COMPUTER-PACED VERSUS SELF-PACED ARITHMETIC DRILL-AND-PRACTICE

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ABSTRACT

An analysis of the literature showed that there is very little agreement on when and how a computer program should branch a student through a CAI program. This, together with the fact that research in the field of arithmetic has shown that drill should follow effective teaching of concepts, led the author to investigate whether students working on arithmetic drill-and-practice would do better on a COMPUTER-PACED program or a SELF-PACED program.

COMPUTER-PACED was defined to be where the computer program determined when the students should be branched to more or less difficult questions. SELF-PACED was defined to be where the students determined when they were presented more or less difficult questions by pushing one of the two marked keys on the computer terminal.

The evaluation was done by comparing the achievement of the COMPUTER-PACED and the SELF-PACED groups. For the length of the study the two groups of grade six students had a daily arithmetic lesson followed by a session at a computer terminal to work on arithmetic drill-and-practice programs.

The results of the post-test (adjusted by using a pre-test as a covariate) showed that there was no significant difference between the two selection mechanisms. Further analysis showed that there was no significant

difference between the males and females performance and that there was no significant interaction (sex X groups) effect.

The results of the study indicate that when working with arithmetic drill-and-practice, students will do as well if the computer program controls when to branch as they would if the students control when to branch to a different level of difficulty.

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CHAPTER I

THE PROBLEM

INTRODUCTION

A modern approach to teaching arithmetic is characterized by meaningful drill-and-practice along with the development of arithmetic concepts. After the teacher presents the student with activities and illustrations on the concepts, drill-and-practice is given to reinforce the facts and processes.

The task of adequately developing concepts, furnishing meaningful drill suited to the individual needs, and the checking of results to diagnose weaknesses in understanding is often beyond time limitations of the teacher. The computer lends itself well to the task of drill-and-practice. It can present the exercises suited to the ability of the student, check responses, and identify weaknesses very quickly.

Drill-and-practice, the simplest form of computer assisted instruction (CAI), is the type of computer interaction that is of interest in this study. The role of the computer is to provide regular review and practice to supplement the established curriculum. There are two other types of CAI. The tutorial system is the second and more complex level of interaction between the student and computer program. Here the computer program acts as tutor. The third type of CAI is the dialogue system where the computer carries on a conversation with the student. The third level is still in the planning stages.

The Stanford group headed by Suppes has pioneered the work of drill-and-practice programs in arithmetic fundamentals. By the 1969-70 school year over 8,000 students were taking arithmetic lessons in the Stanford drill-and-practice programs. More details about the Stanford programs may be found in the book by Suppes, Jerman, and Brian (42).

In Stanford's program, like most other drill-and-practice programs, the teacher or the program determines when the student moves from one level of difficulty to the next.

> At the present time we are moving the students up and down the levels of difficulty on the basis of the previous days's performance. If more than 80 per cent of the exercises are correct, the student moves up one level, unless he is already at the top level. If less than 60 per cent of the exercises are correct, the student moves down a level, unless he is already at the bottom. If his percentage of correct answers falls between 60 per cent and 80 per cent he stays at the same level. It should be emphasized that the selection of exactly five levels and of the percentages 60 and 80 has no firm theoretical basis but is based on practical-pedagogical judgments. As systematic data are accumulated, we expect to modify our choices in the light of experience (Suppes. 41:15).

Gentile said that there is a great need for more research in the area of CAI (15:24). Most of the people that are using CAI to-day decide on a criterion for branching from one level to the next, with little or no research in the area of how the student learns. As is pointed out in Chapter II there is very little agreement in the research studies on what decision structures to use.

Gentile (15:23-24) stated that practically all CAI support funds go into the development of systems, equipment, and courses and not into research on learning via CAI.

The computer is capable of following the most complicated decision making structure if the decision making criteria can be stated in a simple objective manner. As pointed out by Suppes, he has no firm theoretical basis for branching the students to different levels of difficulty if he answers less than 60 per cent or more than 80 per cent of the questions correct. Hopefully, with the use of computers in research on learning, a theoretical basis can be made for branching the students through a CAI program.

The major justification for CAI has been the individualization made possible by the computer. The big question now is who decides what instruction or material is appropriate for the student's educational needs. Does the student decide or does some educator decide what is best for the student?

Because of the many factors that influence a person such as age level, ability level, attention span, attitude, sex, anxiety, etc. until more research is done on individual differences (ID), possibly the student should have control of the path taken through a CAI course.

Because there are no theoretical grounds on when the program should branch a student, research on decision making structures has only started, and there are so many factors that influence a student, it is the concern of this study to test to see if the student should control the branching from one level of difficulty to another when working on a CAI program.

STATEMENT OF THE PROBLEM

The present investigation attempts to answer the following question: Do students who have control over the level of difficulty in a learning sequence achieve higher scores than students who do not have control over the level of difficulty when working on an arithmetic drill-and-practice program? A formal statement of the hypotheses is stated at the end of Chapter II.

CHAPTER II

REVIEW OF THE PERTINENT LITERATURE AND THE DEFINITION OF TERMS

INTRODUCTION

The following review of the literature summarizes the research that is applicable to the problem being investigated. It is important to note that the term PACED as used in COMPUTER-PACED and SELF-PACED does not refer to the speed at which the frames or material are presented as in Programmed Instruction. PACED here refers to the choice of the LEVELS of difficulty or the difficulty of the questions presented not on how much time a student has to answer a question or frame.

DRILL IN ARITHMETIC

Many people are still confused with respect to the use of drill in the classroom to-day. When commenting on readiness for division Brownell (5) stated that if children find the topics difficult, many times it is due to inadequate mastery of the skills and basic facts needed. Jerman (23) cited a study by Anaspaugh in which 93 percent of the errors made in long division of decimals and in common fractions in grades 4,5 and 6 were due to the lack of mastery of number facts rather than the number processes.

