, advanced college placement work, use of language laboratories, use of teaching machines, use of programmed instruction, etc. The common element that appears to hold these techniques together is that instruction is given to individual students instead of being given to groups of students. Instructional materials (texts, audio tapes, programs, etc.) are provided so that a single student can learn the content of a course, on his own, and will require only minimal support from a teacher.

This idea is not new in schools; traditionally, many courses currently in existence have long used this approach to instruction. Typing courses and applied arts courses are both good examples. In these subjects students are given a series of projects to complete on their own. The advent of new educational techniques (particularly programmed instruction) in recent years has suggested to many educators that instruction in the individual mode might be extended to the more basic subjects such as mathematics, English, etc. In addition to Theodore High School, three other schools* included in this study are involved in developmental programs aimed eventually at extending individual instruction to all of their courses. In addition, these three schools are attempting to add another dimension to individualization by permitting students to set their own pace while they learn in the individual mode. Treating each student as an individual in terms of his specific progress is certainly educationally sound, but the specific procedures to accomplish it are presently both experimental and indeterminate in effect.

Theodore High School is outstanding with regard to the number of courses that are individualized. The biology course was selected for intensive study because it exemplifies the approach used at the school. The balance of this report describes a system analysis of the procedures used in the biology course and reports the results obtained by simulating the course.

II. THE PROBLEM FOR STUDY

The biology course at Theodore High School operates ostensibly as an individual progress course. Students receive directions in a study guide, elect the specific tasks they will work on, and schedule themselves individually for the many day-to-day tasks that, taken all together, comprise the course. As a consequence, students vary with respect to how many of the tasks they have completed; a single class contains students engaged in a variety of different tasks at any given time. However, all students are constrained in their freedom to take as much time as they would like in completing the various tasks by formal group goals. These goals are published in the study guide and require that all students in the course meet certain minimal progress requirements by specific dates in order to receive a passing grade in the course.

*Brigham Young University Laboratory School, Provo, Utah; Garber High School, Essexville, Michigan; and Nova High School, Fort Lauderdale, Florida.

The first purpose for this study was to examine the concept of individual progress as it related to the organization of courses in general and the biology course in particular. Specifically, three sets of data were contrasted for implications that have a bearing on this purpose. The three data sets were:

- Actual course data obtained from an analysis of records kept by the teacher and students.
- Simulated actual data obtained by computer simulation of the course as described in Section B, below.
- Simulated experimental data obtained by computer simulation of an experimental version of the course described in Section C, below.

The second purpose for the study was to draw implications from the results as they related to the objectives of the project, New Solutions for Implementing Instructional Media Through Analysis and Simulation of School Organization. In brief, these objectives were to:

- Define new roles for school personnel.
- Provide information on use of media as it relates to student/teacher and student/student interaction.
- Describe new applications for data processing.
- Provide information on amount and arrangement of space in innovating schools.
- Provide estimates of characteristics of graduating students.

A third purpose of this study was to draw some conclusions about the use of system analysis and computer simulation at research techniques in the present study.

III. TECHNICAL DISCUSSION

A. THE BIOLOGY COURSE AS A SYSTEM

A description of a system that represents the biology course at Theodore High School is presented below. The system is made up of a sequence of activities, two for each of the 10 units of study that make up the course.* These activities

*TM-1493/111/00, a System Development Corporation document dated 9 December 1965, describes the biology course at Theodore High School.

are presented as a sequence of activities (numbered from 1 to 20) as shown in Table I.

When a student completes an activity, his next activity will always be the succeeding activity in the sequence shown in Table I. Student progress, however, is allowed to vary in the following ways: (1) the particular day during the school year when they start the course; (2) the particular unit of study (the activity) where they begin; and (3) the amount of time spent in each of the 20 activities. Thus, each student processed by the system may have a unique history in terms of the day when he begins a course, what activity he begins, and the amount of time he spends in each of the activities.

Figure 1 is a diagram of that part of the system that controls the starting day and activity for each student. The design of the system assumes that all students who will work in the course during the 175 days that it is in operation start on the first day of the 175.* This is represented in Figure 1 by the rectangle labeled "Start." A pathway leads from "Start" to a choice point (labeled "a" in Figure 1) where two exits are possible. Exit 01 leads to a rectangle labeled "Start Course" and exit 02 leads to a rectangle labeled "Wait."

Students who take the path to "Start Course" are processed to a choice point with 10 exits, labeled "b." At location "b" in the system, students are assigned to one of 10 locations. These locations in the system represent the work activities associated with each of the 10 units of study in the course (the odd-numbered activities in Table I). Students who take the 02 exit from choice point "a," and go to "Wait" are assigned to one of 34 locations in the system at choice point "c." When a student is assigned to one of these locations, he is held there by the system until system time is equal to the value assigned to that location and then starts the course by going to choice point "b" for assignment to a specific work activity.

The start function for the system makes it possible to represent students beginning the course in any one of the 10 units of study. Also, they can begin their work on the first day of each of the 35 weeks that the course runs. Normally students begin work in Unit A on day one in the actual course, but there are a few exceptions and these can be accommodated by the start function described above.

The other way that students vary in the biology course is with respect to the amount of time that each spends in the 20 activities listed in Table I. Figure 2 is a diagram of the function controlling the amount of time students spend in

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*Actually students work in other courses up until the time they begin biology. The start function described here merely duplicates a function external to the real biology course by providing the system with students at certain times and starting them in selected activities. It has no counterpart in the "real" situation.

Table I. Sequence of Activities in Biology Course

Activity	Description
01	Work in Unit A
02	Test in Unit A
03	Work in Unit B
04	Test in Unit B
05	Work in Unit C
06	Test in Unit C
07	Work in Unit D
08	Test in Unit D
09	Work in Unit E
10	Test in Unit E
11	Work in Unit F
12	Test in Unit F
13	Work in Unit G
14	Test in Unit G
15	Work in Unit H
16	Test in Unit H
17	Work in Unit I
18	Test in Unit I
19	Work in Unit J
20	Test in Unit J

