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ABSTRACT

A study sought to identify the engaging characteristics of computer-assisted instruction (CAI) and to determine why engagement in CAI programs remains high, whether engagement can be increased experimentally by changing the level of difficulty of the lessons, whether engagement is highest when lessons match the student's level of competence, and whether engagement and disengagement scores are related. Subjects were 40 fourth graders who had been working with a drill-and-practice mathematics CAI program since first grade. Five lessons of varying difficulty were presented to the students. Their behavior while working on the lessons was videotaped and classified. The engaging characteristics of CAI that were identified were: its curiosity provoking aspects, its immediate feedback, its provision of a form of competence testing for the student, and its presentation of lessons matched to the student's level of competence. Engagement was highest on easy lessons and did not begin to drop until the subjects missed more than 20% of the problems per lesson. The maximum point of engagement could not be dterermined. Measures of engagement and disengagement were found to vary somewhat independently. (JY)

STANFORD CENTER
FOR RESEARCH AND DEVELOPMENT
IN TEACHING

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THE EFFECT UPON STUDENTS' MOTIVATION OF FIT BETWEEN STUDENT ABILITY AND THE LEVEL OF DIFFICULTY OF CAI PROGRAMS

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Introductory Statement

The Center is concerned with the shortcomings of teaching in American schools: the ineffectiveness of many American teachers in promoting achievement of higher cognitive objectives, in engaging their students in the tasks of school learning, and, especially, in serving the needs of students from low-income areas. Of equal concern is the inadequacy of American schools as environments fostering the teachers' own motivations, skills, and professionalism.

The Center employs the resources of the behavioral sciences--theoretical and methodological--in seeking and applying knowledge basic to the achievement of its objectives. Analysis of the Center's problem area has resulted in three programs: Heuristic Teaching, Teaching Students from Low-Income Areas, and the Environment for Teaching. Drawing primarily upon psychology and sociology, and also upon economics, political science, and anthropology, the Center has formulated integrated programs of research, development, demonstration, and dissemination in these three areas. In the Heuristic Teaching program, the strategy is to develop a model teacher training system integrating components that dependably enhance teaching skill. In the program on Environment for Teaching, the strategy is to develop patterns of school organization and teacher evaluation that will help teachers function more professionally, at higher levels of morale and commitment. In the program on Teaching Students from Low-Income Areas, the strategy is to develop materials and procedures for engaging and motivating such students and their teachers.

This report describes some of the relevance of educational technology for instruction in low-income areas.

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Abstract

The purpose of this study was to identify the engaging characteristics of computer-assisted instruction, and to determine why engagement in CAI programs remains high, whether engagement can be increased experimentally by changing the level of difficulty of the lessons, whether engagement is highest when lessons match the student's level of competence, and whether engagement and disengagement scores are related. Subjects were 40 fourth graders who had been working with a drill-and-practice routine since first grade. Five lessons were presented to each student, in a predetermined order, by a teletype similar to the one they had used in the elementary school. The students' behavior, while working on the lessons, was classified in five categories and was recorded on videotape every five seconds. Scores for engagement and disengagement were recorded per minute after each observation and graphed after each lesson. Because of faulty videotape equipment, it was only possible to include nine subjects in the final study; results were therefore presented graphically rather than statistically.

The engaging characteristics of CAI that were identified are (a) its curiosity-provoking aspects, (b) its immediate feedback, (c) its provision of a form of competence testing for the student, and (d) its presentation of lessons matched to the student's level of competence. Engagement was high on easy lessons and did not begin to drop until the subjects missed more than 20 percent of the problems per lesson. The maximum point of engagement could not be determined. Measures of engagement and disengagement were found to vary somewhat independently. The experimenters still predict that there are levels of both ease and difficulty at which engagement should decrease.

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THE EFFECT UPON STUDENTS' MOTIVATION OF FIT BETWEEN STUDENT ABILITY AND THE LEVEL OF DIFFICULTY OF CAI PROGRAMS

Ruth Miller and Robert D. Hess

The purpose of this study was to identify some of the engaging characteristics of computer-assisted instruction (CAI), that is, the properties that arouse students' interest and maintain it over extended periods of time. Once having identified some of these engaging characteristics, we wished to determine (a) why engagement remains high on CAI programs, (b) whether it might be increased experimentally by changing the level of difficulty of the lessons, (c) whether engagement is highest when lessons match the student's level of competence, and (d) whether engagement and disengagement scores are related.

It has been shown that students in a computer-assisted arithmetic program develop positive attitudes toward the computer (Hess, Tenezakis, Smith, Brod, Spellman, Ingle, & Oppman, 1970). Students approach the computer room eagerly, and they appear to like working with the computer even when the instructional program continues throughout their elementary school years, as it does in the school from which the subjects in this experiment were drawn.

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The Math Drill-and-Practice Routine

From the many types of programs grouped under the rubric of "computer-assisted instruction," we chose a math drill-and-practice routine devised by Patrick Suppes of the Stanford Institute for Mathematical Studies in the Social Sciences. This routine consists of lessons assembled from various texts and used as the teacher sees fit for extra drill and practice on skills in arithmetic. It is analogous to homework assignments and is constantly being revised. (For a general description of Suppes's work in this area, see Suppes, Jerman, & Brian, 1968.) The introduction and explanation of concepts is the responsibility of the classroom teacher.

The Concept Block Approach

From September 1966 to April 1970, the curriculum material in the math drill-and-practice routine for grades 1 through 6 was arranged sequentially in blocks to coincide approximately with the development of mathematical concepts introduced in several series of texts. (After April 1970 the concept block presentation was replaced by a "strands" approach.) There were 20 to 27 concept blocks for each grade level. The materials presented to the student for each of the seven-day blocks were as follows:

Day 1	Pretest
Days 2-5	Drill and review drill
Day 6	Drill and review posttest
Day 7	Posttest

Each problem is printed for the student by the teletype, and the student types his answer in the appropriate place in each problem. If his answer is correct, the teletype prints the next problem. If his answer is incorrect, the teletype prints NO, TRY AGAIN, and presents the problem again. If there is a second error on the same problem, the teletype prints NO, THE ANSWER IS ..., and the problem is presented a third time. This step is included so that the student may have the experience of answering the problem correctly. If the student answers incorrectly for the third time, he is given the correct answer once more, and the teletype prints out the next problem. The student is allowed from 10 to 40 seconds to respond, depending on the type of problem presented. If he takes more time than is allotted to type in his answer, the procedure just described is followed, except that the teletype prints TIME IS UP, TRY AGAIN in place of NO, TRY AGAIN.

Under the concept block schema the level of difficulty of the first day of drill was determined by the student's performance on the pretest. The level of difficulty of each successive drill in the same concept block was determined by the student's performance on the preceding day's drill. Thus, if the student's performance on a drill was 80 percent or better, his next drill was one level of difficulty higher. A score of less than 60 percent brought him down a level for the next drill. If he scored between 60 percent and 80 percent he remained at the same level of difficulty for the next drill. (Description taken from Suppes & Morningstar, 1969.)

Distinguishing Characteristics of CAI

Certain characteristics of the drill-and-practice lessons distinguish them from other forms of instruction. First, CAI has special attention-getting attributes which stem simply from the fact that the material is presented by a machine. The carriage of the teletype is constantly in motion as the problems are typed and the answers verified, and the machine buzzes like an electric typewriter. Thus, both sound and motion are important attention-getting attributes of CAI programs.

The impersonal attributes of the machine's presentation further distinguish drill-and-practice programs from other forms of instruction. A machine is an unbiased grader of each performance. That is, the student's performance on anything other than his lesson is irrelevant to his grade on the lesson. This may relieve some of the anxiety inherent in an encounter between student and teacher during which the affective state of both persons may be changed. The student receives a score that reflects his performance, not the quality of the interaction.

Other distinguishing features of CAI are individualization, small task-size, and feedback. "Individualization" means that the student progresses through the material at his own rate and at his own level of competence. "Task-size" refers to the amount of time spent at the computer; this time, 10 minutes a day, contrasts with a 45-minute time period required to present a similar lesson in the classroom. The pacing of the CAI presentation is rapid, and the flow of information is concentrated in a short period of time. "Feedback" is the information that the teletype gives the student about the correctness or incorrectness of his answer immediately after each problem. At the end of each lesson, the student learns from the computer what percent of the total problems he worked correctly.

The students in schools that employ the CAI arithmetic routines work on these programs daily throughout elementary school. Our observations of the students at work in the computer room confirmed that they do not lose interest in the lessons over the years. What keeps the students engaged in CAI over long periods of time? Why is there so little habituation to--and resulting disinterest in--this method of instruction?

The Process of Engagement

The process of engagement begins with an orientation to a stimulus source that arouses the person's (P's) interest. The stimulus source has a set of engaging characteristics. A sustained interest in the stimulus source or in an activity dealing with the stimulus source may be indicated by a time line (see Fig. 1) that signifies the behavioral indicators of P's engagement at any moment. The initial point of P's engagement is I_e. The behaviors are supposedly motivated by the factors indicated above the time line. That is, some factors may play the most important role in initiating engagement, and others may be more important in sustaining engagement or in recalling interest at a later date or time. If engagement is not sustained, P's involvement ends, at point T_e.