Brownell and Chazel (6) pointed out the dangers of teaching by the drill method alone. They found that after grade three students were given five minutes of drill each day for a month on items taught in grade one and two that 15.4 percent of the responses were obtained by guessing, 19.3 percent by counting, 18.7 percent by indirect solution and 52.5 percent by immediate recall. They concluded that effective teaching must precede drill, as drill only reinforces the procedure the student has learned to obtain an answer. Their study pointed out that drill can be most effectively used to overcome a large percentage of typical errors in arithmetic after the concepts are introduced and discussed by the classroom teacher.

The Stanford arithmetic drill-and-practice programs are the most widely known and used of any of the drill-and-practice programs. As pointed out in Chapter I, in the Stanford drill-and-practice programs the student is moved up and down the LEVELS of difficulty on the basis of the previous day's performance. In the Stanford case the students had no control over whether they moved up or down the LEVELS of difficulty. It is assumed, in programs like the Stanford arithmetic drill-and-practice programs, that the instructor knows what is best for the student.

The studies cited above suggest that effective teaching should be followed by drill. Suppes and others have definitely shown that the computer is capable of presenting drill to the students, as well as checking responses and summarizing the students' work for the teacher. Now the question is; "what is the decision structure that is to be used that determines how the student will be branched through a CAI course?"

DECISION STRUCTURES

Smallwood (35) in A Decision Structure For Teaching Machines developed a model for a decision system that can use past inputs to the system in deciding among various alternate presentations of the material. He attempted to organize his decision process so as to be similar to that of a private tutor. If this decision process is to be useful it must have the ability to adapt to students and to improve its effectiveness with experience.

If a student is very slow and needs many visual aids or if he learns more quickly than others, the teaching machine should detect these characteristics in the student and take advantage of them by branching the student through more appropriate blocks of material. It is possible for a teaching machine to give the more intelligent students a deeper and fuller presentation of the subject matter while presenting a slower student with a less rigorous treatment of the same material.

Smallwood pointed out that "a good teaching machine should be capable of improving its decision processes as it 'learns' more about the effects that are caused by the decisions" (36:2). Smallwood had the computer collect and use information to re-estimate the parameters used in making the branching decisions as the computer taught miniature geometry to twenty Massachusetts Institute of Technology students. He succeeded in demonstrating that his model did adapt the decision rule as more data was used to estimate the parameters of the model. He pointed out at the end of the study that even though his model would adapt the decision rule he did not know if the students learned any better with his model or one that did not adapt to past information.

Stolurow has been closely associated with another instructional system, SOCRATES, that was designed at the University Of Illinois. Stolurow and his associates where attempting to construct a decision making system that, given all the previous information possible on the student, could predict where the student should start a CAI course. Once the student started the course the program was to adapt to responses of the student and appropriately branch the student through the CAI course. The problem of attempting to solve the best way of using all the information available about a student in order to optimize the teaching strategy used with him is very similar to the problem that Smallwood was working with. Stolurow (37) pointed out that much more research must be done in the area of decision structures before we will have a satisfactory model.

Other short term optimization strategies were discussed by Atkinson (2:143-165). He has worked on some decision strategies in reading programs for elementary school children. Atkinson points out that "even if short-term optimization strategies can be devised which are effective, a total reading curriculum that is optimal still has not been achieved (2:163).

Stolurow and Davis (38) reviewed studies of interaction of individual differences (ID) variables with methods of instruction and concluded that such interactions occur in a variety of instructional settings and methods. They finished their paper by suggesting that CAI will be a tremendous aid in conducting research in ID-method interactions and in implementing individualized instruction.

Two years later Davis, Denny and Marzocco (9) reviewed theory and empirical research on individual differences in learning and reported research on the interaction of ID and method variables in CAI and programmed instruction (PI) in a college-level remedial mathematics course. The ID included numerousness ability, attitude, and interest tests. They concluded that the ID variables had no relationship with the treatments and were of no value in prescribing instructional treatments.

It should be clear that there is little agreement on what variables, if any, should be included in a decision making model for CAI. Until there is some agreement on what variables are important it is impossible to decide on a decison making model to control the instructional strategy.

Because of the lack of agreement as to the make up of a decision making model the author suggests that a student, assuming his better self-awareness of all his internal mental processes and immediate states of awareness, can best select his own strategy for acquiring a set of concepts.

Gay (14) has done some research that suggests that males will do better if they have control over the level of difficulty while females will do better if the computer controls the level of difficulty. Gay found that in a CAI course on polynomial equations, boys achieved better results when they controlled their own level of difficulty while girls achieved better results when the number of questions that they were given at any one LEVEL was based on their memory retention.

DEFINITIONS

LEVELS: A series of problems or types of questions arranged sequentially according to the order of difficulty as determined by the author, other teachers, and the professors consulted. See Appendix A for a listing of the 60 LEVELS used.

PATH: a record of the branches to EASIER LEVELS. The first time the student signs onto the computer terminal his PATH is null, and it will stay null until the program branches to an EASIER LEVEL. For example if the program branched to an EASIER LEVEL, e.g. 34, from LEVEL 38 PATH would be the vector of one element,38. Now if the program branches again to an EASIER LEVEL, say 32, from LEVEL 34 PATH would now be the vector PATH=34,38. Now when the program branches to a HARDER LEVEL from LEVEL 32 the program will branch to LEVEL 34 not the next LEVEL,33.

HARDER: a higher LEVEL. In most cases the program will branch to the next higher LEVEL when a HARDER LEVEL is requested. There are two exceptions. The first one is obvious in that if the program is at LEVEL 60 and a HARDER LEVEL is requested the program cannot branch to LEVEL 61 since LEVEL 61 does not exist. In this case the program stays at LEVEL 60. The other exception is when PATH is not the null vector, the program has reached the current LEVEL by branching to an EASIER LEVEL. If PATH is not null then the program will branch to the first element of the PATH vector (see definition of PATH).

EASIER: a lower LEVEL of that operation wherever possible. If a student is at an addition question then an EASIER LEVEL would be an addition question that is at a lower LEVEL. There is a list of the EASIER LEVELS used for all sixty LEVELS in Appendix B. Note that in some cases the EASIER LEVEL is of a different operation: the EASIER LEVEL for the lowest LEVEL of multiplication is an addition LEVEL.