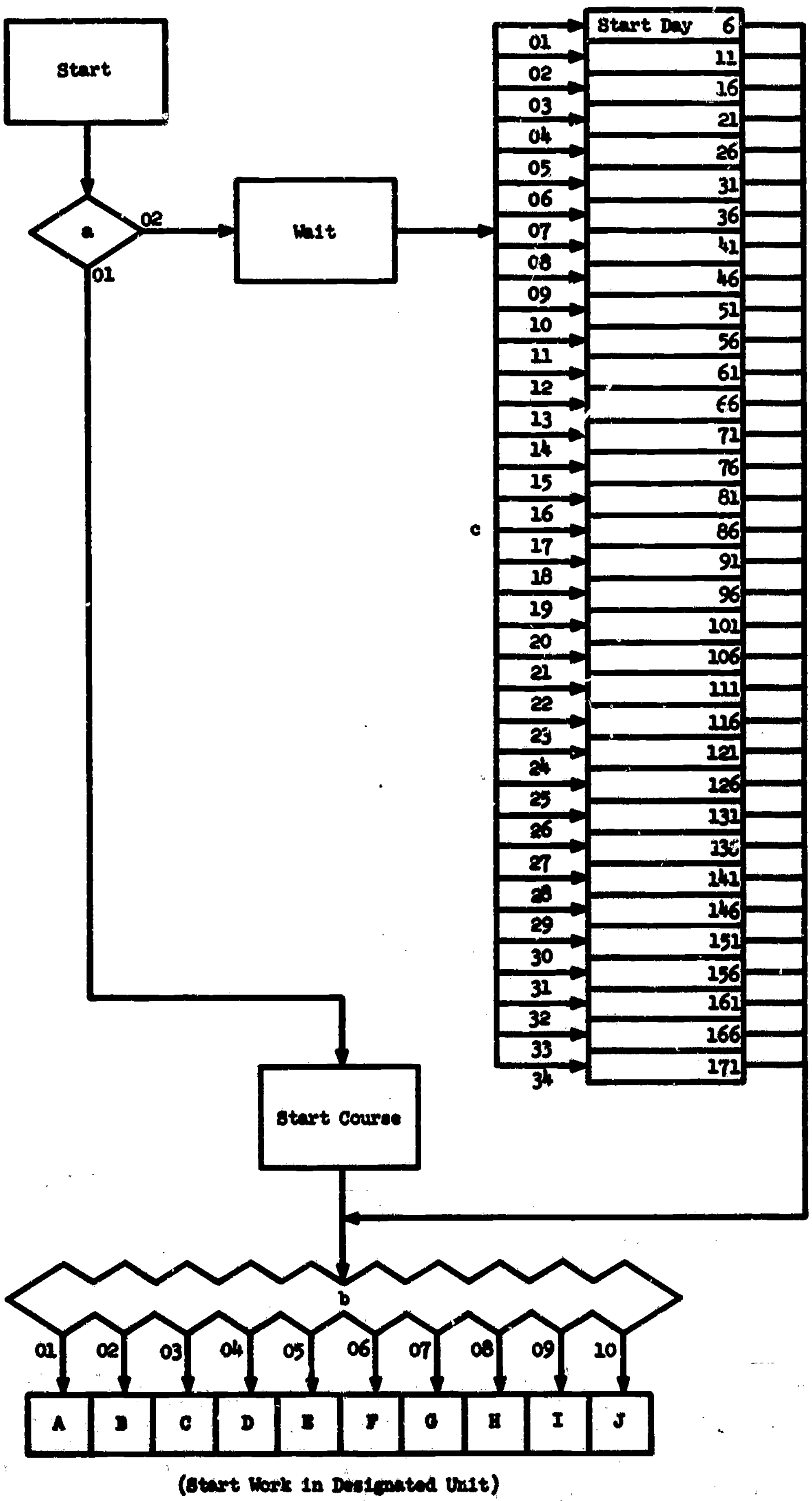

Figure 1 The Start Function

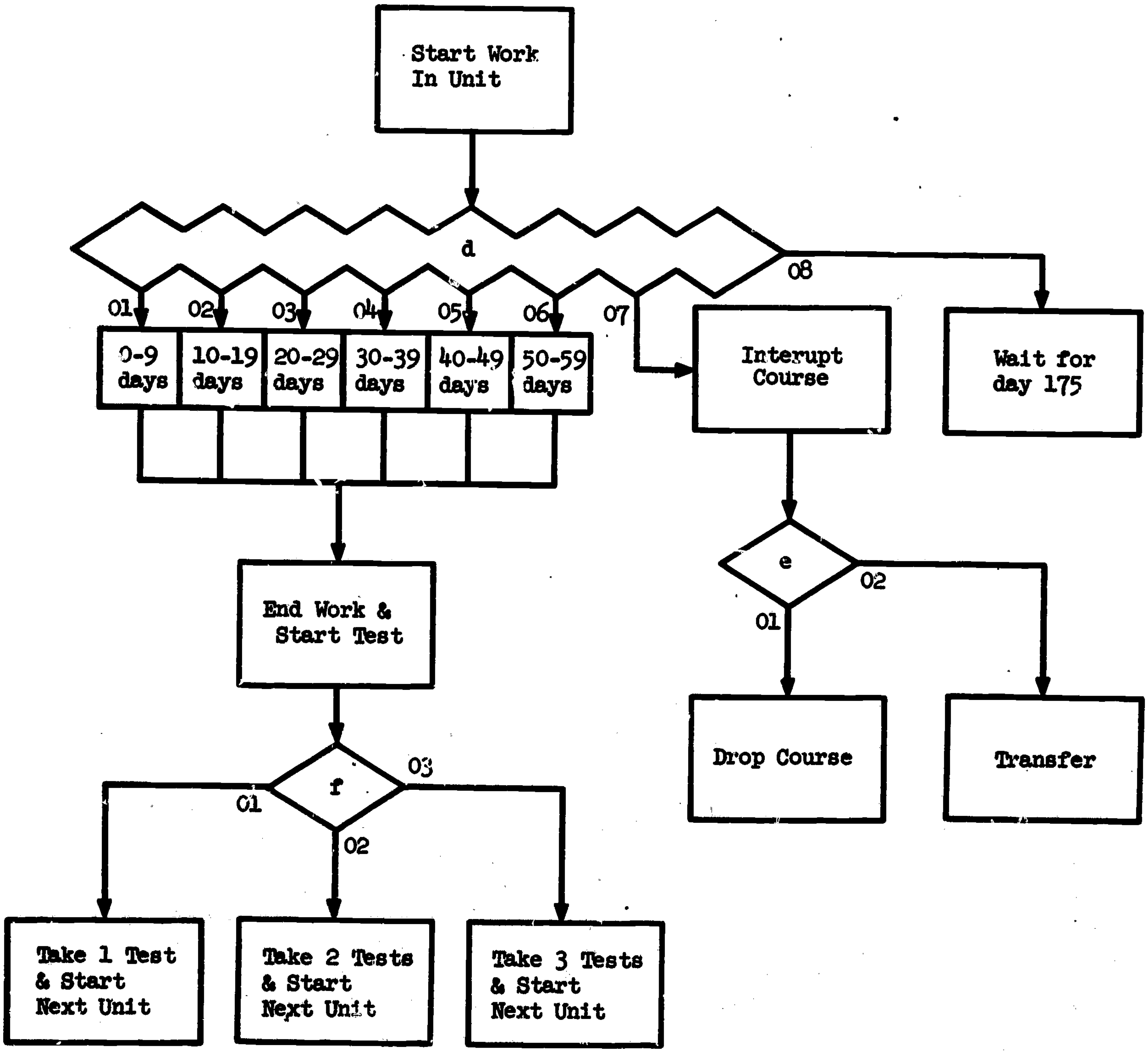

Figure 2. The Timing Function

the various activities. This part of the system is general to all 10 units of the course, that is, each specific unit can be described in its terms. As a part of the start function previously described, students are sent to a location representing the start of work in one of the 10 units. This is shown as the bottom rectangle in Figure 1 which is, in terms of the over-all system, the same location as the rectangle at the top of Figure 2.