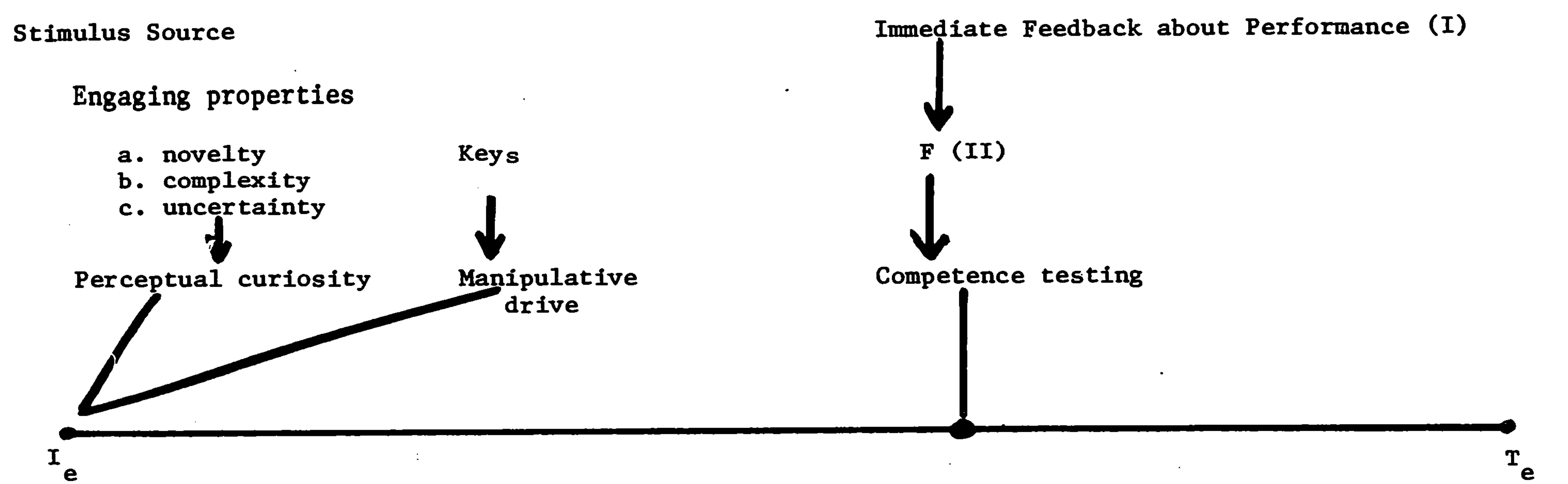

Fig. 1. Stages of engagement in CAI drill and practice.

Initial Engaging Features of CAI

One important property of a set of engaging characteristics, we feel, is their ability to provoke curiosity. For a student working on a computer lesson for the first time, the engagement process would begin at a point when his curiosity was aroused and his attention was focused on the machine. According to Berlyne (1960), curiosity is a state of heightened drive or arousal that increases with the degree of novelty (change, surprise); the complexity (amount of variety or diversity in a stimulus pattern); the uncertainty (of categorization) of the stimulus; and the degree of conflict among the possible responses to the stimulus. He uses the term "perceptual curiosity" to refer to "states of high arousal that can be relieved by specific exploration and in which, therefore, specific exploratory responses are likely to occur [p. 195]." In themselves these exploratory responses reduce novelty and complexity as habituation to the stimulus occurs. Uncertainty and conflict may be reduced by descriptive or explanatory naming and/or through the learning of a new response.

We hypothesized that at the initial point in the engagement process it is the use of a mechanical device to present the lessons that arouses the students' curiosity. The teletype is a novel and surprising instrument. It looks somewhat like a typewriter, but it can type without the student hitting the keys. It appears complex in design, and the students must learn the correct way of responding in order to work their lessons. It is imperative that the teletype have some familiar characteristics because, Berlyne asserts, if a stimulus is completely novel, it will arouse fear and withdrawal rather than curiosity and a desire to experiment.

The curiosity and resulting exploratory behavior induced by the first days with the teletype may be supplemented by a "manipulative drive" such as that proposed by Harlow and his associates (Harlow, 1953; Harlow, Harlow, & Meyer, 1950). This drive was postulated as a result of their experiments with rhesus monkeys, in which the monkeys repeatedly solved a mechanical problem even when it led to no further consequences or rewards. It does not seem likely that novelty is the characteristic of the stimulus that evokes this repeated behavior. Rather, the results could be interpreted as showing a desire to play or "tinker" or, more generally, as Zimbardo and Miller (1958) express it, "to effect a stimulus change in the environment."

Thus we postulated that CAI is initially successful in capturing students' attention because of its curiosity-provoking aspects and because the program is presented by a teletype whose keys must be punched or manipulated. The teletype is novel; it comprises surprising elements; it is complex; and the students must learn about and categorize all these elements to be able to respond to it. This covers the initial engaging features of CAI. Our experiment, however, dealt with the features of CAI that continually engage the students after they have become accustomed to the use of the machine.

Features of CAI that Maintain Engagement

We use the term "feedback" in two senses. In the first (FI), feedback refers to the specific response the computer gives the student immediately after each answer. We regard this immediate feedback as one of the most important engaging characteristics of computer-assisted instruction. In the second sense (FII), feedback refers to an inner response during which the student evaluates his performance, or rates his competence, on the basis of FI, that is, the computer's evaluation of his work on the problems.

White (1959) introduced the concept of "effectance motivation," which, he said,"aims for the feeling of efficacy, not for the vitally important learnings which come as its consequence." The behavior influenced by effectance motivation involves "focal attention to some object--the fixing of some aspect of the stimulus field so that it becomes relatively constant--and it also involves the focalizing of action upon this object in order to effect some change in the object (p. 322)." White said:

> The urge toward competence is inferred specifically from behavior that shows a lasting focalization and that has the characteristic of exploration and experimentation, a kind of variation within the focus. When this particular sort of

> activity is aroused in the nervous system, effectance motivation is being aroused, for it is characteristic of this particular sort of activity that it is selective, directed, and persistent, and that instrumental acts will be learned for the sole reward of engaging in it [p. 323].

We hypothesized that as the student works on the drill-and-practice programs he is engaged in a form of "competence testing." In computer-assisted instruction the student learns how to respond to a novel and complex stimulus, and in the process produces changes in the stimulus. New responsibilities for response are offered in the form of a continual flow of math problems to be solved. As the student receives feedback about his performance (FI), his successfulness in the transaction, or his competence, is confirmed (FII).

We also hypothesized that the importance of FI to the student depends on the level of difficulty of the lesson he receives. If the level of difficulty of the lesson is slightly above the student's proficiency in arithmetic, then he can use the information provided by FI to test his competence in solving the problems. A correct answer is gratifying because he has met the challenge to his competence. If the lesson is too easy, his competence at this level has already been proven. If the lesson is too difficult, eventually he will reject it.

We predicted that engagement in the programs would be sustained only if the level of difficulty of the lessons was suited to the student's highest level of accomplishment. We call this his "level of competence." Because the students do receive lessons that give them practice in solving problems matched to their learning pace in the classroom, we think this programming is another important engaging feature of CAI.

If our hypotheses are correct, one should be able to demonstrate losses of engagement experimentally by varying the levels of difficulty of the CAI lessons presented to a student. A student's engagement in an arithmetic lesson that is either too easy or too difficult for him in terms of what he has learned in the classroom should be less than his engagement in a lesson that is matched to his level of competence.

We also wished to test another hypothesis: that one can experimentally demonstrate increased engagement by changing the level of difficulty of a lesson when the student finds the problems too hard to solve. To do so we made a series of "clues" available to the students. When they were confronted with a problem that they had not learned how to solve, they could ask for one of the clues to its solution.

As noted earlier, some of the most important properties of CAI for attracting attention are novelty, incongruity, surprise, and change. Another of these properties, conceptual conflict, we felt could not be directly examined in the design of the math drill-and-practice routines. Conceptual conflict, or a discrepancy between what one knows and what one wants to know, is effective in mobilizing attention (engaging a student) while one is seeking information to resolve the discrepancy (gap in knowledge) or solve the problem (Berlyne 1960). Berlyn uses the concept "epistemic curiosity" to describe the motivational state aroused by conceptual conflict "Epistemic behavior" is activity that is directed toward reducing epistemic curiosity through acquiring the knowledge needed to fill the gap. The discrepancy between what one knows and what one wants to know must not be too large, however, or the conflict will produce frustration and disinterest.

In reference to the hypothesis just mentioned, if a student encounters a problem in a CAI arithmetic lesson that is too difficult for him to solve, yet may be barely beyond his ability, both conceptual conflict and epistemic curiosity will be aroused. If he can ask for a clue to the solution of the problem in order to fill the gap in his knowledge, his epistemic behavior will be rewarded, and his engagement in the set of problems that were once too difficult should increase.

Method

Subjects in the experiment were students from the fourth grade at Brentwood Elementary School in East Palo Alto, California. All had been in the CAI math drill-and-practice routine since first grade. Only nine out of an estimated forty subjects were included in the final study because of faulty videotape equipment used in filming the experiment.