COMPUTER-PACED: the program will branch to a HARDER or an EASIER LEVEL depending on the number of questions the student has answered correctly at any given LEVEL. The frequency or the number of questions given at any one LEVEL was initialized to 2. The frequency would remain at two until the program branched to an EASIER LEVEL in which case the frequency would be increased by two to a maximum of ten. If the student answered more than one-half the questions incorrectly at any given LEVEL then the program will assume that the student does not understand the concept and branch to an EASIER LEVEL. The program will branch to a HARDER LEVEL if the number correct is greater than one-half the frequency at any given LEVEL.

SELF-PACED: the student determines when he will branch to a

HARDER or an EASIER LEVEL. When the student is presented a question he may push the key marked 'H' for HARDER or a key marked 'E' for EASIER instead of answering the question. When the student pushed the key marked 'H' the student was given the message " IF YOU ANSWER THIS QUESTION CORRECTLY YOU MAY GO ON (to the next LEVEL)." then if the student answered the question correctly the computer branched to a HARDER LEVEL. When the student pushed the key marked 'E' instead of answering the question the program immediately branched to an EASIER LEVEL and presented the student with a question from the EASIER LEVEL.

HYPOTHESES

On the basis of the reviewed literature the author expects the following hypotheses to be true:

H1. Students who have control over the level of difficulty (group S) will achieve higher post-test scores than students who do not have control over the level of difficulty (group C).

H2. Males will achieve higher post-test scores than females when working on arithmetic drill-and-practice.

H3. There will be an interaction effect between the groups and sex. The author is assuming that the interaction that will occur is as follows: (1) the males in the SELF-PACED group will achieve higher post-test scores than the females in the SELF-PACED group and (2) the females in the COMPUTER-PACED group will achieve higher post-test scores than the males in the COMPUTER-PACED group.

In more operational terms, the students that stay at the same level of difficulty (LEVEL) until they push a key marked HARDER or EASIER will achieve higher scores on an arithmetic test than students that have no control over their level of difficulty.

CHAPTER III

EXPERIMENTAL DESIGN

INTRODUCTION

The rationale for having a SELF-PACED program was that it would allow the students freedom in selecting the difficulty of questions presented to them and as a result of the freedom these students would master the material better than students who were COMPUTER-PACED. The hypothesis was tested by comparing the performance of two groups of students answering questions concerning the material presented. One group of students had control over the decision of when to try a HARDER or an EASIER LEVEL, and for the other group the computer program determined when the LEVEL should be changed.

PILOT STUDY

A pilot study was conducted with two above average grade six students. The main objectives of the pilot study were to determine whether the program was working correctly, the instructions were clear enough for the students to follow without any difficulty, and five twenty minute sessions on the drill-and-practice program were reasonable.

The two students were brought out to the University Of British Columbia to work on the drill-and-practice programs for three half-days. The computer terminal used was the same type as used in the main study, a teletypewriter connected to the university's IBM 360/67 computer by telephone lines. The two students alternated working at the computer terminal. The girl working on the COMPUTER-PACED program had her twenty minute session first, then the boy on the SELF-PACED program took his twenty minute session. Both students were encouraged to ask questions while they were working at the computer terminal and after they had finished their turn. Both students asked some questions while working at the terminal but saved most of their questions until their session was finished. While the one student was on the computer terminal the other student was able to ask the author questions or to engage in other activities except watching the other student working at the computer terminal.

There were very few technical problems during the pilot study. The computer shut down once during one of the sessions but the author was able to restart the student at the same point in the program. There was also some interference on the telephone lines but this caused very few problems even though in some cases the student would have to retype his answer.

The students had two twenty minute sessions each day for three days for a total of six sessions each. One student reached the LEVEL 53 while the other student reached LEVEL 51. An analysis of the students progress indicated that too much calculation was involved in some of the higher LEVELS, and as a result the students were making mistakes even when they understood the concept involved. The LEVELS involved were changed so as to necessitate less computation.

As a result of the pilot study the author concluded that the instructions were clear enough for the students to follow and to understand. The author also felt that since some of the LEVELS were changed to involve less computation that five twenty minute sessions would be an appropriate amount of time for the material presented. The students both indicated that they felt that the twenty minute sessions were not too long and one student stated that he felt the length of time per session should be increased.

FORMATION OF GROUPS

A grade six class was selected from a parochial school in Vancouver, British Columbia. The selected school is situated in a lower-middle class district where most of the old homes are being replaced by high-rise apartment buildings. The class could be considered representative for the type of district the school is in. The number of children in the school is declining every year because many of the new apartment buildings will not take children. The Canadian Basic Skills Test In Mathematics was the most recent standardized test that these students had taken. This test was written in the fourth month of the sixth year and the students averaged a grade equivalent of six years eight month with a range from five years zero months to eight years four months.

The class was divided into four groups for this study. The fourteen boys were separated from the ten girls, then the boys were randomly assigned to the SELF-PACED and the COMPUTER-PACED groups. The girls were similarly assigned to the COMPUTER-PACED and SELF-PACED groups.

The random assignment to groups aided in making the groups fairly equal but a pre-test was used as a covariate to adjust for any remaining differences.

MATERIAL

Levels

The two groups, the SELF-PACED and the COMPUTER-PACED, both worked on the same drill-and-practice material consisting of questions involving the four basic operations in whole numbers and in decimal fractions. A complete list of the sixty different LEVELS or types of problems used can be found in Appendix A.

Computer Terminals

Two teletypewriters were installed in the school where the twenty four grade six students worked on the drill-and-practice questions. The teletypewriters were connected by telephone lines to the University of British Columbia IBM 360/67 computer.

Both computer terminals were the same but one terminal was always used by the COMPUTER-PACED group and the other computer terminal was always used by the SELF-PACED group. The ENTER and DECIMAL keys were clearly marked with plastic tape so that the students would be able to find these keys easily. The SELF-PACED computer terminal had two additional keys marked with plastic tape, one marked H for HARDER and the other marked E for EASIER .

Test

All the students were given a pre-test (see Appendix C) and at the end of the study they were given the same test as a post-test. The test was contructed by having the computer program generate one question from each LEVEL.