Upon beginning work in a unit, students are processed to a choice point which has eight exits. This is shown in Figure 2 as "d," and represents a student's behavior in that activity. He may work in a specific unit from 0 to 9, 10 to 19, 20 to 29, 30 to 39, 40 to 49, or 50 to 59 days, he may interrupt the course, or he may just remain in that activity until day 175 when the course is finished. Each of these eight possibilities is represented by an appropriately labeled exit from "d" on Figure 2.

Students who work in the unit, end their work and begin the unit test after a lapse of system time that corresponds with their exit (01 through 06) from "d" (see Figure 2). Students who interrupt the course (take exit 07 from "d") are processed to choice point "e" where they may be represented as either dropping the course or transferring. These who take exit 08 produce no further work. Although they remain enrolled in the course, they make no further progress.

Students who end work and start the unit test (see appropriately labeled box in Figure 2), are processed to choice point "f" which has three exits. Exit 01 leads to a location that represents students taking a single mastery test for the unit and the start of work in the next unit in the sequence. Exit 02 provides a path for students who take two tests, and exit 03 is for those who take three tests.*

B. PROCEDURES FOR SIMULATING THE ACTUAL COURSE

System Development Corporation Document TM-1493/314/00, dated 22 March 1965, describes the computer simulation capability for educational systems. In brief, this capability consists of a set of computer programs in the JOVIAL programming language that are used on a Philco 2000 computer. The programs are modular so that a specific educational organization such as the biology course at Theodore High School can be represented by assembling the modules into a particular configuration. This capability was used in the present study to simulate the progress of students through the activities in the biology course.

*Students in the actual biology course were required initially to meet a criterion on a mastery test before advancing to the next unit. If they did not meet the criterion in one, two or three tests, they automatically advanced. This procedure was changed later, giving the student an option as to whether he wanted to repeat a test (up to three tries) or go on to the next unit.

The system described in Section A, above, is designed to process students through a set sequence of activities, to control the amount of time a specific student spends in each activity, to control the day when a specific student enters the course, and to control the specific activity where he begins the sequence. This system may be used as a basis for simulating the present organization of the biology course at Theodore High School by establishing rules for the distribution of students at the choice points described in Section A, and illustrated in Figures 1 and 2.

Table I in Appendix A details how students are distributed at control points "a," "b," and "c."* At the control point which governs when students begin the course (Figure 1), 88% of the students take exit 01 and start the course immediately, and 12% take exit 02 and wait. The first row of figures under the heading in the table shows these data. The second row in the table shows the distribution at choice point "b" in the figure and the third row in the table is associated with "c" in the figure.

Tables II through XXI in Appendix A contain the distributions used to control the timing of students at control points "d," "e," and "f" as seen on Figure 2. An example associating the tables with Figure 2 will serve to clarify the relationship. Assume that a simulated student has been processed by the start function and begins work in Unit A of the course. This places him at choice point "d" on Figure 2, where a specific exit is selected for him based on the number of days he has been in the course. Table II in Appendix A contains the data governing which exit he will take from "d." Since he must necessarily have accumulated zero days in the course,** his chances in 100 for taking one of the eight particular exits are shown in the row associated with zero to nine cumulative days in the course. Thus the probability of his taking exit 02 is .32, that of taking exit 03 is .43, etc. If he takes exit 03, he is credited with from 20 to 29 days work in Unit A (see exit 03 from "d" on Figure 2). The specific value in this range is assigned randomly to each student. The simulated student has now progressed to control point "f" where three exits are available (see Figure 2). Table III in Appendix A determines his exit from this location, which depends in part on his simulated performance in working in Unit A. If the student was simulated as working rapidly in Unit A (he took exit 02 at choice point "d") according to Table III at choice point "f," he has a 40% chance of taking exit 01 and a 60% chance of taking exit 02. Exit 01 represents the student taking a single test which, on the average, consumes

*The data contained in this and subsequent tables in Appendix A were obtained from an analysis of actual student performance in the biology course at Theodore High School during the 1964-1965 school year.

**The start function consumes no time in the system, and since there is no activity that precedes work in Unit A (see Table I), this student must have accumulated zero time at choice "d."

two days beyond the end of work in Unit A; exit 02 represents two tests taking four days, and exit 03 represents three tests taking six days.

A student who took exit 03 at choice point "d" will probably take exit 02 at choice point "f" (according to Table III his chances for exit 01, 02, and 03 are 39%, 50%, and 11% respectively). Thus the simulated 20 to 29 days he spent in work in Unit A would be incremented by six more days of testing in the same unit. If the specific value he received for work in Unit A was 25 days, his total time in Unit A including the test, would be 31 days.

Thus, this simulated student upon entering work in Unit B would be distributed at choice point "d" on this new cycle through the system according to Table IV in Appendix A. With 31 accumulated days in the course, he would have been in the course a cumulative 30 to 39 days and so would have a 35% chance of taking exit 01, a 57% chance of taking 02, and an 8% chance of taking exit 03 at choice point "d." His behavior at choice point "f" would depend on which exit he takes from "d" as on his cycle through Unit A.

Students who interrupt the course either drop it or are transferred to another school or another version of biology. Table XXII in Appendix A shows the distribution of students at choice point "e" on Figure 2, and represents the proportion of students who interrupt and drop the course versus those who interrupt and transfer from the course.

One hundred simulated students were processed by the course simulator, and an output tape was produced. This tape contains a complete history of every choice made by the simulator. Each decision is associated with a specific student and a record of simulated time. Data reduction programs enabled three types of information to be abstracted from this tape and printed out for analysis. One printout contained the total number of students engaged in each of the 20 activities listed in Table I, for each of the 175 days of the course. Another summarizes the total number of days spent by all students in each activity, and the third summarizes the total number of students who completed each activity. These printouts, voluminous in size, provide the data presented in Section D, below.

C. PROCEDURES FOR SIMULATING EXPERIMENTAL VERSION OF BIOLOGY COURSE

The experimental version of the course attempts to represent the lifting of the requirement in the actual course that all students accomplish the same amount of progress by specified dates. To achieve this, the regular model was altered by changing the rules that apply at choice point "d" in Figure 2. Instead of student time in an activity being dependent on the number of cumulative days in the course as in the regular model, different rules were used in the experimental version. One rule governed the distribution of students at choice point "d" in Unit A and another general rule governed their distribution at the same point for subsequent units.

