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AUTHOR	Federico, Pat-Anthony
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ABSTRACT

To determine whether individual differences in student achievement and learning rate are reduced or eliminated by mastery instruction, 166 Navy trainees who had completed a computer-managed course in basic electricity and electronics were cluster-analyzed into groups, using 24 measures of cognitive characteristics. Discriminant analyses were computed between the two derived groups using module test scores and completion times. Groups differed significantly in their achievement in 4 out of 11 modules and in the time required to complete 1 module, but did not demonstrate a progressive decrease in the variability of their achievement and learning rates. Twenty-eight references are listed. (Author/LMM)

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COMPUTER-MANAGED INSTRUCTION: INDIVIDUAL DIFFERENCES IN STUDENT PERFORMANCE

Pat-Anthony Federico

Reviewed by
E. G. Aiken

Approved by
J. S. McMichael

Released by
J. W. Renard
Captain, U.S. Navy
Commanding Officer

Navy Personnel Research and Development Center
San Diego, California 92152

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To determine whether individual differences in student achievement and learning rate are reduced or eliminated by mastery instruction, 166 Navy trainees who had completed a computer-managed course in basic electricity and electronics were cluster-analyzed into groups, using 24 measures of cognitive characteristics. Discriminant analyses were computed between the two derived groups using module test scores and completion times. Groups differed significantly in their achievement in 4 out of 11 modules and in the time required to complete 1 module, but did not

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FOREWORD

This research was performed under exploratory development work unit RF63-522-801-013-03.04 (Testing Strategies for Operational Computer-based Training) under the sponsorship of the Chief of Naval Material (Office of Naval Technology). The goal of this work unit is to evaluate the impact of different computer-based testing strategies for operational testing.

The results of this study are primarily intended for the Department of Defense training and testing research and development community.

J. W. RENARD
Captain, U.S. Navy
Commanding Officer

J. W. TWEEDDALE
Technical Director

SUMMARY

Problem

Advocates of mastery learning have proposed that individual differences in student performance (i.e., achievement and learning rate) would nearly vanish if this mode of instruction were implemented. Critics of mastery learning have maintained that it does not produce equal school performance among different students. Data are required to support or refute the contention that the computer-managed, mastery-learning approach to instruction can reduce individual differences in student performance.

Objective

The objective of this research was to determine whether individual differences in student performance (achievement and learning rate) are reduced or eliminated in the mastery-learning approach implemented in computer-managed instruction (CMI).

Approach

Subjects—166 Navy trainees who completed a computer-managed course in basic electricity and electronics—were cluster-analyzed into groups, using 24 measures of their cognitive characteristics. Discriminant analyses were computed between the two derived groups using module-test scores and completion times.

Results

Groups differed significantly in their achievement in 4 out of 11 modules and in the time required to complete 1 module. They did not demonstrate a progressive decrease in the variability of their achievement and learning rate throughout the sequential modules.

Discussion and Conclusions

These findings imply for CMI and mastery learning in general--computer-based or otherwise--that individual differences do indeed make a difference. Computer-managed mastery learning does not seem to eliminate entirely the consequences of incoming cognitive characteristics for subsequent subject-matter acqusition. Even though all successful students meet or exceed the mastery level of learning for each module, the amount of their achievement will tend to differ in some of the instructional modules. No method of instruction--not even computer-managed mastery learning--produces identical instructional outcomes in all students.

Recommendations

Diagnostic testing techniques that are very sensitive to the extent of students' subject-matter knowledge should be designed and used. Also, summative assessment methods should be established to supplement these improved formative measurements and identify more accurately how students differ with respect to subject-matter achievement. With this additional information at hand, course supervisors and instructors will be in a better position to remediate students as well as to assign them to follow-on training or job-related tasks.

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INTRODUCTION

Problem

Among the many major features of mastery learning are:

1. Mastery is explained relative to the specific instructional objectives every student is required to achieve.

2. The instruction itself is structured into clearly defined learning units or modules.

3. Every student must master each module completely before proceeding to the next module.

4. A diagnostic objectives-referenced test is administered to every student at the end of each module to provide feedback on the adequacy of the student's learning.