PROCEDURE

All the students in the study were taken out to the University of British Columbia for a tour of the university's Computing Centre and to see the IBM 360/67 computer so that they would have some idea of what a computer is. The students were given a chance to play games such as TICTACTOE and COINFLIP with the IBM 360/67 computer so they all had some familiarity with pushing the keys on computer terminals before they started using the terminals at their school.

The study started on a Friday when the students were told that they would be starting to do their arithmetic exercises on computer terminals the following week. After the students had been given opportunity to ask questions they were given one hour to complete the pre-test. The students were given extra paper where they were asked to do all calculations. At the end of the hour the tests and all the papers were collected. The students were not given the results on the test; nor were they given their tests back until after the end of the study.

The following Monday was a school holiday so Tuesday was the first day that the students worked at the computer terminals.

The only initiation that the students had other than the playing of games on the computer terminals at the university was their first twenty minute session when the author explained how to enter their answers on the computer terminals. None of the students had any trouble after they were helped entering the first two or three answers.

The SELF-PACED students were shown how to request a HARDER LEVEL and an EASIER LEVEL only after they demonstrated that they were not having any difficulty entering their answers. This usually took about two or three minutes.

The students might have needed a longer introduction period if the beginning questions had been more difficult but since the first LEVEL contained questions like $3 + 4 = ?$, the only difficulty with the first LEVEL was getting used to the computer terminal.

For the length of this study the author taught a thirty minute arithmetic lesson to the students at 9 A.M. every morning. The lessons consisted of a review of the four basic operations in whole numbers and in decimal fractions which included all the sixty LEVELS in the drill-and-practice program listed in Appendix A. After their arithmetic lesson the students continued with their normal classes. The students names were listed on the blackboard in the order that they were to have their drill-and-practice session at the computer terminal. There was one list of names for each terminal.

The two terminals were marked 'COMPUTER-PACED' and 'SELF-PACED' as were the two lists on the blackboard in the classroom. The students on the SELF-PACED list always worked on the computer terminal marked 'SELF-PACED' and the students on the COMPUTER-PACED list always worked on the terminal marked 'COMPUTER-PACED'. This proved to be very helpful in that the students soon knew exactly which terminal to go to and no student was ever given the wrong program. The very fact that the students knew that they were working on a different program from the students in the other group may have had some effect on the outcome but they were both experimental groups so the effect should have been the same for both groups.

When the first student on a list finished his lesson on the computer terminal he would notify the next student who would then quietly leave the classroom for his session on the terminal. This process continued until all the students had their turn. Each list was rotated by two students each day so that the students would not be working at the terminal the same time every day and thus miss time in the same subject each day.

Because of the number of sudents involved per computer terminal it was necessary to have the students continue through their recess and their lunch breaks. The students even agreed to stay after school if all the students on a list did not finish. One student could not take his turn if it happened to fall during the lunch hour so the position of the names on one list had to be altered at times.

The last student finished his turn at about 3:10 p.m. on Monday, the fifth school day that the students had been working at the computer terminals. Tuesday morning the students were given one hour to complete the test again. Eleven calendar days had passed since the students first wrote the test. The same test was used as the pre-test and the post-test only because it was extremely unlikely that any student would remember any of the questions. The students had no idea that the same test would be used. All the papers that the students had used for calculations while writing the test were collected. None of the questions on the test were ever discussed with the children, and the students had calculated a great number of problems between the two administrations of the test similar to those on the test. After the students had written the post-test they were asked if they recognized any of the questions. About one-fourth of the students said that they thought they had seen some of the questions before and only one student said that he was sure that it was the same test that they had written before.

STATISTICAL ANALYSIS

Data

For each of the students two scores were obtained. The first was his score on the pre-test and the second was his score on the same test used as a post-test. The LEVEL that each student achieved daily was recorded. This data is in Appendix E.

Design

TABLE 1

THE NUMBER OF SUBJECTS IN THE

TWO FACTOR DESIGN USED

	M	F
C	N=7	N=5
S	N=7	N=5

In order to make it easier for labeling the diagrams the groups were labeled as M (male), F (female), S (SELF-PACED), and C (COMPUTER-PACED).

A standard analysis of covariance program at the University of British Columbia (BMDX64) was used to analyze the data for this two factor fixed design.

An alpha level of 0.05 was selected. The critical value for F with one and nineteen degrees of freedom for this alpha level is 4.38.

CHAPTER IV

ANALYSIS OF RESULTS

TESTING OF HYPOTHESES

A summary of the analysis of the post-test scores using the pre-test scores as a covariate may be found in the following table.

TABLE 2

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F
MEAN	158.38185	1	158.38185	4.74440
GROUPS	35.86396	1	35.86395	1.07432
SEX	67.08819	1	67.08818	2.00965
GROUP X SEX	1.29310	1	1.29310	0.03874
COVS	1252.86695	1	1252.86694	37.53015
COV. 1	1252.86694	1	1252.86694	37.53015
ERROR	634.27590	19	33.38293	

Table 3 contains the expected scores for each of the four cells of two by two factorial design when the pre-test scores were used as a covariate. See Appendix F for the observed means for both the pre-test and the post-test.

TABLE 3

ADJUSTED EXPECTED MEANS

	M	F	
S	46.83	49.74	48.29*
C	43.84	47.72	45.78*
	45.34*	48.73*	47.04**

* THE AVERAGE OF THE TWO MEANS
** THE EXPECTED GRAND MEAN

<u>Hypothesis 1</u> (H1)

Since the F value of 1.07 was less than the critical value of 4.38 H1 was rejected. This indicates that there was no significant difference in achievement of post-test scores between thoses students who had control over the level of difficulty (group S) and those that did not have control over the level of difficulty (group C).

Hypothesis 2 (H2)

Since the F value of 2.01 was less than the critical value of 4.38 H2 was rejected. This means that there was no significant difference in achievement of post-test scores between males and females when working on arithmetic drill-and-practice.

Hypothesis 3 (H3)

The hypothesis that there would be a significant interaction effect between groups and sex, H3, was rejected because the F value of 0.04 is less than the critical value of 4.38.