The setting for the experiment was two rooms at Stanford Research Institute, Menlo Park, California. The students received the experimental lessons from a PDP-10 teletype similar to the one they used every day at Brentwood Elementary School. Differences between the two were explained to them before the experiment: (1) they had to press the "return" key after every answer; (2) the carriage returned to a space below the problem for the answer, rather than to a blank within the problem itself; and (3) the computer did not "sign off" at the end of each lesson. The students had no difficulty with the first two differences, but the third caused a great deal of difficulty because several students did not call the experimenter after they completed the lesson, but instead worked it a second time (and in some cases a third) before the experimenter could give them a new lesson.

The students were brought to SRI in private cars. After they met the experimenter at the entrance of the building, they were given a short tour of the building by the experimenter or by Dean Brown, a researcher at SRI. This informal tour gave them an opportunity to become acquainted with their surroundings. Then they were taken to the floor that houses the computer hardware for SRI. The students were allowed to ask questions about the hardware, to work with any of the programs in Mr. Brown's repertoire, and to type on the card-punch machine. As the students were experimenting with these machines, they were invited, two at a time, to go with the experimenter to try out some new arithmetic programs.

Each student was taken to an office and seated before a PDP-10 teletype. The videotaping equipment in one office was on a metal cart about 4-1/2 feet high. The camera was on a tripod about 5 feet high. The photographer sat behind the cart out of the view of the student. The experimenter explained that a movie was going to be made of the students while they were working, but encouraged them to forget about the camera and to pay attention to the lessons because there would be a time limit for their answers just as at school. The students were not allowed to look through the camera because the cameras were pre-focused on the teletypes and only a short time was allotted for filming each child. The camera in the other office was set up outside the doorway to the office. The photographer sat in the doorway out of the sight of the student.

The students generalized from one teletype to the next when the lessons were similar to those they used at their school. They quickly became absorbed in their work and seemed to forget the presence of the camera and the cameraman, with one notable exception.

The experimenter predetermined the order in which the students received the five lessons. The orders were not random, because lesson H_2 always followed (though not immediately) the presentation of lesson H_1. Because of the small number of subjects in the experiment, the experimenter did not attempt a random ordering of the presentation of the lessons. Care was taken, however, to demonstrate the presence or absence of position effects in the results by attempting to give some of the subjects an easy lesson after they had completed a difficult one. Other children received the lessons in the order easy-to-hard. (See Table 1.)

Description of Experimental Lessons

The experimenter designed five arithmetic lessons to be presented to the subjects by a teletype similar to the one they had been using daily at school. The code names of the experimental lessons were E_1, E_2, E_3, H_1, and H_2. The contents of the first four of the lessons were directly modeled after the Suppes routine.

The first set of problems, E_1, were addition problems with the format:

1. a + b = _____,
$$\begin{array}{r} a \\ +\ b \\ \hline \\ \hline \end{array}$$
or;

2. a + bc = _____, bc + a = ______ or;

3. a + ___ = c, _____ + b = c.

It was not necessary to carry any sums across columns. This lesson would be ordered at grade 2.0 difficulty in the Suppes routine. There was a 10-second time limit for answering the problems.

TABLE 1

Summary of Student Performance and Level of Engagement

	Lessons				
	E_1	E_2	E_3	H_1	H_2
Mark *					
Percent correct	100%	100%[a]	100%	50%	80%
No. of problems worked	10	20	20	10	10
Time in minutes	1.0	2.5	3.0	4.0	2.5
Engagement points	29	56	98	110	64
Disengagement points	0	16	6	24	12
Order of presentation	5th	4th	1st	2nd	3rd
George					
Percent correct	100%[a]	20%	20%	20%	20%
No. of problems worked	10	10	10	10	10
Time in minutes	1.5	4.0	4.5	4.5	5.5
Engagement points	30	101	114	94	114
Disengagement points	5	21	26	30	43
Order of presentation	1st	3rd	4th	2nd	5th
Sally					
Percent correct	100%	100%	80%[a]	100%	90%
No. of problems worked	20	20	10	10	10
Time in minutes	1.0	1.5	1.5	1.5	2.5
Engagement points	27	44	37	41	70
Disengagement points	0	1	1	5	7
Order of presentation	1st	2nd	3rd	4th	5th
David					
Percent correct	95%	100%[a]	90%	70%	90%
No. of problems worked		20 (30)	10	10	10
Time in minutes	3.5	5.5	2.5	6.0	4.0
Engagement	98	147	61	135	97
Disengagement	9	22	10	40	22
Order of presentation	3rd	1st	5th	2nd	4th

TABLE 1 continued

	Lessons				
	E_1	E_2	E_3	H_1	H_2
Mabel					
Percent correct	95%	100%[a]	95%	0%	20%
No. of problems worked	20	20	20	8	10
Time in minutes	2.5	4.0	2.0	5.0	6.0
Engegement	69	105	57	126	124
Disengagement	8	10	4	37	44
Order of presentation	3rd	5th	3rd	1st	2nd
Joseph					
Percent correct	100%	95%[a]	70%	60%	80%
No. of problems worked	20	20	10	10	20
Time in minutes	3.5	4.0	4.0	2.5	2.5
Engagement	87	92	75	66	156
Disengagement	12	4	17	1	10
Order of presentation	1st	2nd	3rd	4th	5th
Amy					
Percent correct	90%	40%	30%[a]	100%	
No. of problems worked	20	10	10	20	
Time in minutes	2.5	2.5	3.0	3.0	1.5
Engagement	61	55	78	72	33
Disengagement	5	21	13	16	17
Order of presentation	2nd	3rd	1st	4th	5th
Alice					
Percent correct	100%	90%[a]	60%	10%	100%
No. of problems worked	10	10	10	10	10
Time in minutes	2.0	1.0	4.5	3.0	2.5
Engagement	63	31	131	63	78
Disengagement	3	1	35	39	11
Order of presentation	4th	5th	3rd	1st	2nd

TABLE 1 continued

	Lessons				
	E_1	E_2	E_3	H_1	H_2
Jan					
Percent correct	90%	80%[a]	30%	100%	100%
No. of problems worked	20	10	10	10	10
Time in minutes	5.0	3.0	2.5	3.0	3.0
Engagement	186	110	67	103	62
Disengagement	15	38	33	5	2
Order of presentation	3rd	2nd	1st	4th	5th

* Names have been changed to pseudonyms.

[a] Lesson at subject's level of competence.

The second set of problems, E_2, were multiplication and division problems with the format:

1. a X b = _____, a X _____ = c, _____ X b = c or;
2. a / b = _____, a / _____ = c, _____ / b = c.

All the products ranged from 0 to 24. This lesson would be ordered at grade 2.8 difficulty in the Suppes routine. There was a 10-second time limit for answering the problems.

The third set of problems, E_3, were multiplication and division problems with the same format as the problems in E_2:

1. a X b = _____, a X _____ = c, _____ X b = c or;
2. a / b = _____, a / _____ = c, _____ / b = c.

All the products ranged from 27 to 81. This lesson would be ordered at grade 3.3 difficulty in the Suppes routine. There was a 10-second time limit for answering the problems.

The fourth lesson, H_1, was a set of problems demonstrating the use of the commutative, associative, and distributive laws of arithmetic. Here are some examples of the use of the laws:

1. Commutative Law

   a X b = b X a   or   a + b = b + c

2. Associative Law

   (a X b) X c = a X (b X c)   or   (a + b) + c = a + (b + c)

3. Distributive Law

   a X (b + c) = (a X b) + (a X c)

The problems in the lesson involved filling in a missing variable on the left side of "=". This lesson would be ordered at Grade 3.8 difficulty in the Suppes routine. There was a 10-second time limit for answering the problems.

The fifth lesson, H_2, consisted of the same problems as H_1. In H_2, however, if a subject did not know how to solve a problem, he could type "H" in place of an answer. Then he received an explanation of the law and two examples of the way the law is used. After receiving this "help," the student was given another chance to work the problem. This program is not included in the Suppes routine. There was no time limit for answering the problems in H_2.

There were 20 problems in each lesson. After the first ten problems, the computer typed: "Are you ready to continue these problems? Please respond by typing a YES or NO." Making it possible for a subject to terminate a lesson after the first ten problems gave him a measure of control over the amount of time spent on each lesson. The experimenter added this option after she found that the subjects were spending more time on the experimental lessons than they spent answering their daily CAI lessons. The subject's YES or NO response to this question was not used as a variable to rate his level of engagement in the program because the experiment did not include a method of determining the exact reason why he made one response rather than the other.

According to the Suppes curriculum guide, the first four experimental lessons were ranked in order of increasing difficulty: E_1, E_2, E_3, H_1. The experimenter determined which lesson was at each subject's level of accomplishment by matching the grade level at which he was working in the

CAI program to the grade level of one of the experimental lessons. At the time the experiment was designed, none of the subjects had been introduced to the commutative, associative, or distributive laws (CAD laws). For this reason, only lessons E_1, E_2, or E_3 could be designated as a program at a subject's level of competence.