5. Based upon the diagnostic information, a student's original instruction is remediated and/or supplemented so that he or she can successfully master the module.

6. Time to complete each module is used as the means of individualizing instruction and thus promoting mastery of the material.

Advocates (Block 1974; Bloom, 1974, 1976) of mastery learning have proposed that individual differences in student performance (i.e., achievement and learning rate) would nearly vanish if this mode of instruction were implemented. Critics (e.g., Greeno, 1977, 1978; Resnick, 1977) of mastery learning have maintained that this manner of teaching does not produce equal school performance among different students. Data are required to support or refute the contention that individual differences in student performance can be reduced by the mastery-learning approach to instruction.

Objective

The objective of this research was to determine whether individual differences in student performance (achievement and learning rate) are reduced or eliminated in the mastery-learning approach implemented in computer-managed instruction (CMI).

APPROACH

Subjects

The subjects were 340 individuals who graduated from recruit training at the Naval Training Center (NTC), San Diego and were scheduled for training at the Basic Electricity and Electronics (BE/E) School at NTC San Diego. Before beginning BE/E orientation, the subjects were administered 12 tests--6 designed to measure their cognitive styles; and 6, their abilities. Test data were discarded for 20 subjects who did not follow directions and/or completed less than 9 of the 12 tests and for 40 who did not graduate--35 for academic and 5 for nonacademic reasons. Thus, test data were available for 280 BE/E graduates.

Aptitudes of all individuals entering the Navy are measured by scores obtained on the 12 subtests of the Armed Services Vocational Aptitude Battery (ASVAB). However, ASVAB scores for 108 subjects of this study were either incomplete or missing. For 6 additional graduates, the module test scores and times needed to complete each of the basic modules, which the CMI system usually maintains for all BE/E students, were missing or incomplete. Thus, the final sample used in this study consisted of 166 BE/E graduates.

Individual Difference Measures

Cognitive styles are the dominant modes of information processing that individuals typically employ when perceiving, learning, or problem solving (e.g., tolerance of ambiguity). Abilities are the intellectual capabilities of individuals that are general and pervasive to the performance of many tasks (e.g., verbal comprehension). Aptitudes are indices used to select personnel to perform tasks that demand specific skills and to find the right person for a certain job or school (e.g., mathematical or mechanical aptitude). Table 1 presents and briefly describes the 24 tests used in this study. The six tests designed to measure cognitive styles were selected because of their implications for adaptive instruction (Kogan, 1971); and the six tests designed to measure abilities, because they represent various types of information-processing tasks (Carroll, 1976) and are relevant to the BE/E subject matter. The 12 ASVAB subtests were selected as measures of aptitudes because the scores of Navy personnel are typically readily available and are used in assigning personnel to different Navy schools. All of the tests are (1) relatively independent, (2) moderate to high in reliability, (3) paper and pencil in nature, and (4) fairly short in duration.

CMI and Instructional Materials

In CMI, students self-study and self-pace themselves through off-line lesson modules (i.e., they do not directly interact with the system while learning). This differs from computer-assisted instruction where students interact in real time with course contents and tests stored in the computer via on-line terminals. Also, in CMI, the computer via its distributed terminals (1) scores criterion-referenced multiple-choice tests that the students take off-line, (2) interprets test results and provides students with feedback regarding their performance, (3) advises students to learn the next or alternative lesson or to remediate mastery modules, and (4) manages student records, instructional resources, and administrative data (Baker, 1978; Orlansky & String, 1979).

The instructional material consisted of the first 11 modules of the computer-managed BE/E curriculum. Table 2 summarizes the subject matter content. These modules were used in this study since students from all electronics-related Navy ratings must master them successfully before proceeding to more specialized training. The achievement test score for each of these sequential hierarchical modules was simply the number of items correct on a student's first attempt at taking a mastery quiz. These end-of-module tests consisted of from 10 to 45 four-alternative multiple-choice items that were congruent with instructional objectives. The number of contact hours each student required to master the instructional material of each module was retrieved from the CMI system.