INTERPRETATION OF RESULTS

The expected values in TABLE 3 indicate that the students on the COMPUTER-PACED program scored higher than those on the SELF-PACED program though not significantly higher. Even though the females did not achieve significantly higher scores than the males it is interesting to note that the girls in both the COMPUTER-PACED and the SELF-PACED groups did better on the post-test.

It was expected that the females would do relatively better on the COMPUTER-PACED than the SELF-PACED program but it was not expected that the females would do better on the COMPUTER-PACED than the SELF-PACED program.

ANALYSIS OF ADDITIONAL DATA

The students in the SELF-PACED group achieved higher LEVELS on the average than did the students in the COMPUTER-PACED group every day except on day one (see Appendix F). It appeared to take some time for the SELF-PACED students to become familiar with how to ask for questions from HARDER or EASIER LEVELS.

The LEVELS achieved on the fifth day correlate fairly well with the criterion scores on the post-test. This was expected since the test was constructed by taking one question from each LEVEL.

The SELF-PACED students answered approximately the same number of questions as did the COMPUTER-PACED group but the number of questions that they answered at each LEVEL varied a great amount. Some of the students from the SELF-PACED would answer more questions on the difficult LEVELS and only one from LEVELS that they considered trivial. This was the behavior the author hoped for but there were about four students in the SELF-PACED group that did just the opposite. When these students came to a LEVEL that was easy for them they would stay on that LEVEL for about ten questions before moving on to a HARDER LEVEL. When they were presented a question from a LEVEL that they considered difficult they would request an EASIER LEVEL or else request a HARDER LEVEL and guess at the answer just so that they could get to another LEVEL that they considered easy.

Student #15 would not have ventured much past LEVEL one or two had it not been for the pressure exerted by the other students. Each student was given his printout from the computer terminal when he finished his turn. The first time student #15 brought his printout back to the classroom he bragged about how many questions he had done. The other students quickly looked at his printout to see the questions that he did and then teased him about doing questions like 7 - 3 = ?, which is LEVEL two.

Student #15 was really thrilled with doing the drill-and-practice exercises at the computer terminal for the first two days but after the second day the pressure from the other students forced him ahead to questions where he had to calculate the answers on the scrap paper provided and this became too much work for him. He is a very slow student, day dreams a great deal and is the only one in the class that will repeat grade six next year.

Other than student #15 there was nothing but excitement and enthusiasm shown toward the drill-and-practice exercises. As shown in Appendix F the students averaged a gain of eight marks on the post-test over the pre-test. This is a gain of 20 per cent. Some of the gain is because of the novelty effect of having a different teacher for arithmetic, some because they were able to use computer terminals and some because they were re-taught the material and were given questions to do similar to those on the test.

CHAPTER V

CONCLUSION AND SUGGESTIONS FOR FURTHER RESEARCH

SUMMARY

This study was designed to determine whether or not it makes any difference if the student controlled when the computer program branched to a different LEVEL or if the computer program controlled when it branched to a different LEVEL. There was no significant difference between the two methods of the selection of different LEVELS. The results of this study indicate that when working with arithmetic drill-and-practice, students will do as well if the computer program controls when to branch as they would if the students control when to branch to a different level of difficulty. Further analysis showed that there was no significant difference between the males and females performance and that there was no significant interaction (group X sex) effect.

DISCUSSION

The author of this study is optimistic about the future of the computer in the classroom especially for arithmetic drill-and-practice. The students seemed to enjoy working at the computer terminals and they had very little trouble getting used to the computer terminals. The fact that one can summarize a student's work for the day, as shown in Appendix F, or for the week or month and see exactly where the student is having difficulty is probably the most important aspect of computerized drill-and-practice.

The result that the females scored higher, though not significantly higher, on both the COMPUTER-PACED and the SELF-PACED programs is contrary to the results that Gay (14) found when he had students working at a CAI tutorial program written to teach first year college students polynomial equations. The reason for the different results could have been because the students in this study were much younger than those in Gay's study. Silberman pointed out that "undoubtedly there will be an age gradient in determining the extent to which the student should control his own instruction, younger children will require more structure" (33:51). Another reason for the different results could have been that the material was different.

LIMITATIONS OF THE STUDY

The students were all told that there were 60 LEVELS. They were also told that everyday after they finished their session at the computer terminal they would be told the LEVEL achieved only if they asked. This was a personal thing between the author and the student, the student would only be told his own LEVEL. For many of the students it was a competition to see if they could reach a higher LEVEL than their friend. Some of the students set their goal at LEVEL 60 before the five sessions were finished. If the students had not been told that there were 60 LEVELS and if they had not been told their own LEVEL at the end of each session the results might have been different.

A grade six class of twenty four students was selected from a parochial school. The results of the study may have been different if a large class in a public school had been selected. The students that attend parochial schools may not be representative of all students.

The subjects chosen were from a small class of twenty four students. The class was very close in that they always played together at recess, noons, and after school as a group with vey few outsiders. This closeness would result in more interaction between the students about the experimental program than if the class were not so close.

The decision model used is only one of an infinite number of possible decision models. If a different decision model was used for the students in the COMPUTER-PACED group the results may have been very different.

The situation of the teacher teaching concepts followed by drill-and-parctice was not really achieved in that the concepts presented were not new concepts to the students. The students had previously been taught how to do all the material covered by the drill-and-practice programs. The students were re-taught, or given a review of, the concepts and the review was followed by drill-and-practice.

SUGGESTIONS FOR FURTHER RESEARCH

A study should be conducted using the same material with a different decision model for the COMPUTER-PACED group. The study could have many decision making models if the study involved enough students to make more groups. The study may show that one decision making model that was used was superior to the others or it may show that it make very little difference which decision making model is used. The SELF-PACED group may achieve higher post-test score than some of the COMPUTER-PACED groups.

Another study similar to this study should be conducted with students over many grades. Possibly the results may be very different for students in grade three, six, and nine.

There is a need for more research into the ways a person learns. As more research is done with decision making models possibly man will learn much more of how he learns. Once more knowledge about learning is known then the decision can be made of whether the student or the computer can best guide the student through the course material.

