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ABSTRACT

The purpose of this paper is to report on a pilot investigation of the operation of the Bloom and Carroll hypothesis which states that aptitudes are predictive of rate of learning given a situation in which the time allowed for learning is unlimited, and pupil perserverance, ability to understand instruction, and quality of instruction are optimized for each student. Data for this study were obtained for six separate samples of elementary school students in the individually prescribed instruction project from grades 2 through 6 studying in six different units in arithmetic; sample size varied from 42 to 182. The analyses were carried out in three steps: 1) the correlation between aptitude and rate of learning using two measures previous year rate of learning, and non-verbal I.Q. using Lorge-Thorndike: four rate measures were includ[illegible] [illegible]cribed by Wang (1968); 2) examination of the effectivenes[illegible] ea[illegible] aptitude measure as predictors of a composite rate measure; and, 3) examination of the other variables using the two measures in step one plus aptitude measures of mathematics achievement using the Stanford Achievement Tests and Lorge-Thorndike. Multiple regression analysis was used to investigate the composite contribution of these measures of Carroll's variables to each of the four learning rate measures. The three analyses substantiated the hypothesis that there is no simple relationship between pupil aptitude and rate of learning. (Author/SBE)

# UNIVERSITY OF PITTSBURGH - LEARNING R & D CENTER

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Since Carroll's initial presentation of his model of school learning (Carroll, 1963), a number of investigators have carried out studies to examine the hypothesized relationships suggested by the model. Bloom (1968), in a paper that should prove highly valuable to persons concerned with the individualization of school programs, has used the variables discussed by Carroll to contrast conditions in the typical group instruction situation with the conditions that should characterize effective individualized instruction.

Bloom introduces his application of the Carroll model as follows:

> Put in its most brief form the model proposed by Carroll (1963) makes it clear that if the students are normally distributed with respect to aptitude for some subject (mathematics, science, literature, history, etc.) and all students are provided with exactly the <u>same instruction</u> (same in terms of amount of instruction, quality of instruction, and time available for learning), the end result will be a normal distribution on an appropriate measure of achievement. . . . Conversely, if the students are normally distributed with respect to aptitude, but the kind and quality of instruction and the amount of time available for learning are made appropriate to the characteristics and needs of <u>each</u> student, the majority of students may be expected to achieve mastery of the subject (Bloom, 1968).

He then goes on to describe the basic variables in the Carroll model, (a) aptitude for particular kinds of learning, (b) quality of instruction, (c) ability to understand instruction, (d) perseverance, and (e) time.

## Purpose of the Study

The writers, in working with a program for individualized instruction, the Individually Prescribed Instruction Project (Lindvall & Bolvin, 1967), have been concerned with the problem of mastery learning and have examined the operation of certain measures of the variables identified by Carroll and Bloom. Their hypothesis is that "aptitudes are predictive of rate of learning" (Bloom, 1968), given a situation in which the time allowed for learning is unlimited, and pupil perseverance, ability to understand instruction, and quality of instruction are optimized for each student (or where their relationship to rate is partialed out). Bloom and Carroll do not imply that there is necessarily a neat mathematical relationship among their variables. Rather, they seem to suggest that these are factors which must be considered if mastery is to be achieved by all.

The purpose of this paper is to report on a pilot investigation of the operation of such variables in an individualized learning system, the Individually Prescribed Instruction Project, in which each student takes whatever time he needs to achieve mastery of each unit of instruction, and in which all students are expected to master each lesson.

Data for this study were obtained for six separate samples of elementary school students in grades 2 through 6 studying in six different units in arithmetic. The students in each of these units represented one of the six samples, sample size varying from 42 to 182. The same relationships among the Carroll variables were studied in each of the six samples. The analyses of these relationships were carried out in three steps:

Step 1

The first relationship investigated was the simple correlation between aptitude and rate of learning. This analysis can be considered as bearing on the question, "In a system which provides for individualized rates of progress, is aptitude significantly correlated with rate of learning even if perseverance, ability to understand instruction, and quality of instruction are ignored or are assumed to be optimized?" In studying this, two measures of aptitude were used, (a) rate of learning during the previous year, and (b) non-verbal I.Q. as measured by the Lorge-Thorndike (since the content area involved was math).

Four different rate measures were used in the analyses. The rate measures were:

$$Rate_1 = \frac{\text{100\% on pretest}}{\text{days worked on unit}}$$

$$Rate_2 = \frac{\text{number of pages worked}}{\text{days worked on unit}}$$

$$Rate_3 = \frac{\text{number of skills learned}}{\text{days worked on unit}}$$

$$Rate_4 = \text{total number of skills acquired}$$

The decision to use four different measures of current rate of learning was based on findings from an earlier study (Yeager & Lindvall, 1967) which indicated that any one measure had certain obvious restrictions in terms of describing a pupil's rate of progress. The four measures are described in detail by Wang (1968). Note that each rate index involves the ratio of amount of content covered to a given time period, and that the major variation from one index to another is in the measure of amount of content covered.