Statistical Analyses

Subjects were cluster analyzed (Everitt, 1974; Hartigan, 1975) into groups using a procedure developed by Wolfe (1970, 1978) which used as input data the 24 measures

Table 1

Cognitive Characteristic Measures

Cognitive Characteristic	Abbreviation	Description	Measurement Instrument
		Cognitive Styles	
Field independence vs. field dependence	FILDINDP	Analytical vs. global orientation	Hidden figures test, part I (Ekstrom, French, Harman, & Derman, 1976)
Conceptualizing style	CONCSTYL	Span of conceptual category	Clayton-Jackson object sorting test (Clayton & Jackson, 1961)
Reflectiveness-impulsiveness	REFLIMPL	Deliberation vs. impulse	Impulsivity subscale from personality research test, form E (Jackson, 1974)
Tolerance of ambiguity	TOLRAMBQ	Inclined to accept complex issues	Tolerance of ambiguity scale from self-other test, form C (Rydell & Rosen, 1966)
Category width	CATEWIDH	Consistency of cognitive range	Category width scale (Pettigrew, 1958)
Cognitive complexity	COGCOMPX	Multidimensional perceptions of the environment	Group version of role construct repertory test (Bieri, Atkins, Briar, Leaman, Miller, & Tripodi, 1966)
		Abilities	
Verbal comprehension	VERBCOMP	Understanding the English language	Vocabulary test, part I (Ekstrom et al., 1976)
General reasoning	GENLREAS	Solving specific problems	Arithmetic aptitude test, part I (Ekstrom et al., 1976)
Associational fluency	ASSOFLUN	Producing similar words rapidly	Controlled associations test, part I (Ekstrom et al., 1976)
Logical reasoning	LOGIREAS	Deducing from premise to conclusion	Nonsense syllogisms test, part I (Ekstrom et al., 1976)
Induction	INDUCTON	Forming hypotheses to fit certain facts	Figure classification test, part I (Ekstrom et al., 1976)
Ideational fluency	IDEAFLUN	Generating ideas about a specific type	Topics test, part I (Ekstrom et al., 1976)
		Aptitudes	
General information	GENLINFO	Recognizing factual information	General information subtest, ASVAB
Numerical operations	NUMROPER	Completing arithmetic operations	Numerical operations subtest, ASVAB
Attention to detail	ATTNDETL	Finding an important detail	Attention to detail subtest, ASVAB
Word knowledge	WORDKNOL	Comprehending written and spoken language	Word knowledge subtest, ASVAB
Arithmetic reasoning	ARTHREAS	Solving arithmetic word problems	Arithmetic reasoning subtest, ASVAB
Space perception	SPACPERC	Visualizing objects in space	Space perception subtest, ASVAB
Mathematics knowledge	MATHKNOL	Employing mathematical relationships	Mathematics knowledge subtest, ASVAB
Electronics information	ELECINFO	Using electronics relationships	Electronics information subtest, ASVAB
Mechanical comprehension	MECHCOMP	Reasoning with mechanical concepts	Mechanical comprehension subtest, ASVAB
General science	GENLSCIE	Perceiving relationships between scientific concepts	General science subtest, ASVAB
Shop information	SHOPINFO	Knowing shop tools	Shop information subtest, ASVAB
Automotive information	AUTOINFO	Knowing automotive functions	Automotive information subtest, ASVAB

Table 2

Subject-matter Content of First 11 Modules of BE/E School
(Course File 69)

Module Number	Subject-matter Content
1	Electrical current--electron movement, current flow, measurement
2	Voltage--electromotive force (EMF), magnetism, induction, AC/DC
3	Resistance--characteristics, resistors, ohmmeters
4	Measuring current and voltage in series circuits--using the multimeter
5	Relationships of current, voltage, and resistance--Ohm's law, power, trouble-shooting series circuit
6	Parallel circuits--rules for voltage and current, resistance and power trouble-shooting
7	Combination circuits and voltage dividers--solving complex circuits, voltage reference, and dividers
8	Induction--electromagnetism, inducing voltage, flux density, inductance
9	Relationships of current, counter EMF, and voltage in inductance-resistance circuits--rise and decay of current and voltage, LR time constants, reactance, phase relationships
10	Transformers--construction, theory, operation, turns and voltage ratios, efficiency, rectifiers
11	Capacitance--theory, resistance-capacitance time constant, capacitive reactance, phase and power relationships, capacity design considerations