In order to obtain a progress rate that was least affected by the time constraints, student performance in Unit C in the actual course was selected as representing their ideal progress rates. The average amount of time spent in this unit was the same as the time allocated to it by the study guide (21 days: see procedures for analysis of study guide in Section D, below). A distribution of students' actual times in this unit was used as a rule for distributing simulated students at choice point "d" in Unit A (see Table XXIII, Appendix A). This rule started the simulated students in Unit A with a progress rate based on the actual rates of students in the course in Unit C. The rates were adjusted for the relative length of Unit A as compared to the other units.* Thus 16% of the students would spend from 3 to 12 days, 69% from 13 to 22 days, 8% from 23 to 32 days, 4% from 33 to 42 days, 2% from 43 to 52 days, and 1% from 53 to 62 days, working in Unit A. As in the regular model, the specific values within a range were randomly assigned by the computer to individual students. The same rules used in the regular model for allocating time in the unit tests were used in the experimental model (see Appendix A, Table II for Unit A and the even-numbered tables; Table IV through Table XX for the other nine units).

For assigning time in the work activities for Units B through J in the experimental model, a hypothetical rule was used. It was hypothesized that most students would perform on subsequent units pretty much as they performed in the past; however, a few students would improve and a few would do more poorly. Table XXIV in Appendix A shows the hypothetical rule that was used. Following this rule, an "average" student in Unit A, performing in the range of 13 to 22 days, has a 5% chance of going to a faster category, a 90% chance of remaining in the same category, and a 5% chance of going to a slower category when he works in Unit B.

One hundred students were simulated as working in this experimental course. All began in Unit A on the first day of the course and were processed by the model for 175 days. No students were added or dropped as occurred in the actual course and as was simulated in the actual version.

D. RESULTS

1. Summary of Enrollment

In the actual biology course, 140 students began the course on the first day. During the school year, 16 were added because they transferred into the school,

*Analysis of the study guide indicated that the 10 units were not presumed to require equal amounts of time for their completion. Unit C equaled 21 days as a baseline; the weights assigned to the other units were: A = -2, B = -5, C = 0, D = -4, E = -2, F = -3, G = -5, H = -4, I = -5, and J = -5.

finished ninth-grade science or repeated units unfinished in the previous year. A total of 156 students were enrolled in the course during the year. Twenty-eight students left the course during the year because they lost interest, were transferred to an easier version of biology, or moved from the school district. One hundred and twenty-eight students were enrolled in the course when it finished. These data are shown in Table II (in the column labeled "Actual") with corresponding data from the simulated actual course (in the column labeled "Sim Act") and the simulated experimental course (in the column labeled "Sim Exp").

Table II shows that the enrollment data from the simulated actual course is virtually identical to the actual course. The similarity shows that the model can reproduce this aspect of the behavior of the course with great fidelity. By contrast, the simulated experimental course only reproduces the same total enrollment as the actual course, because no students were added or subtracted from the experimental course during the simulated year.

2. Time Spent in Course Activities

Each student in the biology course consults the study guide upon beginning a unit of study and completes the tasks (reading, working experiments, writing reports, etc.) that are specified. The amount of time he spends in this work varies, depending on the student. He is guided in his expenditure of time, however, by requirements that he complete Unit B by the end of the first quarter, Unit E by the end of the semester, Unit H by the end of the third quarter, and Unit J by the end of the course.

When a student completes the work for a unit, he can schedule himself for a test to determine his mastery of the unit. He can spend a day or more preparing for the test if he wishes, or he can take the test on the day following the completion of the work. Moreover, if he is dissatisfied with his grade on a test, the student can take up to three different versions of the same test before he is forced to go on to the next unit. Therefore, the amount of time a student spends in taking tests for a unit varies depending on the student.

The average amount of time spent by all students in each of the 10 units that comprise the biology course provides an indication of the relative importance of each unit from an over-all system viewpoint. The results of an analysis of the study guide used in the actual course are shown in the column labeled "Study Guide" in Table III. In this analysis, the various specific tasks general to all units in the course, such as reading a chapter in the text, answering the questions at the end of the chapter, conducting a laboratory exercise, writing a report, doing library research, taking the mastery test, etc., were given estimated times for their accomplishment. The number of times that these general tasks are required in each specific unit was used to estimate the relative length (in time) for each unit, based on an assumption that the course would be completed in 175 days.

Table II. Summary of Enrollment in Biology Course

Category	No. of Students		
	Actual	Sim. Actual	Sim. Exp.
Started First Day	140	140	156
Added During Year	16	17	--
Total Enrollment	156	157	156
Dropped or Transferred	28	28	--
Enrollment at End	128	129	156

Table III. Average Number of Days Spent by All Students in Biology Course in Each Unit

Unit	Average Days in Unit			
	Study Guide	Actual	Sim. Actual	Sim. Exp.
A	19	25.5	24.4	20.4
B	16	17.5	19.2	18.2
C	21	21.0	21.0	23.1
D	17	18.0	16.6	18.7
E	19	12.4	13.0	19.7
F	18	21.5	23.4	19.1
G	16	10.6	10.4	15.7
H	17	14.7	15.8	17.1
I	16	26.3	25.9	15.7
J	16	07.2	09.9	09.9

The column labeled "Actual" in Table III shows the average number of days that the students actually spent in each of the 10 units during 1964-1965. The column labeled "Sim Act" shows the results obtained through simulating the actual course, and the column labeled "Sim Exp" shows the results obtained in the simulated experimental course. The similarity between the actual data and the simulated actual data indicates that the model is capable of representing the behavior of the course in producing data that summarizes the average amount of time students spend in accomplishing each unit of the course. By contrast, the simulated experimental course produces data similar in range and pattern to that derived by the study guide analysis. The outstanding exception is for Unit J, where students in the experimental course averaged about 10 days as compared with 16 indicated by the study guide. This discrepancy can be explained by the known fact that the students who completed Unit J in the experimental course were made up of the 38% of all students with the greatest ability to progress. It would be expected that they would need less average time as a subgroup to complete the course than the total group would require.

3. Student Progress at End of Course

An index of the over-all effectiveness of the biology course is the extent of progress made by the 128 students who were enrolled at the end of the course. Table IV, in the column labeled "Actual," shows these data for the students in the actual course. All students (100%) completed Unit A, but only 54% of the students completed Unit J. Table IV, in the column labeled "Sim Actual," shows similar data from the simulation of the actual course; the column labeled "Sim Exp" shows the over-all effectiveness of the experimental course. A comparison between the data from the actual course and the simulated actual data shows a high degree of similarity in Unit A and Units G through J. A comparison in Units B through F shows some substantial differences in percentages, probably due to a known limitation of the model that could be corrected in a second version.* This limitation is not regarded as important to the conclusions that are reached from these data.

A comparison of the data from the simulated experimental course with the actual course shows that the latter was considerably more effective in getting students to complete Unit J (and the course).

*The maximum number of days a simulated student could spend in work was limited to 47, even though it was known that some would exceed this limit. This limitation accelerated the progress of a few students thereby inflating the values in Units B through F. Because the averages in Table III are based on a much larger number of students, they are probably not noticeably affected by this limitation.