Level of Competence	Grade Level	Number of Subjects at this Level
E_1	2.0 - 2.7	1
E_2	2.8 - 3.0	6
E_3	3.1 - 3.7	2

Because none of the subjects had been introduced to the CAD laws, it was expected that H_1 would be the most dfficult program for all of them. Therefore, all but one of the subjects were given at least one program that was less difficult than the program at their level of competence, and all of the subjects were given at least one program that was more difficult than the program at their level of competence. Between the time the experiment was designed and the time it was executed, however, an important methodological difficulty arose. Many of the students in the drill-and-practice routine were introduced to the use of the CAD laws when a "strands" rather than a "concept block" form of programming was used to move the students through the lesson plans. During the course of the experiment the students were receiving lessons at random in order to place them at their proper level of competence in the strands program; the difficulty of the lessons that the students were receiving was not recorded, nor was the students' level of competence recorded by grade level (2.8, for example). Thus it was impossible for the experimenter to rank lesson H_1 as the most difficult of the experimental lessons for every student. The final ranking of the lessons E_1, E_2, and E_3 in order of increasing difficulty had to be based on the school records prior to the experiment; and the rank of the difficulty of H_1 had to be based on the subjects' performance score on this lesson during the experiment. Therefore, it was possible to rank the lessons differently for a student if he had been introduced to the CAD laws before the experiment. For example, if a student scored 100 percent on lesson H_1 during the experiment, it would be assumed that she had been introduced to the use of the CAD laws before the experiment. In such a case, the order of difficulty would be adjusted accordingly. For one student the lessons were ordered by increasing difficulty E_1, H_1, E_2, E_3; whereas for the rest of the subjects the order by increasing difficulty remained E_1, E_2, E_3, H_1.

We hypothesized (a) that the rating of the subject's engagement in the lessons E_1, E_2, E_3, and H_1 would be highest for the lesson that matched his level of competence; and (b) that there would be observable losses of engagement (compared with this rating) when the lessons were less difficult or more difficult than his level of competence. We also hypothesized (3) that if the subjects used the clues in H_2, their engagement in this lesson would be greater than their engagement in H_1.

Development of the Observation Instrument

In order to rate the extent to which the subjects were engaged in the experimental lessons, the experimenter developed an observation instrument to be used while viewing the videotapes of the experiment.

Behaviors observed on the tapes were divided into five modes of expression: postural, visual, mobile, gestural, and facial. Behaviors that indicated engagement and behaviors that indicated disengagement were defined. Behaviors that were evidence of engagement indicated the student's attentiveness--his curiosity, interest, involvement, and persistence in the activity. Behaviors that evidenced disengagement were inattentiveness to the activity, disinterest, and lack of curiosity about the activity.

Engagement in the postural mode was expressed by alertness. In the visual mode engagement was reflected in the student's focus of attention; if he was engaged, his eyes were on the stimulus source. The mobile behaviors expressing engagement had to do with the student's active proximity seeking, that is, his movements bringing him into closer contact with the stimulus source. Gestural and facial expressions of engagement are largely idiosyncratic. In the measurement we included gestural and facial expressions that are manifestations of problem solving. There may also be an effective mode of expression, which includes behaviors indicating a mood of satisfaction.

Disengagement in the postural mode is expressed by fatigue or boredom. Again it involves focus of attention in the visual mode; if the student is disengaged, his eyes will have wandered away from the stimulus source. Mobile behaviors expressing disengagement have to do with the child's active withdrawal from the stimulus source. Gestural and facial expressions of disengagement--which like such expressions of engagement are idiosyncratic--may include restless behaviors, protest, and dejection. There may also be an affective mode of expression of disengagement which includes behaviors indicating a mood of dissatisfaction.

Categories of Engagement and Disengagement

A description of the engaged and disengaged behaviors that were used in rating the students' behavior is as follows:

1. Postural Behavior

   A. "(++)" Child leaning forward to examine paper.

   B. "(+)" Child's posture is "normal," i.e., he is sitting with weight supported by lower half of body. Spine may be straight or relaxed.

   C. "(_)" Child is leaning on arm of chair. Weight is not evenly distributed. A "slumping" posture.

   D. "(--)" Child is leaning back in his chair (hips forward) in a position he would have to alter with a whole body movement, rather than a partial one, if he returned to (+) position.

      Or, the child is leaning on the teletype, usually with his head resting on the machine.

2. Visual Behavior

   A. "Eyes on paper"

      Child is looking at the paper or the keyboard.

   B. "Vacillation"

      Child's gaze shifts away from paper and keyboard and returns to them (or vice-versa) within the five-second observation period, i.e., child is both "looking away" and "looking at paper" in that five-second period.

C. "Looking away"

Child is looking at anything other than the paper or keyboard. This may include looking at some other part of the machine (sides), out the window, etc.

3. Mobile Behavior

A. "Pulls body or chair closer to teletype."

Child leans forward to inspect paper; straightens posture noticeably in order to be able to see paper, hit the keys faster, etc.; or pulls his chair closer to the machine for any of the reasons above. This behavior may signify renewed or increased interest in a set of problems.

B. "Touches paper."

Child straightens paper; lifts paper to see the problems he has completed; or lifts paper to read a long paragraph the machine has typed.

C. "Turns around."

Child turns his body around in the chair so that his torso is at an angle to the machine.

D. "Pulls back."

Child lets his weight fall back into a posture defined as (--).

4. Physical Manifestation of Problem-Solving

A. "Reading silently."

B. "Talks to self."

C. "Counts on fingers."

D. "Finger to mouth."

E. "Surprise."

Child indicates he receives unexpected feedback.

5. Disengagement

A. "Actively resistent."

Child rejects program, feedback, or difficulty of problem.

B. "Withdraws."

Listless. Child is no longer interested in reading problems.

C. "Restless."

Child fidgets, flounces, etc.

D. "Talking to someone."

6. Affective Behavior

A. "Satisfaction."

Child derives pleasure from producing the correct response or working on the set of problems.

B. "Dissatisfaction."

Child indicates displeasure with the program or his answer.

Tallying Observations

Engagement		Disengagement	
1. (++)	2 points	1. (--)	2 points
2. (+)	1 "	2. (-)	1 "
3. Eyes on paper	1 "	3. Vacillation	1 "
4. Pulls body, chair close to teletype	1 "	4. Looks away	1 "
5. Touches paper	1 "	5. Turns around	1 "
6. Reads silently	1 "	6. Pulls Back	1 "
7. Talks to self	1 "	7. Actively resistant	1 "
8. Counts fingers	1 "	8. Withdraws	1 "
9. Finger to mouth, scratches head	1 "	9. Restless	1 "
10. Surprise	1 "	10. Talking to someone	1 "

The raters viewed the videotape of three subjects working on the experimental lessons. The behavior was recorded every five seconds. After the observation was completed, the raters tallied the scores for engagement and disengagement per minute and graphed these totals for each lesson. Figure 2 is an example of one of the graphs. No affective behavior was observed.

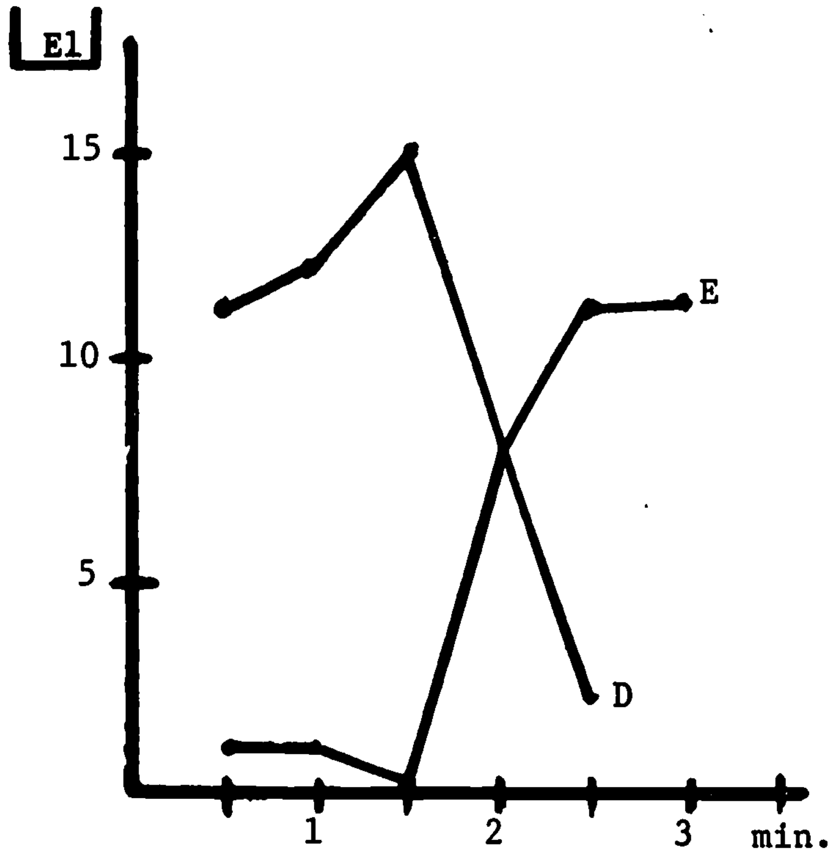

Fig. 2. Engagement and disengagement scores.