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APPENDIX A

LEVELS

A,B AND ? ARE WHOLE NUMBERS FOR LEVELS #1 TO #24

1	A + B = ?	4 + 2 = ?	0<A, B<10
2	A - B = ?	8 - 3 = ?	0<A, B<10; B<A
3	A + B = ?	12 + 46 = ?	10<A, B<100; NO CARRYING
4	A - B = ?	347 - 221 = ?	10<A, B<1000; NO BORROWING
5	A + B = ?	709 + 231 = ?	10<A, B<1000; CARRYING ON DIGIT 1
6	A - B = ?	870 - 454 = ?	100<A<1000 B<=A; BORROWING ON DIGIT 1
7	A + B = ?	61 + 146 = ?	10<A, B<1000; CARRYING ON DIGIT 2
8	A - B = ?	745 - 684 = ?	100<A<1000; B<=A; BORROWING ON DIGIT 2
9	A + B = ?	98 + 665 = ?	10<A, B<1000; CARRYING ON DIGITS 1 AND 2
10	A - B = ?	910 + 641 = ?	100<A<1000; B<=A; BORROWING ON DIGITS 1&2
11	A X B = ?	3 X 4 = ?	0<A, B<10
12	A X B = ?	54 X 10 = ?	0<A<100; B=10 OR 100
13	A X B = ?	12 X 27 = ?	0<A, B<100
14	A / B = ?	72 / 8 = ?	0<B, ?<10
15	A / B = ?	994 / 7 = ?	10<A<1000
16	A / B = ?	100 / 5 = ?	A=10, 100, OR 1000
17	A + ? = B	751 + ? = 780	ONE OF #4, #6, #8, OR #10
18	? + A = B	? + 38 = 379	ONE OF #4, #6, #8, OR #10
19	A - ? = B	902 - ? = 23	ONE OF #4, #6, #8, OR #10

20	? - A = B	? - 72 = 21	ONE OF #3,#5,#7,OR #9
21	A X ? = B	14 X ? = 84	10<A<99; 2<?<19
22	? X A = B	? X 13 = 65	10<A<99; 2<?<19
23	A / ? = B	156 / ? = 13	10<B<99; 2<?<19
24	? / A = B	? / 12 = 6	REFER TO #13

A,B AND ? ARE DECIMAL FRACTIONS UNLESS OTHERWISE SPECIFIED

25	A + B = ?	0.3 + 0.4 = ?	0.0<A,B<1.0,1 DEC PL; NO CARRYING
26	A - B = ?	0.7 - 0.2 = ?	0.0<A,B<1.0,1 DEC PL; NO BORROWING
27	A + B = ?	2.1 + 7.8 = ?	1.0<A,B<10.0,1DEC PL; NO CARRYING
28	A - B = ?	2.5 - 1.4 = ?	1.0<A,B<10.0,1DEC PL; NO BORROWING
29	A + B = ?	8.81 + 1.16 = ?	1.0<A,B<10.0,2 DEC PL; NO CARRYING
30	A - B = ?	8.88 - 3.62 = ?	1.0<A,B<10.0,2 DEC PL; NO BORROWING
31	A + B = ?	0.7 + 0.02 = ?	0.0<A,B<1.0; A 1 DEC PL; B 2 DEC PL; NO CARRYING
32	A - B = ?	0.5 - 0.34 = ?	0.0<A,B<1.0; A 1 DEC PL; B 2 DEC PL; NO BORROWING
33	A + B = ?	151.48 + 833.34 = ?	100<A,B<1000,2 DEC PL; CARRYING ON D1
34	A - B = ?	772.81 - 562.77 = ?	100<A,B<1000,2 DEC PL; BORROWING ON D1
35	A + B = ?	4 + 8.2 = ?	A IS A WHOLE NUMBER; 1.0<B<10.0,1 DEC PL
36	A - B = ?	8 - 1.6 = ?	A IS A WHOLE NUMBER; 1.0<B<10.0,1 DEC PL
37	A + B = ?	23.57 + 104.2 = ?	A HAS 2 OR 3 DEC PL; B HAS 1 DEC PL

38	A - B = ?	267.8 - 63.37 = ?	A HAS 1 DEC PL; B HAS 2 OR 3 DEC PL
39	A X B = ?	2 X 0.3 = ?	A IS A WHOLE # <10; 0.0<B<0.7,1 DEC PL
40	A X B = ?	4 X 1.2 = ?	A IS A WHOLE # <10; 1.0<B<10.0,1 DEC PL
41	A X B = ?	46 X 4.8 = ?	10<A IS A WHOLE #<100; 1.0<B<10.0,1 DEC PL
42	A / B = ?	62.4 / 2.6 = ?	10<? IS A WHOLE #<100; 1.0<B<10.0;
43	A / B = ?	34.8 / 0.29 = ?	100<? IS A WHOLE #<1000; A HAS 1 DEC PL; 0.1<B<1.0,2 DEC PL
44	? X A = B	? X 0.4 = 2.4	? IS A WHOLE #<10; 1.0<=A<=9.0,1 DEC PL
45	? X A = B	? X 1.6 = 36.8	10<? IS A WHOLE #<100; 1.0<A<2.0,1 DEC PL
46	A X ? = B	1.8 X ? = 111.6	10<? IS A WHOLE #<100; 1.0<A<2.0,1 DEC PL
47	A X B = ?	86.6 X 0.344 = ?	A=0.1**N X T WHERE 10<T<1000,N=1,2, OR 3 B=0.1**N X T WHERE 10<T<1000,N=1,2, OR 3
48	A X B = ?	10 X 3.4 = ?	A=10,100, OR 1000; 1.0<B<100.0,1 DEC PL
49	A X B = ?	0.01 X 3.41 = ?	A=0.1,0.01, OR 0.001 ; B=0.1**N X T WHERE 10<T<1000,N=1 OR 2
50	A X B = ?	7.62 X 0.01 = ?	B=0.1,0.01,0.001; A=0.1**N X T WHERE 10<T<1000,N=1 OR 2
51	A + ? = B	38.37 + ? = 892.7	REFER TO #38
52	? + A = B	? + 6.653 = 974.7	REFER TO #38
53	A - ? = B	896.3 - ? = 7.873	REFER TO #38
54	? - A = B	? - 4.2 = 1.6	ONE OF #27,#29,#31,OR #33