Table IV. Extent of Progress of All Students Enrolled at End of Biology Course (175th Day)

Unit Completed	Percent of Students		
	Actual	Sim. Actual	Sim. Exp.
A	100	100	100
B	95	100	100
C	92	100	100
D	89	98	98
E	83	90	95
F	79	88	92
G	77	78	84
H	75	77	73
I	72	73	59
J	54	54	38

4. Student Progress at End of the Simulated Experimental Course

Table IV in the column labeled "Sim Exp" shows the effectiveness of the experimental procedures for a 175-day course. These data were abstracted so that the data could be compared with the actual course. In addition, project personnel continued the simulation for the experimental course for a total of 270 days in order to represent continuation in the course of those simulated students who did not finish in the regular time. These data are shown in Table V. According to these data, some students finished the course in as little as 15 weeks, 38% of the students completed it in 35 weeks (the length of the actual course), and 82% finished in 270 days (54 weeks). From the 35th through the 42nd weeks, 32% more of the initial 100 students finished the course. Thus extending the experimental course a mere seven weeks increased its effectiveness 84%. This suggests that the content of the actual course as outlined in the study guide is not optimally matched to the 35 week length of the actual course.

Another interesting result calculated from the data in Table V enables a comparison to be made between the efficiency of the actual 35 week biology course and the 54 week experimental course. In terms of over-all performance, 54% of the actual students finished the biology course as compared with 82% who finished the longer experimental course. By permitting high-ability students to finish the experimental course early, 425 student-weeks of instruction are saved as contrasted to the actual course requiring all students to attend for 35 weeks. The "cost" to instruct the students continuing beyond the 35th week to the 54th week in the experimental course was 332 student-weeks of time. The "long" experimental course enabled 82% of the students to finish at a savings of 93 weeks of student effort as compared to 54% who finished the actual biology course.

E. DISCUSSION OF SIMULATION RESULTS

The rules that governed student progress in the two simulation studies are interesting because of the implications they have for designing individualized courses. One rule was found to apply when simulating the actual biology course and reflects the use of group minimal progress goals in the design of the actual biology course. A second rule applied to the simulated experimental course and reflects the use of individual progress goals in that course. These two rules are discussed below.

1. Group Minimal Progress Goals

The rule used to control the progress of students in simulating the actual biology course was specified in Section C above, and in Appendix A. It may be summarized as follows: the amount of time students spend in accomplishing the work in a unit of study is determined by the number of days spent in the course. By using this general rule, project personnel produced the data on course

Table V. Progress of Students in Simulated Experimental Course by Week

Week	Percent of Students Completing Course	Cumu-lative Percent
15	01	01
16	--	01
17	--	01
18	--	01
19	02	03
20	02	05
21	08	13
22	01	14
23	03	17
24	01	18
25	--	18
26	01	19
27	02	21
28	01	22
29	01	23
30	03	26
31	04	30
32	02	32
33	01	33
34	02	35
35	03	38

Week	Percent of Students Completing Course	Cumu-lative Percent
36	01	39
37	03	42
38	02	44
39	07	51
40	11	62
41	04	66
42	05	71
43	--	71
44	02	73
45	01	74
46	02	76
47	01	77
48	--	77
49	01	78
50	--	78
51	--	78
52	01	79
53	02	81
54	01	82

enrollment, average amount of time students spent in each unit and over-all student progress described in the results section. The great similarity between these simulated data and the data obtained from course records is a strong argument for believing that this rule was governing student behavior in the actual course.

The lack of similarity between the average amount of time students spent in each of the 10 units of study and the theoretical times derived from the content analysis of the study guide was noted in the results section. This dissimilarity implies that course content cannot explain the variation in times for the units and lends additional support to the belief that the relative importance of units (as measured by the average time students spend in them) was determined by group minimal progress goals. Additional evidence for this belief comes from an examination of the individual records of students in the actual course. This study showed many specific instances of students pacing themselves to meet group goals. For example, one student started the second semester by spending 50 days in Unit F and 24 days in Unit G. He then accomplished Units H, I, and J in a total of 11 days.

From a course designer's viewpoint, the use of progress goals common to all students in the course is attractive for two reasons. One reason is related to the administrative task of keeping track of the progress of each student. The use of a single progress standard (e.g., "All students will complete a specific amount of work by a specific date") makes it simple to evaluate each student in terms of his success in meeting that standard. The alternative of establishing individual progress goals and of assessing the success of each student relative to his unique goals is a formidable task from an administrative viewpoint.

A second reason for using common progress goals rests on a belief that they have a desirable effect on the amount of work students will accomplish. Data from the course show that, in general, students spend relatively less time on units that precede deadlines. In addition, the data also show that the students spend relatively more time on units that follow deadlines. Apparently students are influenced to meet deadlines but are not influenced to work consistently at their top capability for progress.

The content analysis of the biology course study guide indicates that the 10 units should each require roughly the same amount of effort on the part of students. In considering these theoretical figures, it is of interest to speculate as to how it is possible for students to vary so greatly from these expected times. One possibility is that the course is "too easy" for some of the students. These students tend to spend a great deal of time on the units that interest them in order to consume the time that is available to meet the minimal progress goals. Another possibility is that unit mastery standards are so loosely defined that mastery depends mainly on the grade that a student is willing to accept.

Both of these possibilities appear to be operating in the biology course. Simulating the experimental course which, in effect, took the performance of students on one unit in the actual course and extrapolated it through simulation to the others, shows that under these conditions about one-third of the students would complete the course before the time it ended in the actual situation. This suggests that some high-ability students were "marking time" in the actual course. Evidence that the standards in the course are subject to a wide range of interpretation came from an inspection of individual records. For example, one student was noted as requiring 53 days to complete the work in Unit B; later in the course he spent two days to complete Unit I. According to the content analysis of the study guide, Unit B and Unit I should each require 16 days work. This student's record strongly suggests that the mastery standards used for him in the two units were not comparable.

2. Individual Progress Goals

The rule used to govern the progress of students in the simulated experimental course was specified in Section C above, and in Appendix A. In brief, the progress rate for a student depends mainly on his progress rate in Unit C in the actual course. For each particular unit, this basic rate was given a 90% chance of remaining the same, a 5% chance of increasing, and a 5% chance of decreasing. The use of this specific rule attempted to simulate the progress of students based on their ability (as defined by performance in Unit C of the actual course) and the effects of individual progress goals (90% of the students would meet their goals, 5% would exceed them, and 5% would fall short of their goals). Some of the consequences that may result from operating an actual course with individual progress goals are implied by the results obtained through simulation. Simulation predicts that some students would finish the course as early as the 15th week and that if the course were extended to 54 weeks, 82% of the students who began the course would finish it. Moreover, simulation shows that the 54 week individual progress course is more efficient than the 35 week actual group progress course. This is because the individual progress course, by permitting higher-than-average ability students to finish the course before the end of the normal 35 week school year, saved a total of 93 weeks of student time even though it ran 19 weeks longer.