Indices and Variables

Data were analyzed from several different perspectives. From the raw scores of engagement and disengagement per lesson for each child, the following set of variables and indices was derived:

1. E/T Engagement/Time
   Engagement points per minute of time spent on the lesson tallied for each of the subject's five lessons.
2. D/T Disengagement/Time
   Disengagement points per minute of time spent on the lesson tallied for each of the subject's five lessons.

3. E/D Ratio of Engagement to Disengagement
Derived by dividing the number of disengagement points received for one lesson into the number of engagement points received for the same lesson.[1]

4. Rank of Lesson's "Engagingness"
Lesson ranked 1 (most engaging) to 5 (least engaging) for each subject, based on rates E/D.

5. Predicted Level of Difficulty Adjusted to Subject's Level of Competence
Origin is the lesson at each subject's level of competence as determined by the school records. Lessons decrease in difficulty: -1, -2, -3...and increase in difficulty: +1, +2, +3....

In order to graph the relationship of E/T, D/T, and E/D to the subject's level of competence as shown on an experimental lesson, the experimenter ranked the lessons for each subject, from least difficult to most difficult. The lessons were put into matrix form with the lesson that matched each subject's level of competence at the "0" point. A lesson that was less difficult by one rank was put in the "-1" column; a lesson that was more difficult by one rank was put in the "+1" column, etc. (See Tables 3, 4, 5.)

6. "Actual" Level of Difficulty
Determined by the subjects' percent correct scores on any lesson. 100 percent correct compares to lessons that are (-1) level of difficulty; 99-80 percent correct would include the lesson at the subject's level of competence, the "0" point; 79-50 percent correct compares to lessons that are (+1) level of difficulty; 49-0 percent correct compares to lessons that are (+2) level of difficulty. The summary of the analysis of the results for each student is shown in Tables 6 and 7.

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[1]There was a total of 45 lessons for the 9 subjects. Two of the subjects did not receive a score for disengagement on one of their lessons. This means that 2 lessons out of 45 had D = 0. It was possible to compute D/T when D = 0, but it was not possible to compute E/D when D = 0. In order to compute E/D, the experimenter made D = 1 for these two lessons, justifying this manipulation for the following reasons: since D varies from 0 to 44, the difference of the addition of one point is not as great as it would be if the variance were small, e.g., 0 to 5; furthermore, the two lessons where no disengagement score was recorded were observed for only one minute, and because the average time spent on each lesson was 3.1 minutes, the experimenter believed that one minute was not, perhaps, an adequate amount of time for a subject to become disengaged in an easy program. All of the subjects that were observed for 1.5 minutes received at least D = 1, and therefore the experimenter believed that making D = 1 in 2 cases did not constitute a misleading representation of the data.

TABLE 2

Indices of Engagement and Disengagement for Individual Subjects

	L	E/T	D/T	E/D
Mark	E_1	29	0	29:1[a]
	E_2	22	6	3.6
	E_3	33	2	16.5:1
	H_1	27	6	4.6:1
George	E_1	20	3.3	6:1
	E_2	25	5.5	5:1
	E_3	25	5	4.4:1
	H_1	21	7	3:1
Sally	E_1	27	0	27:1[a]
	E_2	29	0.7	44:1
	E_3	25	0.7	37:1
	H_1	27	3.3	8:1
David	E_1	27	2.4	11:1
	E_2	27	4	67:1
	E_3	25	4	6:1
	H_1	22	6	3.4:1
Joseph	E_1	25	3.5	7:1
	E_2	13	1	23:1
	E_3	19	4.2	4.4:1
	H_1	26	0.4	66:1

TABLE 2, Continued

	L	E/T	D/T	E/D
Mabel	E_1	28	3.1	8.6:1
	E_2	25	2.5	10:1
	E_3	29	2	14:1
	H_1	25	7.4	3:1
Amy	E_1	24	2	12:1
	E_2	22	8.4	2.6:1
	E_3	26	4.3	6:1
	H_1	24	5.3	4.5:1
Alice	E_1	31	1.5	21:1
	E_2	31	1	31:1
	E_3	29	7.8	3.7:1
	H_1	21	13	1.6:1
Jan	E_1	37	3	12:1
	E_2	37	1.3	2.9:1
	E_3	27	13	2:1
	H_1	21	.67	21:1

[a] D = 1 for computation of ratio.

TABLE 3

Distribution of "E/T" by Ranking Predicted Level of Difficulty of Lessons E_1, E_2, E_3, H_1 for Each Subject

	-2				-1		0		+1		+2			
	L	E/T	L	E/T	L	E/T	L	E/T	L	E/T	L	E/T	L	E/T
Mark					E_1	29.0	E_2	22.0	E_3	33.0	H_1	27.0		
Sally	E_1	27.0	E_2	29.0	H_1	27.0	E_3	25.0						
George							E_1	20.0	E_2	25.0	E_3	25.0	H_1	27.0
David					E_1	27.0	E_2	27.0	E_3	25.0	H_1	22.0		
Mabel					E_1	28.0	E_2	25.0	E_3	29.0	H_1	25.0		
Joseph					E_1	25.0	E_2	13.0	E_3	19.0	H_1	26.0		
Amy	E_1	24.0	H_1	24.0	E_2	22.0	E_3	26.0						
Alice					E_1	31.0	E_2	31.0	E_3	29.0	H_1	21.0		
Jan			E_1	37.0	H_1	21.0	E_2	37.0	E_3	27.0				
Average E/T =	28				26		25		27		24			

TABLE 4

Distribution of "D/T" by Ranking Predicted Level of Difficulty of Lessons E_1, E_2, E_3, H_1 for Each Subject

	-2				-1		0		+1		+2			
	L	D/T	L	D/T	L	D/T	L	D/T	L	D/T	L	D/T	L	D/T
Mark					E_1	0	E_2	6.0	E_3	2.0	H_1	6.0		
Sally	E_1	0	E_2	0.7	H_1	3.3	E_3	0.7						
George							E_1	3.3	E_2	5.0	E_3	5.5	H_1	7.0
David					E_1	2.4	E_2	4.0	E_3	4.0	H_1	6.0		
Mabel					E_1	3.1	E_2	2.5	E_3	2.0	H_1	7.4		
Joseph					E_1	3.5	E_2	1.0	E_3	4.2	H_1	0.4		
Amy	E_1	2.0	H_1	5.3	E_2	8.4	E_3	4.3						
Alice					E_1	1.5	E_2	1.0	E_3	7.8	H_1	13.0		
Jan			E_1	3.0	H_1	0.7	E_2	1.3	E_3	13.0				
Average D/T =	2.2				2.8		2.7		5.4		6.5			

TABLE 5

Distribution of "E/D" by Ranking Level of Difficulty of Lessons
E_1, E_2, E_3, H_1 for Each Subject

	-2				-1		0		+1		+2			
	L	E/D	L	E/D	L	E/D	L	E/D	L	E/D	L	E/D	L	E/D
Mark					E_1	29.0	E_2	3.5	E_3	16.5	H_1	27.0		
Sally	E_1	27.0	E_2	44.0	H_1	8.0	E_3	37.0						
George							E_1	6.0	E_2	5.0	E_3	4.4	H_1	3.0
David					E_1	11.0	E_2	6.7	E_3	6.0	H_1	3.4		
Mabel					E_1	8.6	E_2	10.0	E_3	14.0	H_1	3.0		
Joseph					E_1	7.0	E_2	23.0	E_3	4.4	H_1	66.0		
Amy	E_1	12.0	H_1	4.5	E_2	2.6	E_3	6.0						
Alice					E_1	21.0	E_2	31.0	E_3	3.7	H_1	1.6		
Jan			E_1	12.0	H_1	21.0	E_2	2.9	E_3	2.0				
Average E/D =	20				11		14		6		12			

TABLE 6

Ratio of Engagement to Disengagement by Actual Level of Difficulty of CAI Lessons

	100%		99-80%		79-50%		49-0%	
Student	L	E/D	L	E/D	L	E/D	L	E/D
Mark	E_1	29			H_1	4.6		
	E_3	16.5						
	E_2	3.5						
George	E_1	6.0			E_2	5.0		
					E_3	4.4		
					H_1	3.0		
Sally	E_2	44.0	E_3	37.0				
	E_1	27.0						
	H_1	8.0						
David	E_2	6.7	E_1	11.0	H_1	3.4		
			E_3	6.0				
Mabel	E_2	10.0	E_3	14.0			H_1	3.0
			E_1	8.6				
Joseph	E_1	7.0	E_2	23.0	H_1	66.0		
					E_3	4.4		
Amy	H_1	4.5	E_1	12.0			E_3	6.0
							E_2	2.6
Alice	E_1	21.0	E_2	31.0	E_3	3.7	H_1	1.6
Jon	H_1	21.0	E_1	12.0			E_3	2.0
			E_2	2.9				
Average E/D		15.7		15.7		11.8		3.0

TABLE 7

The Average Levels of Engagement and Disengagement per Minute in Relation to Actual Level of Difficulty

	100%		99–88%		79–50%		49–0%	
	E/T	D/T	E/T	D/T	E/T	D/T	E/T	D/T
	29	30	27	2.4	27	6	25	7.4
	33	2	25	4	25	5	26	4.3
	22	6	29	2.0	25	5.5	22	8.4
	20	3.3	28	3.1	21	7	21	13
	27	4	13	1.0	22	6	27	
	29	10	24	2.0	26	.4		
	27	3.5	31	1.0	19	4.2		
	27	5.3	37	3.0	29	7.8		
	25	1.5						
	25	.7						
	24							
	21							
	21							
Av.	26	2.4	27.6	2	24	5.2	24	9.2

Results

Our predictions were that: (a) E/T would be highest (and D/T would be lowest) for the lesson that best matched the subject's level of accomplishment in arithmetic; (b) E/T would be lower (and D/T would be higher) for lessons that were either less difficult or more difficult than this base; and (c) E/T would be higher (and D/T would be lower) on lesson H_2 than on lesson H_1 if the subject made use of the hints available in H_2 to decrease the level of difficulty of the problems. It was not possible to analyze the results of (c) because the subjects did not understand the directions about when to ask for help.