55	? / A = B	? / 2.88 = 0.352	REFER TO #47
56	A / B = ?	16.984 / 4.4 = ?	1.0<B<10.0, 1 DEC PL; A<B ?=0.1**N X T WHERE 10<T<1000,N=0 OR 1
57	A / B = ?	1.8122 / 8.2 = ?	1.0<B<10.0 ,1 DEC PL; A<B; ?=0.1**N X T WHERE 10<T<1000,N=3 OR 4
58	? X A = B	? X 4.6 = 2.1068	ONE OF #56 OR #57
59	A X ? = B	6.2 X ? = 3.9928	ONE OF #56 OR #57
60	A / ? = B	6.0918 / ? = 7.1	ONE OF #56 OR #57

APPENDIX B

EASIER LEVELS

A LISTING OF THE EASIER LEVELS

FOR EACH OF THE 60 LEVELS

LEVEL	EASIER	LEVEL	EASIER
1	1	31	29
2	2	32	30
3	1	33	31
4	2	34	32
5	3	35	27
6	4	36	34
7	5	37	33
8	6	38	34
9	7	39	25
10	8	40	39
11	9	41	40
12	11	42	16
13	11	43	42
14	13	44	43
15	14	45	44
16	15	46	45
17	10	47	41
18	10	48	12
19	10	49	48
20	9	50	49
21	15	51	17
22	21	52	51
23	15	53	19
24	13	54	53
25	1	55	47
26	2	56	43
27	25	57	56
28	26	58	57
29	27	59	58
30	28	60	23

APPENDIX C

TEST

1. 8 + 9 = ?
2. 8 - 2 = ?
3. 41 + 57 = ?
4. 459 - 12 = ?
5. 706 + 246 = ?
6. 291 - 285 = ?
7. 371 + 458 = ?
8. 709 - 518 = ?
9. 293 + 628 = ?
10. 815 - 68 = ?
11. 6 x 5 = ?
12. 59 x 100 = ?
13. 82 x 36 = ?
14. 24 / 3 = ?
15. 558 / 93 = ?
16. 100 / 4 = ?
17. 334 + ? = 411
18. ? + 63 = 886
19. 512 - ? = 233
20. ? - 129 = 243
21. 25 x ? = 75
22. ? x 66 = 462
23. 468 / ? = 26
24. ? / 79 = 97
25. 0.1 + 0.7 = ?
26. 0.9 - 0.1 = ?
27. 8.1 + 1.8 = ?

28. 6.5 – 5.4 = ?

29. 1.11 + 8.83 = ?

30. 4.76 – 4.55 = ?

31. 0.4 + 0.48 = ?

32. 0.8 – 0.17 = ?

33. 111.49 + 786.31 = ?

34. 778.56 – 115.39 = ?

35. 9 + 4.1 = ?

36. 9 – 4.6 = ?

37. 52.92 + 411.2 = ?

38. 391.9 – 17.38 = ?

39. 1 x 0.1 = ?

40. 5 x 7.8 = ?

41. 83 x 5.9 = ?

42. 275.4 / 3.4 = ?

43. 210.8 / 0.62 = ?

44. ? x 0.8 = 2.4

45. ? x 1.8 = 97.2

46. 1.3 x ? = 33.8

47. 0.541 x 7.28 = ?

48. 1000 x 57.7 = ?

49. 0.01 x 8.88 = ?

50. 7.52 x 0.001 = ?

51. 67.94 + ? = 698.6

52. ? + 7.587 = 795.7

53. 892.9 – ? = 7.839

54. ? – 0.1 = 0.61

55. ? / 0.72 = 0.373

56. 225.05 / 3.5 = ?

57. 0.22661 / 4.3 = ?

58. ? x 2.1 = 0.8715

59. 3.1 x ? = 2.4397

60. 129.6 / ? = 1.5

APPENDIX D

SAMPLE PRINTOUTS

SAMPLE OF A SELF-PACED PRINTOUT

NOTE THE USE OF THE 'H' ANS 'E' RESPONSE

```
 HI   GOOD LUCK IN YOUR WORK TO-DAY

 PLEASE TYPE IN YOUR I.D. NUMBER
#:        14
 TYPE 1 IF YOUR NAME IS     WENDY      OTHERWISE TYPE 0
#:        1
 GOOD  NOW ON WITH TO-DAYS QUESTIONS

  658.71  -  618.32  = ?      ?=                      (34)*
#:        40.39
 JOLLY GOOD SHOW

  879.95  -  317.18  = ?      ?=                      (34)
#:        H
 ANSWER THIS QUESTION CORRECTLY THEN YOU WILL GO ON
#:        562.77
 O.K.

  3  +  3.2  = ?      ?=                              (35)
#:        H
 ANSWER THIS QUESTION CORRECTLY THEN YOU WILL GO ON
#:        6.2
 O.K.

  9  -  3.3  = ?      ?=                              (36)
#:        12.3
 TRY AGAIN
  9  -  3.3  = ?      ?=
#:        5.7
 THAT IS CORRECT   WENDY

  6  -  5.9  = ?      ?=                              (36)
#:        H
 ANSWER THIS QUESTION CORRECTLY THEN YOU WILL GO ON
#:        0.1
 O.K.

  22.76  +  727.1  = ?      ?=                        (37)
#:        E

  152.56  +  411.37  = ?      ?=                      (33)
#:        563.93

 GOODBYE FOR NOW,  SEE YOU AGAIN  WENDY
```