of cognitive characteristics. After discarding data for subjects who were outliers and who formed a group with a small sample, a stepwise multiple discriminant analysis (Cooley & Lohnes, 1962; Overall & Klett, 1972) was performed on the two remaining groups to specify how their cognitive attributes differed. Subsequently, two more stepwise multiple discriminant analyses were computed between these two groups using module test scores and completion times to determine if and how they varied in school performance.

RESULTS

In general, students whose cognitive characteristics varied did not attain the same level of achievement or maintain the same learning rate throughout all the elementary modules of computer-managed mastery instruction. The following paragraphs explain how students were grouped on the basis of individual differences in cognitive attributes and how their learning performance was evaluated.

Clustering Students into Groups

Wolfe's NORMIX procedure indicated that the optimal clustering of students using their measured cognitive characteristics was a four-group solution (logarithm of likelihood ratio of four to three groups = .66; χ^2 = 110.09; p = .00); that is, four distinctly different groups existed within the sample of students. According to the discriminant functions with their respective coefficients, these four derived groups varied along three independent dimensions; namely, TOLRAMBQ and MECHCOMP (.32 and .23), REFLIMPL (.51), and VERBCOMP and GENLREAS (.19 and .17). The three two-dimensional plots relative to the discriminant axes revealed that group 2 consisted of three outliers, and group 4 with only 15 members formed too small a group for subsequent statistical analyses. Consequently, groups 2 and 4 were omitted from further consideration in this study.

Distinguishing Characteristics of Groups 1 and 3

The summary of the stepwise discriminant analysis between groups 1 and 3 using measures of their cognitive characteristics is presented in Table 3. The effectiveness of this discrimination to differentiate significantly between the two groups was reflected in the prediction results based upon the derived classification functions using students' cognitive characteristics. One-hundred percent of the members of groups 1 and 3 were correctly classified into their respective groups. The means, standard deviations, univariate F-ratios, and standardized discriminant coefficients for these clusters are tabulated in Table 4. The discriminant coefficients, together with the univariate F-ratios, indicated that the primary measures distinguishing between groups 1 and 3 were SPACPERC, MECHCOMP, and AUTOINFO. Table 4 shows that group 3 scored higher in SPACPERC and MECHCOMP than did group 1 with the opposite true for AUTOINFO.

Examining the Performance of Groups 1 and 3

1. Achievement within modules. The summary of the stepwise discriminant analysis, means, standard deviations, univariate F-ratios, and standardized discriminant coefficients of module scores for groups 1 and 3 are tabulated in Table 5. These statistics indicate that the members of groups 1 and 3 differed significantly in their achievement in modules 4, 5, 6, and 11. Table 5 shows that group 3 learned slightly more than did group 1 in modules 4, 5, and 6. There was a reversal in their achievement in module 11.

Table 3

Summary of Stepwise Discriminant Analysis for Groups 1 and 3 Using Cognitive Characteristics

Step Number	Variable Entered[a]	F to Enter or Remove	Wilks' Lambda (Λ)[b]	Rao's V	Change in Rao's V[b]
1	SPACPERC	61.12	.71	61.12	61.12
2	AUTOINFO	20.85	.62	90.92	29.80
3	TOLRAMBQ	19.41	.54	122.85	31.93
4	MECHCOMP	22.40	.47	164.97	42.11
5	ARTHREAS	17.58	.42	203.45	38.49
6	INDUCTON	16.08	.38	243.30	39.84
7	VERBCOMP	16.23	.34	288.42	45.12
8	GENLINFO	27.27	.28	373.64	85.22
9	LOGISREAS	13.73	.26	425.33	51.69
10	NUMROPER	7.32	.24	455.85	30.52
11	IDEAFLUN	8.94	.23	495.40	39.55
12	ASSOFLUN	5.97	.21	523.75	28.35
13	MATHKNOL	3.54	.21	541.46	17.71
14	GENLSCIE	4.35	.20	563.93	22.47
15	WORDKNOL	3.61	.20	583.32	19.39
16	CONCSTYL	4.43	.19	607.98	24.66
17	GENLREAS	2.72	.19	623.76	15.78
18	CATEWIDH	2.76	.19	640.25	16.48
19	REFLIMPL	2.50	.18	655.50	15.35
20	ATTNDETL	2.05	.18	668.56	12.97
21	FILDINDP	1.94	.18	681.08	12.51