The actual implementation of a course like the experimental course simulated in the present study involves solutions to problems that pertain to the individual progress rule used in simulation. These problems are discussed in connection with two assumptions on which the individual progress rule is based:

- There is an assumption that each student will work at a relatively consistent rate of progress that is unique to him as an individual. The necessary procedures to determine this rate and to ensure its consistency are requirements for a course to operate as the experimental course did. Project personnel have suggested a set of procedures that use a computer to collect, store, and print out information useful for the task of maintaining a consistent rate of progress for students. This system is described in System Development Corporation document TM-1493/103/00, dated 28 February 1964. In brief, this system sets individual goals for each student based on his ability and performance; it records his day-to-day progress in a course; and it produces displays of information so that the student and instructor can act to maintain consistent progress for the student.

- There is a second assumption that must be met by a course that seeks to duplicate the experimental course; namely that the variation among students in their progress is due to the length of time that each individual requires to master the content of a unit. This means that mastery of each unit must have a rigorous and consistently applied definition. Some of the procedures necessary to define mastery include: (1) a content analysis of each unit of the course to specify the behavioral changes that students are expected to show as a result of their learning experience; and (2) the construction of assessment devices to determine whether or not these changes have occurred. The first step defines mastery of the unit in terms of observable behavior; the second provides a means for determining whether mastery has been attained. The concept of content mastery takes its definition solely and completely from the student behavior associated with it.

IV. IMPLICATIONS OF STUDY FOR PROJECT OBJECTIVES

The biology course at Theodore High School is sufficiently innovative in its individualized aspect to have many implications for the objectives of this project. This section summarizes what has been learned.

A. NEW ROLES FOR PERSONNEL

Compared to conventional classrooms, the organization of the biology course places increased demands on both students and other school personnel. For example, biology students have a major responsibility for their own education in the sense that they must make many decisions. Using the study guide to get information about the objectives for a unit and the activities that must be accomplished in order to complete the unit, the student must choose what he will do on a given day and then must schedule himself for many of these activities. For example, he may have a choice whether he will study his text, work in the laboratory, or go to the library to prepare a research paper. For laboratory work, he is required to plan ahead and schedule himself there prior to the day he wishes to work; the same is true for discussion groups and tests. This requirement to do advanced planning is necessary from the instructor's viewpoint, so that he may anticipate the requirements of students for space, materials, etc.

The student's responsibility for decision-making has an even larger dimension when the total school is concerned. Procedures exist so that a student can schedule himself on a day-to-day basis out of his regular biology period into another subject if he can justify his need to the instructor. The converse is also true--a student can spend additional time in biology at the expense of another subject. Moreover, although assigned to a regular period in biology, he can arrange to attend additional sessions of the course during the other periods it is given.

During the current year (1965-1966) Theodore High School has made a procedure available to about 50 of its students whereby they can arrange their daily schedule to suit their own needs without prior permission. If a student needs to work for two or three periods in one subject on a particular day, he makes the decision and may do so merely by not attending his other classes. He is expected to "pay back this time" to the courses he misses at some later, more appropriate time, so that each subject gets its fare share of his time. School officials report that this procedure is working well; they intend to extend the privilege to more students with the eventual goal of including all "responsible" students.

The use of group progress goals in connection with this procedure may make it difficult for students to balance the amount of time spent on each of their subjects. It is entirely possible that students may spend time in a class, as it appears they have done in the biology course, merely to satisfy the requirement of equal time for each course. The suggested solution is to use individual progress goals as was assumed for the simulated experimental course described above. With this procedure a student's time would apply to his own goals and not be constrained by the group.

The instructor's roles in the biology course differ from the roles in a conventional course with regard to two functions. One of these is related to his role as a course designer and the other pertains to his responsibility for monitoring and controlling the progress of his students. At Theodore High School, most instructors have designed their courses through the medium of a study guide and associated mastery tests. This is done so that the instruction can be individualized, that is, so that a student can learn the content of a course on his own. The specific skills and techniques for designing courses are not well defined, consequently courses and units within courses vary considerably. The variation in the average amount of time spent on the 10 units in the biology course is an example (Table I).

Project personnel believe that there is a technology currently available for designing courses. Briefly, this technique involves analyzing the substantive content of a course in terms of the observable behavioral changes in students that the course intends to accomplish, and devising assessment devices to determine whether or not the changes occur. The practical problem, however, is not the lack of technology, but the lack of personnel resources within the school to use the techniques. The present biology course design took about three man-months to produce. Design of this course to the more exacting specifications implied here could very well take two man-years of effort. The prospect of providing well-designed courses for secondary schools in general is very dim unless substantial support external to the schools is forthcoming.

The second function that shapes the roles of the biology instructors is the management role as contrasted with the designer's role discussed above. The procedures used in performance of the monitoring aspect of instructional management in the present biology course include the establishment of minimal progress requirements for the course; the checking of products produced by students (papers, research reports, quizzes, etc.); the recording of the activities completed; the administration of mastery tests; and the assignment of unit grades relative to the group progress goals. The controlling aspect of instructional management includes most of the instructors' interaction with students as a result of the data collected through monitoring. This may include explaining content material or requiring a student to do additional remedial work.

The tasks involved in instructional management in the experimental course are not different from what they are in the actual biology course, but the size of the job would be substantially increased because of the use of individual progress goals and the need to monitor student progress with respect to them. This task is best conceived in connection with an information processing system to provide personnel with useful information.

B. THE USE OF MEDIA

The media used for instruction in the biology course are primarily a study guide, a textbook, a laboratory manual, and assigned "outside" reading. The study guide directs students as to the specific reading and laboratory work that is to be accomplished in connection with each unit in the course. Since the instructors do not present content through group lecture or demonstration, the media used are of fundamental importance in the communication of substantive material to students.

Use of a study guide provides a course designer with optimum flexibility in choosing the media he believes will meet his course objectives. The guide enables the designer to direct students to multiple sources for instruction. The biology course, for example, is able to incorporate several standard texts into the course in this way, although one particular text serves the course as a primary source of instruction. In addition, the course makes use of filmstrips, biological specimens, and small group discussions which are programmed into the instructional sequence by the course designer. The selection of media should be completely dependent on the educational objectives of a course. In practice, however, the presence of media resources often predetermine course objectives, as when a school has purchased a language laboratory or a closed-circuit television system.

There is a generalized uneasiness expressed by some educators that individualized instruction will rob students of the opportunities for student/student and student/teacher interaction that are afforded by conventional classrooms. To the contrary, this problem can be handled quite easily in an individualized course. Once a course designer recognizes interaction as an objective of his course, he can program group discussion or student/teacher consultations into the instructional sequence. This procedure ensures that each student will be exposed to the same interaction experiences. By contrast, interaction in a typical conventional classroom is subject to the teacher's style and the personality characteristics of the students.