Step 2

On the assumption that any one of the four measures for current rate in a given unit may be lacking in comprehensiveness and reliability (Wang, 1968), the effectiveness of each of these two aptitude measures as predictors of a composite rate measure was examined. This involved finding the multiple correlation between a composite of these four rate measures and each of the two aptitude measures.

Step 3

As will be seen, the results of Steps 1 and 2 indicate that there is little relationship between rate and aptitude if perseverance, ability to understand instruction, and quality of instruction are ignored or if these factors are assumed to be operating at an optimum level for all. This suggested the need for examining the effects of these additional variables from the Carroll model as they operate in our individualized system. Just how these variables are to be measured is a difficult question, and Bloom and Carroll do not offer specific guidelines.

Table 1 lists all measures used in the analyses for Step 3, with an indication of which Carroll variable is estimated by each.

Besides the two aptitude measures used in Step 1 of the study, two additional indices of aptitude for mathematics were identified for inclusion in the analyses for Step 3. These measures were added to reduce the probability that some important aspect of aptitude was being neglected in the analysis. The four aptitude measures used in Step 3 are (a) non-verbal I.Q. as measured by the Lorge-Thorndike, (b) number of mathematics skills mastered during the previous year (1967), (c) mathematics achievement as measured by the Stanford Achievement Tests and (d) M.A. as measured by the Lorge-Thorndike.

In discussing perseverance, Carroll emphasizes the "time the student is actively engaged in learning." We decided to measure this variable by observing a time sample of each student's behavior while he was working on a unit of study, and determining the percent of time that he was overtly attentive to his lesson materials. This involved the use of a trained observer, centering his attention on one student at a time and observing each student during three different ten-minute time samples (i.e., for a total of 30 minutes).

For estimating "ability to understand instruction," Carroll suggests the use of verbal ability and reading achievement measures. The tests used in the present study were the Verbal I.Q. obtained from the Lorge-Thorndike and the Reading score from the appropriate level of the Stanford Achievement Tests.

The problem of obtaining an estimate of the "quality of instruction" was much more difficult. In most situations the straightforward way to measure quality of instruction would be to evaluate pupil performance under instruction, using either level of achievement or time required to learn. Neither of these measures was available here since level of achievement was the same for all (i.e., every pupil is required to attain a mastery score), and time required was the major component of the dependent variable. In a sense, of course, the objective of the whole investigation was to learn more about assessing quality of instruction. Given this situation, it was decided to investigate the use of a very simple estimate of quality of instruction. At the end of each lesson within a unit the student was asked to respond to two specific questions:

Question 1 "Was this work hard or difficult for you?"
(responses: 'very easy' to 'very difficult')

Question 2 "How well did you like the things you did?"
(responses: 'like very much' to 'dislike very much')

The pupil's score for each given unit was the average of his responses to each of these questions over all lessons in the unit.

Step 3, which represents the major analysis carried out in this study, was undertaken to investigate the contribution of the above measures of the Carroll variables to the variance in rate of learning. To do this a multiple regression analysis was carried out. This involved determining the multiple r's and the regression equations for predicting each of the four rate measures from a composite of the nine measures of the Carroll variables ($X_1$ through $X_9$ in Table 1). This was done for each of the six math units.

## Results

Results of the simple analysis carried out in Step 1 are shown in Table 2, which presents the correlation of the two measures of aptitude, rate in previous year and non-verbal I.Q., with each of four different measures of rate in six different units of elementary school mathematics.

It can be seen from Table 2 that only a few of the correlations between aptitude and rate are significant and that even the significant r's are quite small. One point that seems to be suggested by the data is that, of the two aptitude measures, rate in previous year is the more promising as a possible predictor of present rate.

Since no one of the four rate measures was significantly correlated with either of the measures of aptitude over all six units, the second step in the analysis investigated the relationship of a composite rate measure to aptitude. This involved determining the multiple correlation coefficients between a composite of the rate measures and each aptitude measure (non-verbal I.Q. and rate in the preceding year). These are presented in Table 3. Note that only two out of twelve multiple r's are significant. This suggests that the lack of correlation between aptitude and rate probably is not a function of a lack of comprehensiveness in the rate measures used.

The first two analyses carried out in this study served to substantiate our hypothesis that there is no simple relationship between pupil aptitude and rate of learning under IPI. For this reason, the major investigation of this study, carried out in Step 3, was concerned with the extent to which other variables in the Carroll model are associated with variance in rate of learning. This was carried out through a multiple regression analysis in which each rate measure was used separately as the dependent variable, and various measures of the Carroll variables, as described previously, were used as predictors. Table 4 presents the data for those units and those rate measures for which the multiple r was significantly different from zero.