If these predictions (a) and (b) were correct, the graph would appear as in Figure 3.

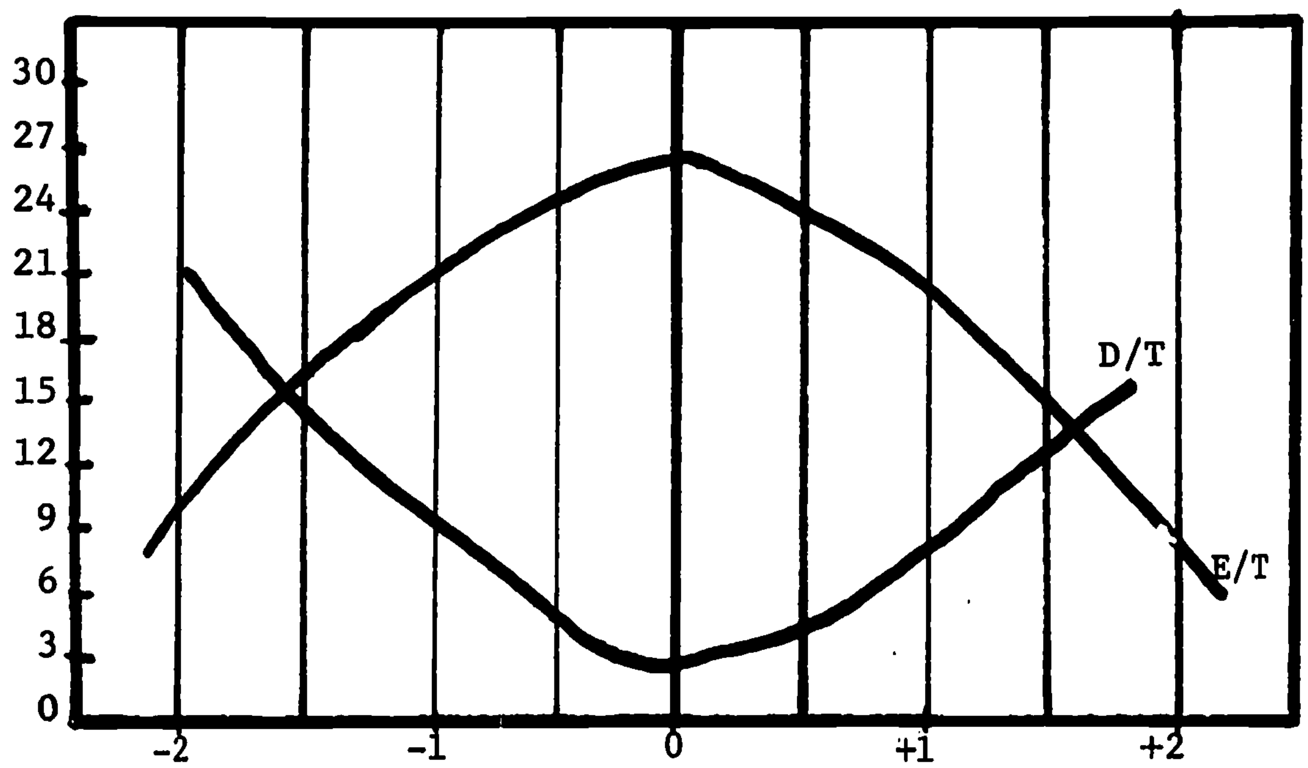

Fig. 3. Hypothetical relationship between level of difficulty, engagement, and disengagement.

The results are represented graphically because of the small size of the research group. The changes in engagement and disengagement over time as the lessons become either more difficult or less difficult is an important aid to understanding the engagement process as we have described it.

The ratio of engagement to disengagement is a useful way to represent the data because it shows the ratio of the number of points received for "engaged" behavior to every point received for "disengaged" behavior by the same subject in the same amount of time. For example, if the ratio of engagement to disengagement is 29:1, the subject was very much engaged in the lesson; he received only one point for disengaged behavior for every 29 points for engaged behavior. If, however, the ratio is 3:1, the subject was not very much engaged in the lesson; he received one point for disengaged behavior for every three points for engaged behavior.

Findings

The data did not confirm our predictions when the difficulty of the lessons was below the subject's level of competence. The relationship of E/T to the predicted level of difficulty shows that engagement recorded for the easy lessons was a few points higher than engagement recorded at the level of competence. E/T dropped only at the lesson rated two ranks more difficult than the lesson at the level of competence, and it dropped only about seven points. (See Figure 4.)

The relationship of D/T to the level of predicted difficulty shows that the disengagement recorded for the easy lessons was low, about the same as that recorded for the lesson at the level of competence. As the lessons became more difficult, the amount of recorded disengagement rose by a few points and remained there. (See Figure 4.) The relationship of the ratio E/D to the level of predicted difficulty appears random, possibly because of the unusual results within the small sample.

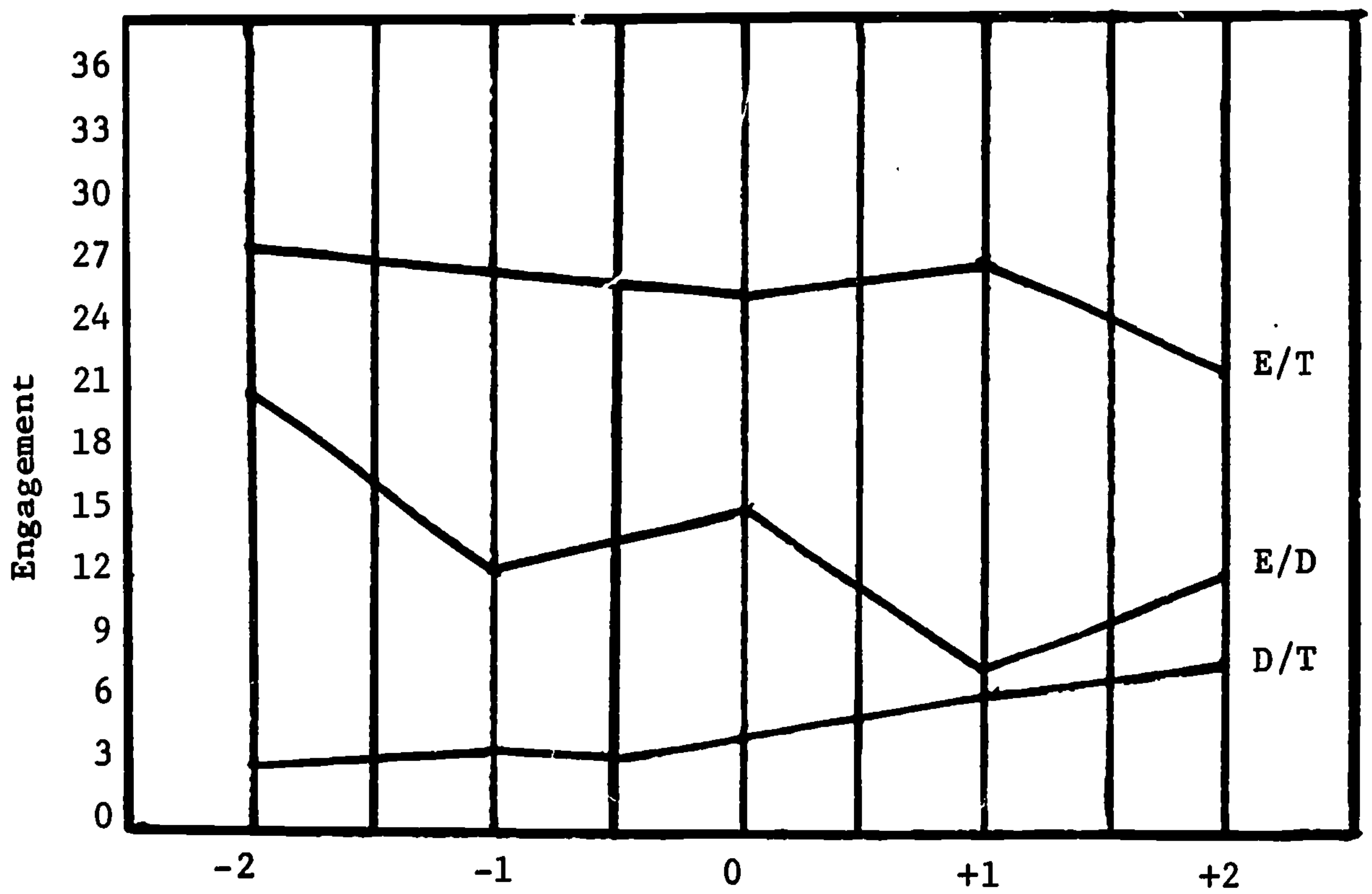

Fig. 4. Relationship of engagement to the predicted level of difficulty of the lessons. (The predicted difficulty was determined by subjects' level of competence. The difficulty of E_1, E_2, and E_3 for each subject was taken from school records; the difficulty of H_1 was determined by performance on an experimental lesson.)