[a]Variables are defined in Table 1.

[b]The exact probabilities of Wilks' lambda and change in Rao's V were all zero.

Table 4

Means, Standard Deviations, Univariate F-ratios, and Standardized Discriminant Coefficients of the Cognitive Characteristics for Groups 1 and 3

Cognitive Characteristics[a]	Group 1		Group 3		F	D
	Mean	SD	Mean	SD		
FILDINDP	4.85	3.60	6.10	3.97	3.93	-.07
CONCSTYL	12.74	4.08	13.05	4.17	0.20	-.09
REFLIMPL	2.50	2.13	2.91	2.34	0.67	-.09
TOLRAMBQ	5.24	1.67	6.23	2.26	9.40	.28
CATEWIDH	31.35	9.19	32.14	9.13	0.26	.09[b]
COGCOMPX	73.33	16.79	72.43	20.42	0.08	--
VERBCOMP	8.74	3.12	9.50	3.14	2.06	.29
GENLREAS	8.34	2.58	8.39	2.85	0.01	-.10
ASSOFLUN	10.05	4.38	11.46	5.78	2.82	.10
LOGIREAS	3.37	4.71	1.70	4.32	4.67	-.23
INDUCTON	62.58	14.78	59.25	15.98	1.66	-.29
IDEAFLUN	12.13	4.58	10.43	3.17	5.97	-.18
GENLINFO	59.54	6.47	57.27	6.45	4.31	-.27
NUMROPER	54.39	6.77	55.46	6.80	0.87	.14
ATTNDETL	51.91	8.02	51.18	11.24	0.21	-.07
WORDKNOL	59.45	5.42	60.14	6.01	0.53	.12
ARTHREAS	61.85	5.30	60.48	7.13	1.77	-.31
SPACPERC	54.21	6.84	63.07	6.44	61.12	.58
MATHKNOL	61.33	5.99	62.20	5.68	0.76	.20[b]
ELECINFO	60.20	5.60	62.25	5.50	4.75	--
MECHCOMP	58.70	5.70	62.57	5.53	16.46	.57
GENLSCIE	60.64	6.57	61.18	7.30	0.21	-.20[b]
SHOPINFO	58.06	5.43	58.46	7.87	0.13	--
AUTOINFO	59.12	5.56	56.66	7.57	5.15	-.53

Notes.

$F(1,146) \geq 3.91$; $p < .05$.

$\Lambda = .18$; $\chi^2(21) = 235.00$; $p = .00$.

$\lambda = 4.66$; % = 100.00; $R_c = .91$.

$c_1 = -.71$; $c_3 = 1.16$.

$n_1 = 92$; $n_3 = 56$.

λ = Eigenvalue.

% = Relative percentage.

R_c = Canonical correlation.

c_1 = Centroid group 1; c_3 = Centroid group 3.

D = Standardized discriminant coefficient.

[a]Cognitive characteristics are defined in Table 1.

[b]As COGCOMPX, ELECINFO, and SHOPINFO did not enter into the stepwise discriminant function, no discriminant coefficients are reported for them.