Since Beta weights are so inconsistent from sample to sample, it has been recommended that structure R's be examined to indicate the relative contribution of various variables (Cooley, 1965). Structure R's are correlations between the original predictors and the derived linear composite of the predictors. The results are shown in Table 5. The most significant overall result apparent from Tables 4 and 5 is that there is no simple explanation of the relationship between our measures of variables in the Carroll model and pupil rate of learning.

## Discussion

The relative contribution of the different variables to the variance in rate of learning is quite inconsistent from one situation to another. The lack of a consistent pattern for the predictability of rate of learning would seem to have implications both for measurement of the variables involved and for the operation of an individualized system. The lack of a significant multiple correlation in some instances even when all of the predictor variables are used may, for example, suggest the need for a more reliable measure of rate or a more comprehensive measure of quality of instruction. On the other hand, in almost all cases in which significant multiple R's are found, the structure R associated with "previous rate" ($X_3$) is rather consistently of substantial size, suggesting that this measure is a major component of the composite that correlates highly with rate. Since "previous rate" is treated as a measure of "aptitude" in our study--an indicator of the student's ability to learn mathematics under an individualized instructional system--this result would seem to substantiate the basic hypothesis of the Carroll model, namely, that rate of learning is a means of aptitude.

The writers also suspect that their failure to demonstrate a consistent and significant correlation between aptitude and rate suggests something about the efficiency of the individualized system that they were studying. Although IPI has been shown to be a successful system for achieving mastery learning for all on an individualized basis, it may not yet be an efficient system, defined here as one in which such variables as those listed in Carroll's model for school learning (amount of instruction, quality of instruction and time required for learning) are operating at a maximum efficiency level.

Bloom points out that the "task of a strategy for mastery learning is to find ways of altering the time individual students need for learning as well as to find ways of providing whatever time is needed by each student." At the same time, he cautioned about the difficulty of achieving such efficiency in an individualized system (Bloom, 1968).

The writers recognize that their efforts to measure the variables suggested by the Carroll model have involved some very crude measures in several instances. More valid and reliable measures might have resulted in stronger relationships between aptitude and rate than those that were found. However, what would seem to be a more fruitful path to follow in demonstrating a stronger relationship would be to develop such a variety of instructional treatments that one would closely approximate the situation in which every student receives a high quality of instruction. If, as Bloom suggests, this could also reduce the importance of perseverance, the relationship between some measure of aptitude and a measure of rate of learning should be a relatively simple one.

If this latter relationship should emerge and should be verified over many units and subjects, that is, if it could be shown that in situations in which a high quality of instruction has been developed there is a relatively high correlation between aptitude and rate of learning (perhaps with a partialing out of some measure of ability to understand instruction), then in subsequent development efforts the magnitude of this correlation between aptitude and rate could be used in evaluating the effectiveness of instruction.

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TABLE 1

MEASURES EMPLOYED IN THIS STUDY TO ESTIMATE THE VARIABLES INVOLVED IN THE CARROLL MODEL

| Variable as Named by Carroll | | Measures of Variable Used in this Study |
|---|---|---|
| Aptitude | ($X_1$) | Non-verbal I.Q. (Lorge-Thorndike) |
| | ($X_2$) | Number of Math Skills Mastered in 1967 |
| | ($X_3$) | Math Achievement (Stanford) |
| | ($X_4$) | M.A. (Lorge-Thorndike) |
| Quality of Instruction | ($X_5$) | Question 1 |
| | ($X_6$) | Question 2 |
| Ability to Understand | ($X_7$) | Verbal I.Q. |
| | ($X_8$) | Reading Achievement (Stanford) |
| Perseverance | ($X_9$) | Attention as Observed |
| Time Allowed for Learning | | (Not measured. Each pupil given time needed.) |
| Rate of Learning | (Rate 1) | $\frac{100 - \% \text{ on Pretest}}{\text{days worked on unit}}$ |
| | (Rate 2) | $\frac{\text{no. of pages worked}}{\text{days worked on unit}}$ |
| | (Rate 3) | $\frac{\text{no. of skills learned}}{\text{days worked on unit}}$ |
| | (Rate 4) | total no. of skills acquired |

TABLE 2

CORRELATION OF TWO MEASURES OF APTITUDE (RATE IN PREVIOUS YEAR AND NON-VERBAL I.Q.) WITH FOUR MEASURES OF RATE OF LEARNING IN EACH OF SIX UNITS OF INSTRUCTION
(ONLY SIGNIFICANT CORRELATIONS ARE REPORTED)

| | E-Num (N=182) | | E-PV (N=109) | | E-Add (N=42) | | E-Sub (N=103) | | E-Mult (N=111) | | E-COP (N=62) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ |
| Rate 1 | | | .245* | | .403** | | .255** | | | | | |
| Rate 2 | .193** | | .335** | | .314* | | .341** | .242* | | | | |
| Rate 3 | | | | | | | .247** | | .293** | | | |
| Rate 4 | | | | | | | | | | | .288* | |