When the level of difficulty of the lessons is represented according to the subjects' performance on them during the experiment (see Figure 5), there is a bit more substantial support for our predictions on the positive side of the point of origin. The relationship of E/T to the actual level of difficulty shows that E/T was high and remained almost constant until the subject missed more than 20 percent of the problems per lesson. After the subject missed more than 20 percent of the problems, E/T dropped slightly and again remained constant, even when the subject missed more than 50 percent of the problems.

The relationship of D/T to the actual level of difficulty of the lessons showed that D/T was low until the subject began to miss more than 20 percent of the problems. As the lessons became more and more difficult and the subject began to miss more than 50 percent of the problems, more disengagement was recorded, and D/T rose.

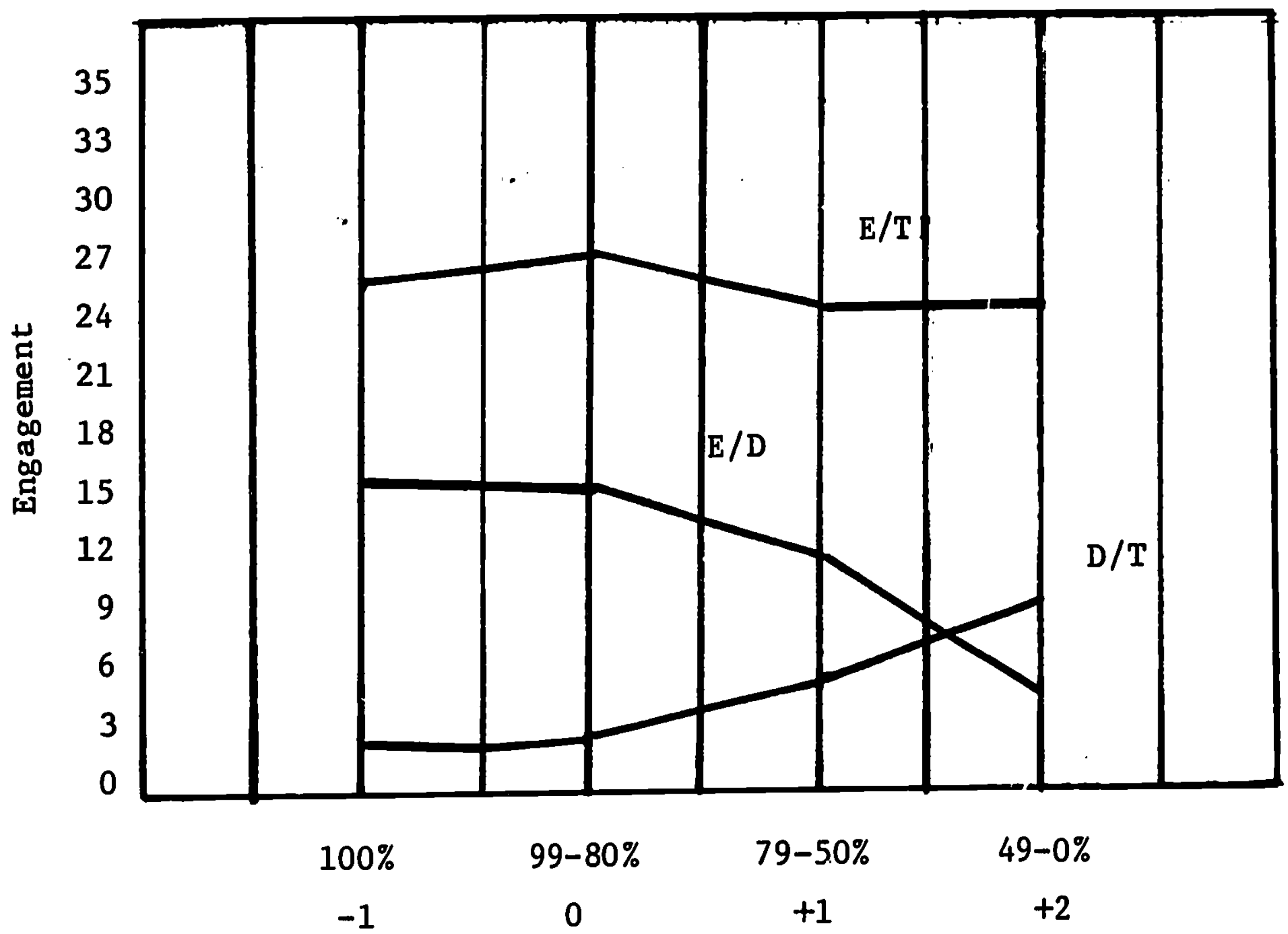

Fig. 5. Relationship between the indices of engagement and actual level of difficulty in CAI. (The actual scores of difficulty of the lessons was determined by percent correct scores.)

Again the data show that the subjects' engagement did not drop as the lessons became less difficult than the lesson at their level of competence. Engagement is high and disengagement is low on the lessons that were easy for them to do. On the other hand, the ratio of E/D began to drop quickly as the subjects missed more than 20 percent of the problems or as the lessons became too difficult for them.

In Figure 6 it can be seen that our subjects were more interested in the easy programs (the lessons they did well on) than in the difficult ones (the lessons they did poorly on). The "engagingness" of the lesson for each subject was determined by a comparison of the ratio E/D for all the lessons.

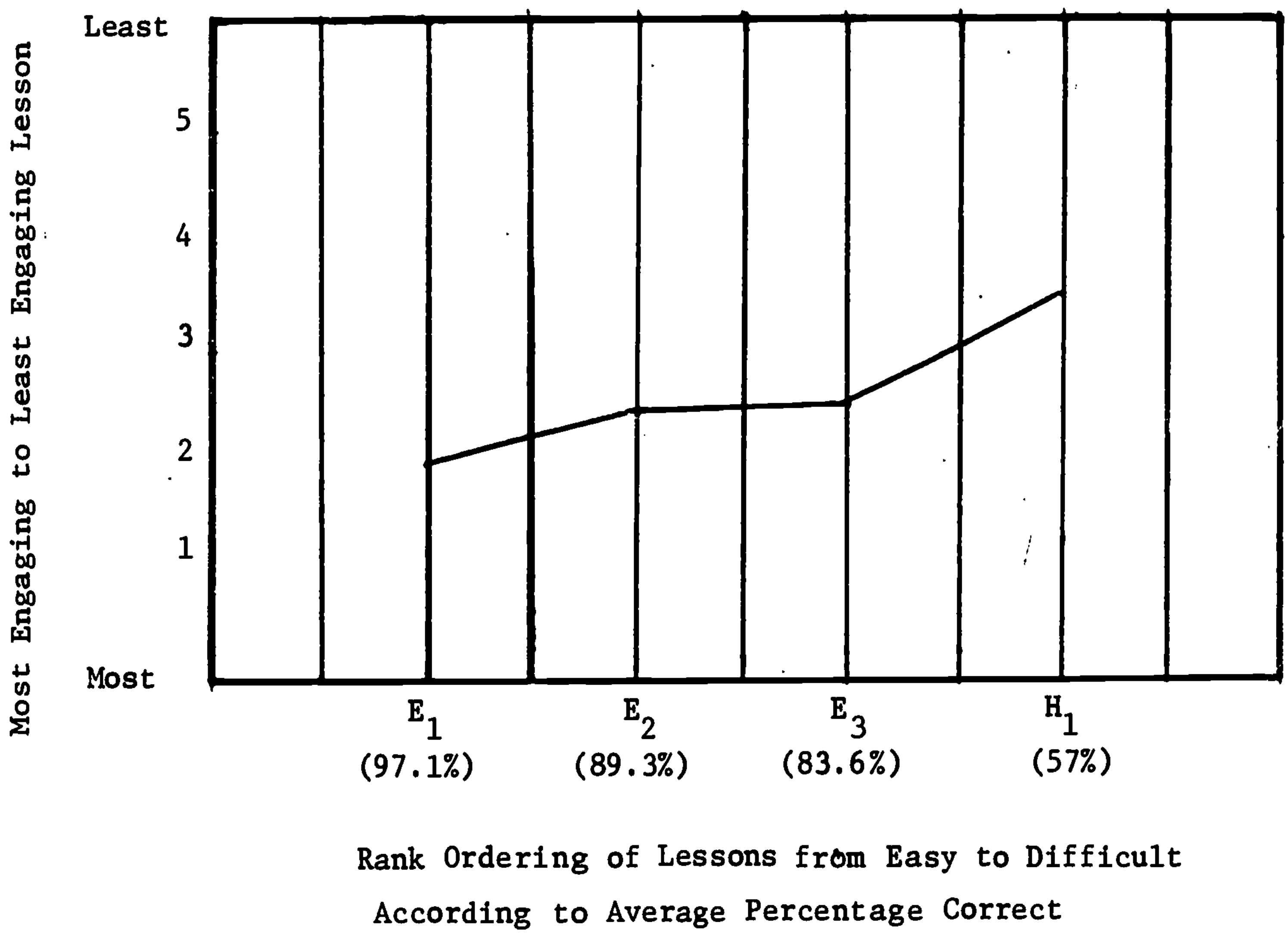

Fig. 6. Relationship of the ease of the lesson to its motivating properties.