* THE NUMBER WITHIN THE PARENTHESES WERE ADDED LATER ONLY TO INDICATE THE LEVEL

SAMPLE OF A COMPUTER-PACED PRINTOUT

NOTE THE 'TRY AGAIN' AND 'THE ANSWER IS 101.75' RESPONSES

```
 HI   GOOD LUCK IN YOUR WORK TO-DAY

 PLEASE TYPE IN YOUR I.D. NUMBER
#:        7
 TYPE 1 IF YOUR NAME IS      JOHN      OTHERWISE TYPE 0
#:        1
 GOOD  NOW ON WITH TO-DAYS QUESTIONS


  0.6  -   0.15  = ?      ?=                              (32)
#:        0.55
 TRY AGAIN
  0.6  -   0.15  = ?      ?=
#:        0.45
 THAT IS RIGHT    JOHN

  356.09  +  423.81  = ?      ?=                          (33)
#:        779.90
 GOOD WORK

  232.38  +  241.47  = ?      ?=                          (33)
#:        473.85
 GOOD   NOW TRY THE NEXT ONE

  879.94  -  778.19  = ?      ?=                          (34)
#:        101.85
 TRY AGAIN
  879.94  -  778.19  = ?      ?=
#:        100.85
 THE ANSWER IS  101.75

  0.9  -   0.85  = ?      ?=                              (32)
#:        0.05
 CORRECT ANSWER

  0.6  -   0.29  = ?      ?=                              (32)
#:        0.31
 GREAT

  996.91  -  231.32  = ?      ?=                          (34)
#:        765.59
 FANTASTIC   JOHN


 GOODBYE FOR NOW,  SEE YOU AGAIN   JOHN
```

* THE NUMBERS WITHIN THE PARENTHESES WERE ADDED LATER ONLY TO INDICATE THE LEVEL

APPENDIX E

ANALYSIS OF A STUDENT'S WORK

SAMPLE ANALYSIS OF A STUDENTS WORK FOR THE DAY

ANALYSIS OF CORRECTLY SOLVED PROBLEMS FOR
DARRELL I.D. NO.2 DATE JUNE 2, 1971

PROBLEM	RESPONSE TIME	NO. OF TRIALS	LEVEL
483.07 + 212.77 = ?	48.3	1	33
514.09 + 284.71 = ?	48.9	1	33
121.25 + 553.28 = ?	35.0	1	33
161.56 + 737.17 = ?	31.8	1	33
214.08 + 552.52 = ?	28.7	1	33
1.092 + 815.7 = ?	42.9	1	37
20.51 + 355.1 = ?	30.7	1	37
72.74 + 213.2 = ?	33.2	1	37
3.384 + 256.4 = ?	38.2	1	37
772.3 – 51.41 = ?	54.0	1	38
693.7 – 5.167 = ?	43.9	1	38
572.8 – 15.66 = ?	41.4	1	38
988.9 – 1.799 = ?	34.4	1	38
4 X 0.2 = ?	7.9	1	39
3 X 0.6 = ?	8.2	2	39
1 X 0.5 = ?	7.6	1	39
4 X 0.2 = ?	6.7	1	39
8 X 8.7 = ?	52.9	1	40
7 X 4.8 = ?	23.4	1	40
5 X 1.2 = ?	15.8	2	40
9 X 7.2 = ?	13.6	1	40
28 X 8.6 = ?	53.9	1	41
85 X 2.7 = ?	29.6	1	41
22 X 8.4 = ?	31.7	1	41
87 X 7.6 = ?	64.1	2	41
1000 / 5 = ?	17.5	2	16

MEDIAN RESPONSE TIME: 31.8 SECONDS

ANALYSIS OF UNSOLVED PROBLEMS:

PROBLEM	RESPONSE TIME	ANSWER GIVEN	LEVEL
426.23 + 233.38 = ?	66.1	66000	33
77.4 / 1.8 = ?	11.3	37.3	42

MEDIAN RESPONSE TIME: 11.3 SECONDS

APPENDIX F

EXPERIMENTAL DATA

SUMMARY OF THE LEVELS ACHIEVED AND

THE TEST SCORES FOR THE COMPUTER-PACED GROUP

COMPUTER-PACED MALES

STUDENT NO.	LEVELS ACHIEVED ON DAY 1	2	3	4	5	PRE-TEST SCORE (A)	POST-TEST SCORE (B)	B-A
1	21	31	37	42	42	38	55	17
2	19	25	33	37	42	30	45	15
3	21	37	45	49	54	47	50	3
4	23	34	41	45	47	36	46	10
5	8	17	21	29	36	31	34	3
6	22	38	42	43	45	38	52	15
7	23	41	45	51	55	52	51	-1
AVERAGES	19.6	31.9	37.8	42.3	45.9	38.9	47.6	8.9

COMPUTER-PACED FEMALES

STUDENT NO.	LEVELS ACHIEVED ON DAY 1	2	3	4	5	PRE-TEST SCORE (A)	POST-TEST SCORE (B)	B-A
8	24	38	38	42	43	34	47	13
9	27	37	42	47	52	45	55	10
10	10	10	13	14	19	23	34	11
11	20	30	35	41	43	36	50	14
12	17	14	15	21	28	36	48	12
AVERAGES	19.6	25.8	28.6	33.2	37.0	34.8	46.8	12.0

SUMMARY OF THE LEVELS ACHIEVED AND THE TEST SCORES FOR THE SELF-PACED GROUP

SELF-PACED MALES

STUDENT NO.	LEVELS ACHIEVED ON DAY 1	2	3	4	5	PRE-TEST SCORE (A)	POST-TEST SCORE (B)	B-A
13	6	15	23	39	46	37	39	2
14	13	29	37	44	53	40	53	13
15	2	12	14	20	30	24	16	-6
16	8	13	23	31	37	37	47	10
17	11	23	35	42	46	36	44	8
18	14	25	33	40	48	41	47	6
19	15	34	44	57	60+	47	55	8
AVERAGES	9.9	21.6	29.9	39.0	45.8	37.5	43.3	5.9

SELF-PACED FEMALES

STUDENT NO.	LEVELS ACHIEVED ON DAY 1	2	3	4	5	PRE-TEST SCORE (A)	POST-TEST SCORE (B)	B-A
20	15	29	37	43	53	37	49	12
21	11	40	57	60+	60+	56	60	4
22	15	33	45	59	60+	50	56	6
23	7	16	24	29	33	25	33	8
24	22	37	45	57	60+	37	54	17
AVERAGES	14.0	31.0	41.6	59.6	53.2	41.0	50.4	9.4

NOTE: 60+ INDICATES THAT THE STUDENT HAS REACHED LEVEL 60 AND HAS STARTED OVER AT LEVEL 25.