Table 5

Summary of Stepwise Discriminant Analysis, Means, Standard Deviations, Univariate F-ratios, and Standardized Discriminant Coefficients for Groups 1 and 3 Using Module Scores

Step Number	Variable Entered	F to Enter or Remove	Wilks' Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
1	SCORM04[a]	4.97	.97	.03	4.97	4.97	.03
2	SCORM11	3.32	.95	.02	8.43	3.46	.06
3	SCORM06	3.84	.92	.01	12.55	4.12	.04
4	SCORM05	1.18	.91	.01	13.86	1.31	.25

Variable	Group 1 Mean	Group 1 SD	Group 3 Mean	Group 3 SD	F	D[b]
SCORM01	23.45	1.57	23.57	1.56	0.19	--
SCORM02	26.04	2.76	26.27	2.91	0.22	--
SCORM03	17.33	1.65	17.50	1.38	0.44	--
SCORM04	8.92	1.02	9.29	0.85	4.97	-.64
SCORM05	27.65	2.42	28.32	1.97	3.05[c]	-.36
SCORM06	19.37	2.91	20.00	2.48	1.82[c]	-.42
SCORM07	21.74	4.15	22.59	4.50	1.37	--
SCORM08	16.62	2.05	16.89	2.02	0.62	--
SCORM09	14.95	1.74	14.93	1.93	0.00	--
SCORM10	14.99	1.58	15.12	1.71	0.24	--
SCORM11	15.27	1.73	14.86	2.17	1.64[c]	.76

Note.

$\Lambda = .91$; $\chi^2(4) = 13.06$; $p = .01$.

$\lambda = .09$; % = 100.00; $R_c = .29$.

$c_1 = .23$; $c_3 = -.38$.

$n_1 = 92$; $n_3 = 56$.

$F(1,146) \geq 3.91$, $p < .05$.

λ = Eigenvalue.

% = Relative percentage.

R_c = Canonical correlation.

c_1 = Centroid group 1.

c_3 = Centroid group 3.

D = Standardized discriminant coefficient.

[a]SCORM04 = Test score for module 4.

[b]Discriminant coefficients are reported only for four modules since the others did not enter into the stepwise analysis.

[c]If a module score has a high standardized discriminant coefficient and a low univariate F-ratio, then it may be performing as a moderator variable (Spector, 1977).

2. <u>Module completion times</u>. Table 6 summarizes the stepwise discriminant analysis and presents means, standard deviations, univariate F-ratios, and standardized discriminant coefficients for groups 1 and 3 using module completion times. Groups 1 and 3 differed significantly in the time required to complete module 7. Table 6 indicates that group 3 finished this module about 4 hours faster than did group 1.

Table 6

Summary of Stepwise Discriminant Analysis, Means, Standard Deviations, Univariate F-ratios, and Standardized Discriminant Coefficients for Groups 1 and 3 Using Module Completion Times

Step Number	Variable Entered	F to Enter or Remove	Wilks' Lambda Λ	p	Rao's V	Change in Rao's V	p of Change
1	TIMEM07[a]	6.29	.96	.01	6.29	6.29	.01

Variable	Group 1		Group 3			
	Mean	SD	Mean	SD	F	D[b]
TIMEM01	5.83	3.60	5.21	3.78	0.98	--
TIMEM02	7.30	3.45	6.37	3.48	2.56	--
TIMEM03	6.30	2.44	6.26	3.24	0.00	--
TIMEM04	8.33	4.30	7.21	4.21	2.38	--
TIMEM05	14.90	8.40	12.73	5.89	2.85	--
TIMEM06	9.68	4.30	8.05	4.83	4.50[c]	--
TIMEM07	21.23	10.04	17.27	7.99	6.29	1.00
TIMEM08	6.63	3.20	5.87	3.57	1.80	--
TIMEM09	10.03	4.45	8.92	4.95	1.98	--
TIMEM10	6.89	3.33	6.56	3.80	0.30	--
TIMEM11	8.75	3.81	8.22	3.88	0.68	--

<u>Note</u>.

$\Lambda = .39$; $\chi^2 (1) = 135.36$; $p = .00$.

$\lambda = 1.54$; $\% = 100.00$; $R_c = .78$.

$c_1 = .16$; $c_3 = -.26$.

$F(1,146) \geq 3.91$; $p < .05$.

$n_1 = 92$; $n_3 = 56$.

λ = Eigenvalue.

% = Relative percentage.