Why did our subjects show the most interest in the easy problems? According to our hypotheses, these lessons should not have provided an adequate challenge to their competence. Actually, our results indicate that there is a wider margin of tolerance for easy lessons than for difficult ones.

If this is so, the graph of the relationship of E/D to the level of difficulty of the lesson should look something like Figure 7.

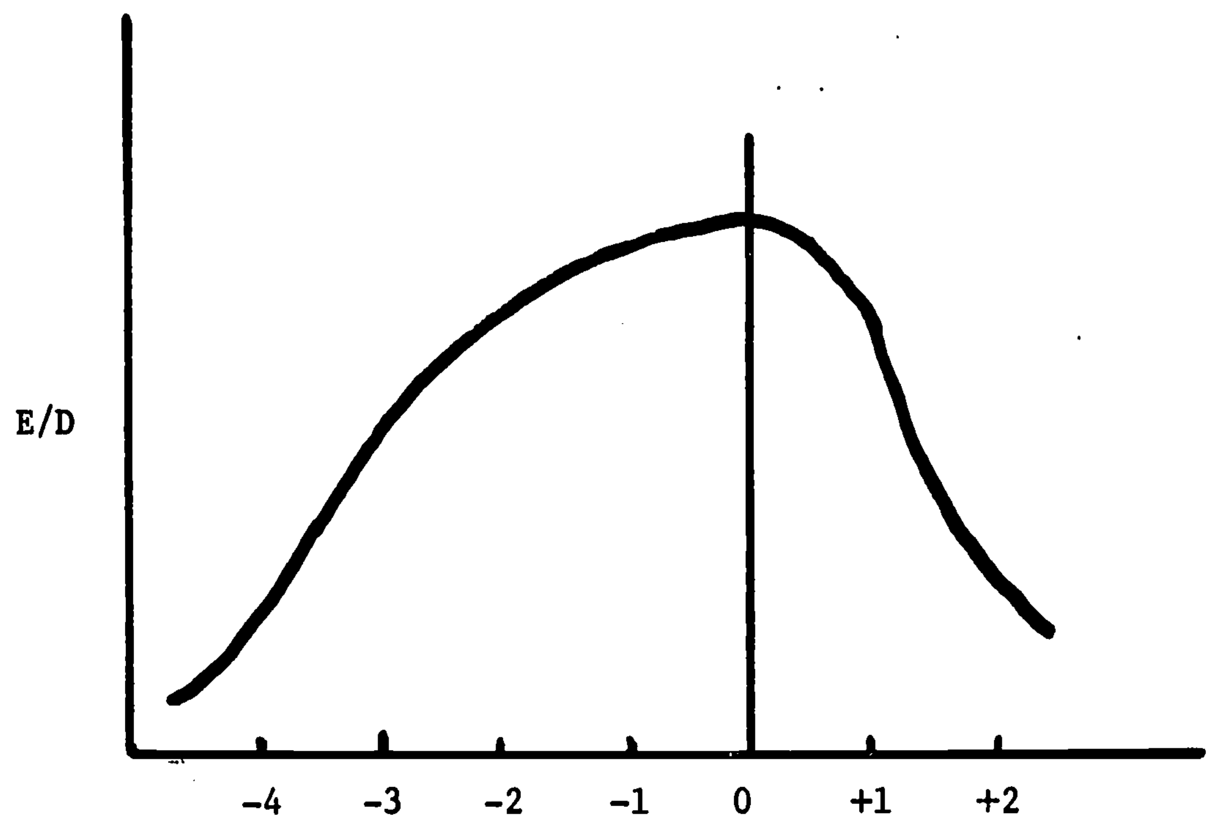

Fig. 7. Hypothetical relationship between engagement and ease of lesson.

We predict that there is a point at which the lesson will be so easy that it is disengaging, but that the point is much further away from the child's level of competence than we had originally predicted. Why might this be so, and why might we have obtained the results that we did in the experiment?

The questions we wished to answer were: (1) Why does engagement remain high throughout the lessons? (2) Where is the point of maximum engagement? (3) Are engagement scores and disengagement scores related?

The teletype is a complex instrument. It cannot accept a mis-typed response any more than it can accept an incorrect answer to a problem. Students then probably have to maintain a high level of engagement in the programs simply to avoid making typing errors. Another possible reason for the high engagement scores is that standards in the experimental environment may have appeared more rigorous than those in the computer classroom. As a result, students may have been highly engaged in the programs at which they could excel because they needed more assurance of their competence. It is also possible that because no competing stimuli were present during the experiment, the subjects were not tempted to play with the easy programs as they do in the computer classroom where many other students are working at the same time.

Possibly we did not place enough importance on the engaging properties of the machine itself. The results of the experiment show that engagement remained high for the length of the experiment--for some of the subjects, one hour. The data may suggest that students do not become habituated to the machine, but remain continually interested in seeing what the machine will type next. Thus, the element of surprise may never be lost.

We found no answer to the second question: Where is the maximum point of engagement? According to our predictions, a lesson at the student's level of competence, or one slightly above that level, would be the most engaging. Instead, the students found the easy lessons just as engaging--or more engaging--than those at their level of competence. If the graph of the relationship of E/D to the level of difficulty of the lesson looks like Figure 7, it may be that our data fit only a section of this curve. It should be possible to provide a lesson so easy that engagement drops, as well as a lesson so difficult that, in the complete absence of reward, engagement drops.

In answer to the third question, we find that E/T and D/T vary independently. We can, therefore, regard engagement and disengagement as independent measures. Consequently the amount of engaged behavior may remain high while the amount of disengaged behavior is rising. Thus we might predict that a rise in disengaged behavior will be a more sensitive indicator of loss of engagement than an actual drop in recorded engaged behavior. This is to say, the student may still be attentive to the lesson although he is beginning to be restless and to fidget. Unless something occurs to recapture his attention, engaged behavior may become less frequent as disengaged behavior becomes more frequent. This may be an important finding. The computer, insensitive to the increase in disengaged behavior, is not flexible enough to employ a strategy designed to renew the student's interest in the activity. A teacher, therefore, should be aware of the implications of a slight increase in disengaged behavior and regard it as a warning that a total loss of engagement may be approaching if something is not done to rekindle the student's interest in the activity.

Conclusions

In conclusion, it may be argued that in our hypotheses we did not give enough importance to the engaging properties of the machine itself. If this is so, in our time-line conceptualization of the engagement process we should find that the properties of the machine that are important in providing initial engagement are also important in sustaining engagement, because they constantly recall attention to the stimulus source. It is important to keep in mind the complexity of the machine. The combination of sound, motion, and fast pacing may encourage a high level of engagement at all times.

We still predict a decrease in engaged (or an increase in disengaged) behavior as the programs become more and more difficult, eventually surpassing the student's level of competence. We also predict that there will be a level of ease at which the student's engagement decreases and/or disengagement increases. In the computer classroom, we observed a qualitative difference in the disengagement resulting from a lesson that is too difficult and a lesson that is too easy. On lessons that were too difficult the students slumped down dejectedly with their heads on the teletypes. On lessons that were too easy, restless behavior predominated.

One flaw in the study may have been the isolation of the subjects while they were working on the experimental lessons. There are frequent child-child and child-adult interactions in the computer classooom, such as (a) requests for help from a neighbor or the proctor, (b) social interchanges, or (c) venting of frustration on a neighbor, e.g. by kicking. This may be one reason for the consistently high engagement scores recorded during the experiment. Unquestionably, however, engagement is also high in the computer classroom.

We may draw a few more tentative conclusions from the results of our study. Engagement and disengagement appear to be independent m.asures; disengagement proved to be the more sensitive measure in this study. Affective behavior seemed to have no relation to engagement and disengagement, but it may be a factor in classroom engagement. And, finally, engagement was high on easy lessons and did not begin to drop until the subjects missed more than 20 percent of the problems on each lesson.

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