C. USES FOR DATA PROCESSING

The instructional management role of the instructor, as discussed in Section A above, causes a problem in the use of data processing. There is a strong likelihood that monitoring and controlling students with regard to their individual goals is a major deterrent to the development of individual progress courses. Solutions to this problem are available through application of modern data processing technology.

Project personnel held a conference with Theodore High School officials that resulted in the formulation of some general requirements for an instructional management information system. These requirements are:

- The system will store a model of a course which is, in effect, the designer's version. This model includes all of the discrete activities provided in the course definition with a time value assigned to each activity. In concept, this model is similar to the column in Table I labeled "Study Guide" where the amount of time for each unit in the biology course, as derived from the content analysis of the study guide, is presented. The time values in the model are estimates provided by the designer as to how long each activity should take the average student.
- The system will store individual goals for each student as these goals relate to this general model. Original estimates can be based on his aptitude, but these estimates should be updated periodically in terms of his actual performance.
- The system will collect and store daily progress data from each student and compare these data with his individual goals.
- The system will generate displays providing information for instructors so that they can make decisions about allocation of their time among their students.

It is quite feasible to implement a manual system for accomplishing the above requirements in the biology course. Such a system would probably require the full time services of one clerk to collect data and maintain charts for display purposes. However, a computer-based system would be much more powerful and useful for this task and could be used for all courses. In addition, a computer could be used for many other tasks in the school, such as attendance accounting, cost accounting, scheduling, etc.

D. SPACE

The biology course is conducted in an area where one instructor can easily supervise students, whether they are studying, working in the laboratory, taking tests, or engaged in a small group discussion. Testing, study, and discussion share a large classroom. The laboratory is in an adjacent room. The use of student assistants to aid in supervision enables the instructor to consult with students in his office which is connected to the laboratory.

The major problem with space is that study, test, and group discussion occur in the same area. Testing and studying are compatible when sufficiently isolated, because both are quiet activities. Group discussion is not compatible with the other two activities, however, and interference results. The instructors are aware of this problem and propose to place a screen between the two areas.

The general procedure at Theodore High School of having students do their individual study and testing in large classrooms supervised by a teacher who can give assistance in the subject should be noted. School officials are supportive of this procedure as compared to the use of individual study carrels. They believe that students in an open area are easier to supervise because they are visible.

The advantages of open study space as compared with study carrels in an individualized course are not well understood, in a general sense. Before a school spends a great deal of money to build carrels, this problem should be studied.

E. STUDENT CHARACTERISTICS

The study of the biology course at Theodore High School has not provided specific information pertaining to the characteristics of high school graduates. The procedure of allowing students to make daily decisions concerning their activities in the course and of requiring them to schedule these activities may have subtle long-range effects, however. Giving students this kind of experience at the secondary level may result in better preparation for postgraduate activities, educational or otherwise.

The data from the simulated experimental course provides implications for graduates from the school of the future, where every course is organized on an individual progress basis. The data indicate, for example, that some students will finish a typical course such as biology in as little as one semester, while others will take more than three. If these data are extrapolated to all courses in the school, they show that some students may finish a standard four-year high school education in two years while others take more than six. Another important difference between the graduates of this hypothetical school and those of today's schools is that all students in the school of the future will have learned the same skills to the same level of proficiency when they finish a particular course, whether they take one semester or three to complete the work. If such is the case, a starting place for post high school education will be more precisely defined than it presently is.

While not directly related to the topic of student characteristics, this may be the place to indicate two major problems whose solutions are assumed in individual progress courses. The first is that students who finish a course will be able immediately to begin work in another course. This implies that all courses in a school must be organized for individual progress before the system can work in one course. There is a possibility, however, that a single department may be organized for individual progress while others in the school are kept on a group progress basis. Many schools, for example, operate their typing courses in this way.

The second problem is much larger in scope, and pertains to crediting students on national standards. The presently used standard, the Carneigie unit, is based on the number of hours a student spends in a classroom. Obviously this idea is directly opposed to a concept of credit based on individual achievement. In the simulated experimental course, the students who finished in 15 and 54 weeks both attained the same degree of mastery in biology, yet neither took a "standard" biology course as measured by classroom hours.

One alternative to standards based on time in the classroom is to base them on individual scores attained in national achievement tests. Both the lay public and the educational community share a concern on the advisability of using national tests to describe an individual's achievement. It may be a number of years before resistance to the idea diminishes to the point that students can be credited in this way.

V. CONCLUSIONS ABOUT THE USE OF SYSTEM ANALYSIS AND COMPUTER SIMULATION TECHNIQUES IN THIS STUDY

The technique of analyzing and formulating the biology course as a system led directly to the theory that students were governed in their progress by course deadlines. This information seems patently obvious at this point, particularly when the course deadlines appearing in the study guide are considered. However the effects of the deadlines were not at all clear until the analysis formulated a rule that governed student progress through the course.

The analysis and formulation effort put the group progress theory into a form whereby the consequences of the theory could be simulated. The fact that data representing these consequences virtually matched similar data gleaned from the actual course strengthens the theory. The use of system analysis and simulation to represent a theory about the behavior of existing school organization is, in the view of project personnel, both feasible and fruitful.

A second use illustrated by this part of the project involves simulating a theoretical organization which appears desirable but has no counterpart in real life. This was the case when the results of individual progress procedures were simulated with reference to the biology course. The data generated by simulation represent predictions as to what will occur if the theoretical rule used for student progress is used. In this case, the data may be of practical value to course designers who are looking for a theoretical model to guide their efforts. If these are the kind of results desired, a designer can now devise procedures to implement the theory.

Whether analysis and simulation techniques are used to construct a theory about the behavior of an existing school organization or to simulate the consequences of a nonexisting organization, they force the analyst to be explicit in his theory. Verbal theories sometimes tend to be equivocal, as for example in the assertion that students who do well in one unit of study will do well in the next. In simulating this behavior, the analyst must specify precisely what "well" means in each unit, and must define exactly the degree of interaction. The penalty for nonspecificity is that his model will not function.