R_c = Canonical correlation.

c_1 = Centroid group 1.

c_3 = Centroid group 3.

D = Standardized discriminant coefficient.

[a]TIMEM07 = Time to complete module 7.

[b]A discriminant coefficient was reported for only one module since none of the others entered into the stepwise analysis.

[c]If a module completion time has a high univariate F-ratio and a low standardized discriminant coefficient, then it is likely differentiating between groups 1 and 3. However, it is correlated with a more powerful discriminator producing redundancy of measurement (Spector, 1977).

DISCUSSION AND CONCLUSIONS

The discriminant coefficients derived from the analysis for groups 1 and 3 using their cognitive characteristics indicated that these clusters differed significantly from each other primarily in SPACPERC, MECHCOMP, and AUTOINFO. To perform well on SPACPERC, individuals must be able to visualize and manipulate objects in space. This aptitude task requires subjects to imagine folding flat patterns into three-dimensional objects. MECHCOMP estimates individuals' understanding of mechanical and physical principles and concepts by determining their familiarity with common tools and mechanical relationships. Finally, AUTOINFO assesses subjects' diagnosis of automobile malfunctions and their understanding of specific parts and components, as well as appropriative terminology.

The SPACPERC and MECHCOMP aptitudes of group 3 members were higher than were those of group 1 members. Probably, group 3 members possess the schemata, knowledge, competencies, and learning sets required to acquire and master the subject matter of modules 4, 5, and 6 to a greater extent than do group 1 members. This appears even more reasonable when the contents of these three modules are identified and the tasks demanded of the learners analyzed. Module 4 dealt with explaining series circuits, using a multimeter as an ammeter, determining current in a series circuit, teaching potential difference, measuring voltage use and drop, connecting multimeters, and interpreting its many scales. Module 5 involved determining relationships among voltage, current, and resistance; deriving and applying Ohm's Law for series circuits; using power formulas; and troubleshooting series circuits. Module 6 addressed identifying and using Ohm's and Kirchhoff's Laws for parallel circuits, estimating branch resistance, solving for equivalent resistance, conducting variational analysis, and troubleshooting parallel circuits. Learning the contents of each of these three modules demanded facility in comprehending schematic diagrams of series and parallel circuits; understanding electrical facts, concepts, principles, and rules; solving simple algebraic equations; manipulating and interpreting multimeters; and detecting faults in series and parallel circuits. The students who had higher SPACPERC and MECHCOMP aptitudes would likely bring more "cognitive baggage" to these learning situations, which would facilitate their acquisition of the subject matter of modules 4, 5, and 6.

Similarly, group 3 members, more than group 1 members, probably possessed the prerequisite cognitive competencies and knowledge that are critical for quickly assimilating and mastering the contents of module 7. Module 7 presented solving complex circuits, branch currents, and voltage drops; composing and reviewing rules for series and parallel circuits; finding equivalent and total resistance; redrawing circuits; measuring negative and positive voltages; determining common ground and polarity of circuit components; and understanding voltage dividers and supplies as well as load/no-load conditions. Since group 3 members had higher SPACPERC and MECHCOMP aptitudes than did group 1 members, they likely had more of the necessary mental schemata or metacognitive strategies required to comprehend the many circuit schematics, simplify complicated circuits, solve the numerous algebraic equations, and perceive the several relationships among voltage, resistance, and current. Consequently, group 3 members learned and mastered module 7 sooner than than did group 1 members.

In module 11, however, the opposite was found (i.e., group 1 exceeded group 3 in achievement). The fact that group 1 members had higher AUTOINFO scores than did group 3 members implies that the former might have had more of the cognitive structures needed to learn the contents of module 11. Module 11 consisted of learning factors affecting capacitance, identifying series and parallel capacitors, computing time constants, determining how frequency influences capacitive reactance, estimating phase relations in capacitive circuits, representing phase relationships with vectors, and understanding variable and fixed capacitors. Having greater AUTOINFO aptitude, group 1 members were more likely to be familiar with electrical as well as mechanical troubleshooting and the workings of electrical circuits, ignitions, and capacitors. This prior knowledge, as reflected in the AUTOINFO scores, could have readily transferred to facilitate the acquisition of the subject matter of module 11.