*Significant at .05 level
**Significant at .01 level

TABLE 3

MULTIPLE CORRELATION BETWEEN APTITUDE AND A COMPOSITE RATE MEASURE FOR EACH OF TWO MEASURES OF APTITUDE IN EACH OF SIX UNITS OF INSTRUCTION

| | E-Num (N=182) | | E-PV (N=109) | | E-Add (N=42) | | E-Sub (N=103) | | E-Mult (N=111) | | E-COP (N=62) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ | Rate | NV-IQ |
| Composite Rate | .220 | .197 | .352 | .236 | .479 | .232 | .429** | .263 | .348* | .139 | .387 | .263 |

*Significant at .05 level
**Significant at .01 level

TABLE 4

BETA COEFFICIENTS FOR MULTIPLE REGRESSION EQUATIONS FOR PREDICTING INDICATED RATE MEASURE IN MATHEMATICS UNITS FOR CASES WHERE THE MULTIPLE CORRELATION IS SIGNIFICANT

| Rate Measure | Unit | Multi. R | Non-verb I.Q. ($X_1$) | Skills 1967 ($X_2$) | Math Achieve. ($X_3$) | Total M.A. ($X_4$) | Ques. 1 ($X_5$) | Ques. 2 ($X_6$) | Verb I.Q. ($X_7$) | Read Achieve. ($X_8$) | Atten. ($X_9$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Place Value | .433* | -.024 | .189 | .247 | -.172 | -.049 | -.033 | -.093 | .022 | -.059 |
| 1 | Addition | .642* | -.494 | -.353 | -.122 | .131 | .081 | -.217 | .325 | -.203 | .292 |
| 1 | Subtraction | .524** | -.467 | .171 | .113 | .219 | .194 | -.056 | .219 | .086 | .159 |
| 2 | Numeration | .343** | -.133 | .280 | -.027 | -.077 | -.113 | -.088 | .213 | -.194 | -.049 |
| 2 | Place Value | .450** | -.132 | .371 | .193 | -.040 | -.209 | -.004 | .016 | .044 | -.032 |
| 2 | Subtraction | .502** | -.380 | .243 | .008 | .275 | .048 | .083 | -.025 | .033 | .205 |
| 3 | Subtraction | .517** | -.370 | .138 | .107 | .247 | .290 | -.084 | .187 | .263 | .035 |
| 3 | Multiplication | .416* | .037 | .241 | .210 | .072 | -.099 | .026 | .064 | -.046 | .136 |
| 3 | Numeration | .337** | -.139 | -.041 | .073 | .265 | .166 | .133 | -.024 | -.029 | .213 |

**.01 level of significance
*.05 level of significance

TABLE 5

STRUCTURE R'S OF EACH VARIABLE FOR THE INDICATED RATE MEASURE IN MATHEMATIC UNITS FOR CASES WHERE THE MULTIPLE CORRELATION IS SIGNIFICANT

| | | | | Structure R | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rate Measure | Unit | Non-verb I.Q. ($X_1$) | Skills 1967 ($X_2$) | Math Achieve. ($X_3$) | Total M.A. ($X_4$) | Ques. 1 ($X_5$) | Ques. 2 ($X_6$) | Verb I.Q. ($X_7$) | Read Achieve. ($X_8$) | Atten. ($X_9$) |
| 1 | Place Value | .150 | .567 | .796 | .718 | .141 | -.112 | .084 | .539 | -.272 |
| 1 | Addition | -.077 | .628 | .208 | .304 | .075 | .110 | .230 | .602 | .643 |
| 1 | Subtraction | -.265 | .487 | .426 | .292 | .384 | -.024 | .146 | .418 | .384 |
| 2 | Numeration | -.328 | .562 | -.193 | -.257 | -.383 | -.363 | -.139 | -.349 | -.073 |
| 2 | Place Value | -.261 | .743 | .388 | .221 | -.286 | -.334 | -.105 | .257 | -.131 |
| 2 | Subtraction | -.483 | .679 | .185 | .125 | .088 | -.302 | -.304 | .177 | .366 |
| 3 | Subtraction | -.091 | .477 | .230 | .420 | -.450 | -.013 | .246 | .613 | -.014 |
| 3 | Multiplication | .081 | .484 | .038 | .369 | .132 | .181 | .594 | -.157 | -.166 |
| 4 | Numeration | .204 | .068 | .293 | .369 | .543 | .479 | .160 | .203 | .489 |