APPENDIX A

TABLES SHOWING DISTRIBUTION OF STUDENTS AT CHOICE POINTS IN MODEL OF BIOLOGY COURSE

Table I. Distribution of Students to Start Course, Select Unit and Wait

Control Point	Distribution of Population at Control Points to Exit (%)																
	01	02	03	04	05	06	07	08	09	10	16	18	19	20	21	22	24
Start Course (a)	88	12															
Select Unit (b)	94		01	02		01	01	01									
Wait (c)			06				06			06	06	19	06	13	06	19	13

Table II. Distribution of Students to End Work in Unit A

	Range in Days	Distribution							
		01	02	03	04	05	06	07	08
Cumulative Days in Course	0-09		32	43	10	03	01	11	
	10-19								
	20-29								
	30-39								
	40-49								
	50-59								
	60-69								
	70-79								
	80-89								
	90-99								
	100-109								
	110-119								
	120-129								
	130-139								
	140-149								
	150-159								
	160-169								
	170-179								

Table III. Distribution of Students to End Test in Unit A

	Distribution		
From	01	02	03
01			
02	40	60	
03	39	50	11
04		67	33
05			100
06			100

Table IV. Distribution of Students to End Work in Unit B

Cumulative Days in Course: Ranges in Days	Distribution 01	02	03	04	05	06	07	08
0-09								
10-19		90	10					
20-29	02	85	11				02	
30-39	35	57	08					
40-49	60	10		10			20	
50-59			33				67	
60-69								
70-79								
80-89								
90-99								
100-109								
110-119								
120-129								
130-139								
140-149								
150-159								
160-169								
170-179								

Table V. Distribution of Students to End Test in Unit B

From	Distribution 01	02	03
01	64		36
02	61	14	25
03	74	13	13
04	100		
05	100		
06	100		

Table VI. Distribution of Students to End Work in Unit C

	Range in Days	Distribution							
		01	02	03	04	05	06	07	08
Cumulative Days in Course	0-09								
	10-19								
	20-29								
	30-39		64	32		04			
	40-49	03	81	10	02	02			02
	50-59	22	32	22	12		12		
	60-69		50						50
	70-79		33					34	33
	80-89			100					
	90-99								
	100-109								
	110-119								
	120-129								
	130-139								
	140-149								
	150-159								
	160-169								
	170-179								

Table VII. Distribution of Students to End Test in Unit C

	Distribution		
From	01	02	03
01	50	25	25
02	48	20	32
03	53	18	29
04	33		67
05	50		50
06	100		

Table VIII. Distribution of Students to End Work in Unit D

	Range in Days	Distribution							
		01	02	03	04	05	06	07	08
Cumulative Days in Course	0-09								
	10-19								
	20-29								
	30-39								
	40-49								
	50-59		92	04					04
	60-69	05	79	09	02			03	02
	70-79	33	67						
	80-89	67	33						
	90-99		50						50
	100-109	50					50		
	110-119								
	120-129								
	130-139								
	140-149								
	150-159								
	160-169								
	170-179								

Table IX. Distribution of Students to End Test in Unit D

	Distribution		
From	01	02	03
01	45		55
02	61	10	29
03	45	10	45
04			100
05		100	
06	100		

Table X. Distribution of Students to End Work in Unit E

Cumulative Days in Course: Range in Days	Distribution 01	02	03	04	05	06	07	08
0-09								
10-19								
20-29								
30-39								
40-49								
50-59								
60-69	67	33						
70-79	42	58						
80-89	54	40	04				02	
90-99	50	12	13		12			13
100-109		75					25	
110-119								100
120-129								
130-139								
140-149								
150-159								
160-169								
170-179								

Table XI. Distribution of Students to End Test in Unit E

From	Distribution 01	02	03
01	44	36	20
02	40	42	18
03	100		
04	100		
05	100		
06			

Table XII. Distribution of Students to End Work in Unit F

Cumulative Days in Course: Range in Days	Distribution							
	01	02	03	04	05	06	07	08
0-09								
10-19								
20-29								
30-39								
40-49								
50-59								
60-69								
70-79			100					
80-89		67	29	04				
90-99		48	46	02			02	02
100-109	11	25	50	07				07
110-119		20	40		20			20
120-129		50						50
130-139		100						
140-149		100						
150-159								
160-169								
170-179								

Table XIII. Distribution of Students to End Test in Unit F

	Distribution		
From	01	02	03
01			100
02	58	16	26
03	64	15	21
04		67	33
05	100		
06	100		

Table XIV. Distribution of Students to End Work in Unit G

	Range in Days	Distribution							
		01	02	03	04	05	06	07	08
Cumulative Days in Course	0-09								
	10-19								
	20-29								
	30-39								
	40-49								
	50-59								
	60-69								
	70-79								
	80-89								
	90-99								
	100-109	75	20	05					
	110-119	70	30						
	120-129	83	08	09					
	130-139	43	28	14					15
	140-149				100				
	150-159								100
	160-169	100							
	170-179								100

Table XV. Distribution of Students to End Test in Unit G

From	Distribution		
	01	02	03
01	41	14	45
02	75	10	15
03	33		67
04	100		
05	100		
06	100		

Table XVI. Distribution of Students to End Work in Unit H

	Range in Days	Distribution							
		01	02	03	04	05	06	07	08
Cumulative Days in Course	0-09								
	10-19								
	20-29								
	30-39								
	40-49								
	50-59								
	60-69								
	70-79								
	80-89								
	90-99								
	100-109								
	110-119	19	75					06	
	120-129	53	43	04					
	130-139	57	14	29					
	140-149	40		60					
	150-159	33	67						
	160-169	80							20
	170-179								

Table XVII. Distribution of Students to End Test in Unit H

	Distribution		
From	01	02	03
01	30	12	58
02	26	36	38
03	33	34	33
04			
05			
06			

Table XVIII. Distribution of Students to End Work in Unit I

	Range in Days	Distribution 01	02	03	04	05	06	07	08
Cumulative Days in Course	0-09								
	10-19								
	20-29								
	30-39								
	40-49								
	50-59								
	60-69								
	70-79								
	80-89								
	90-99								
	100-109								
	110-119								
	120-129			100					
	130-139			67	33				
	140-149		19	75	06				
	150-159	20	80						
	160-169	79	21						
	170-179	100							

Table XIX. Distribution of Students to End Test in Unit I

From	Distribution 01	02	03
01	80	07	13
02	37	36	27
03	42	30	28
04	61	39	
05			
06			

Table XX. Distribution of Students to End Work in Unit J

Cumulative Days in Course: Range in Days	Distribution 01	02	03	04	05	06	07	08
0-09								
10-19								
20-29								
30-39								
40-49								
50-59								
60-69								
70-79								
80-89								
90-99								
100-109								
110-119								
120-129								
130-139								
140-149								
150-159	67	33						
160-169	91	09						
170-179	100							

Table XXI. Distribution of Students to End Test in Unit J

From	Distribution 01	02	03
01	66	30	04
02	75	25	
03			
04			
05			
06			

Table XXII. Distribution of Students Who Interrupt the Biology Course

	EXIT	
	01	02
Percentage	65	35

Table XXIII. Distribution Rule for Simulated Students at Choice Point "d" in Unit A: Experimental Model

Branch at A					
01	02	03	04	05	06
16%	69%	08%	04%	02%	01%

Table XXIV. Distribution Rule for Simulated Students at Choice Point "d" in Units B Through J: Experimental Model

If Branch on Last Unit Was	Branch on Present Unit: 01	02	03	04	05	06
01	95%	05%				
02	05%	90%	05%			
03		05%	90%	05%		
04			05%	90%	05%	
05				05%	90%	05%
06					05%	95%