Students whose cognitive characteristics varied did not attain the same level of achievement throughout all the elementary modules of a computer-managed course. Contrary to what the advocates of mastery learning (Block, 1974; Bloom, 1974, 1976) proposed, individual differences in achievement did not entirely vanish as students progressed through sequential, hierarchical lessons. This heterogeneity in student achievement can probably be explained by dissimilarities in their task and/or instructionally-relevant entry attributes. It seems impractical to assume that all students possess to the same degree (1) the characteristics demanded by a series of learning tasks and (2) the cognitive styles, abilities, and/or aptitudes necessarily congruent with the manner of instruction. As demonstrated, individual variabilities in these attributes resulted in dissimilarities in some learning outcomes. It appears that the mastery method of instruction does not completely diminish individual differences in student achievement. There was no evidence of a progressive decrease in the variability of student performance--achievement and learning rate--throughout the sequential modules. However, there was some support to the claim made by mastery proponents that this mode of instruction tends to reduce individual differences in student learning rates.

The fact that mastery learning did not always produce equality of student achievement within the sequential modules of instruction might have also been due to some students (1) trying to assimilate the material too rapidly, (2) denying themselves sufficient exposure to lesson units, (3) neglecting to practice certain skills, and (4) not studying enough examples. Not all students learned the same knowledge. A few had greater comprehension of the subject matter than did others. Students might have differed too in how they related and integrated newly acquired material to their already existing knowledge structures (Greeno, 1977, 1978). The disparity among students in acquiring, retaining, and retrieving information might have been due to dissimilarities in learning sets, competencies, schemata, knowledge, and rules that the students brought into the instructional environment (Federico, 1978, 1980; Federico & Landis, 1979a, 1979b, 1980). This implies that, to master a primary task, students must learn the supporting subordinate skills sufficiently and integrate these secondary competencies properly. These learning sets, schemata, and skills are cognitive mediators that facilitate the transfer of lower-level competencies to higher-level competencies in the knowledge hierarchy. Individual differences among students in their cognitive processing during acquisition, retention, and retrieval can produce considerable variation in their learning outcomes. No amount of mastery instruction can completely homogenize these differences that exist among learners.

If student performance differences are not completely reduced by mastery learning, then the consequences of initial selection of individuals are noticeable and enduring throughout much of the curriculum. This emphasizes the careful selection of students for a specific course of study. While variabilities in cognitive styles, abilities, and aptitudes may exist, the selection process for and mastery learning in computer-managed instruction do not completely homogenize individual differences in student achievement and learning rate.

These dissimilarities underscore the need for (1) improving the mastery method by providing additional instructional elaboration and supplementation to bring more students to a higher level of achievement, thus establishing in them the cognitive structures necessary for them to learn following curricular materials, (2) adapting instruction to individual differences in students' cognitive attributes to maximize their achievement and learning rate through a computer-managed mastery course, and (3) ranking graduates according to their school performance for better assignment to subsequent instructional programs.

These findings imply for CMI and mastery learning in general--computer-based or otherwise--that individual differences do indeed make a difference. Computer-managed mastery learning cannot entirely eliminate the consequences of incoming cognitive characteristics for subsequent subject-matter acquisition. Even though all successful students meet or exceed the mastery level of learning for each module, the amount of their achievement in some of the instructional modules will tend to differ.

No method of instruction--not even computer-managed mastery learning--produces identical instructional outcomes in all students. CMI is not a computerized procedure for producing student "clones." With student achievement for each module varying above the mastery level, the cumulative effects of these individual differences may become more important and enduring as students proceed from one hierarchical module to another. Some students may begin to learn subsequent instructional modules with fewer prerequisite facts, concepts, rules, and/or principles than do others. Over the long term, such deficits can multiply to the extent that these students--even though they may have met or surpassed modular mastery levels--may do progressively worse than others as they proceed through the curriculum.

RECOMMENDATIONS

Diagnostic testing techniques that are very sensitive to the extent of students' subject-matter knowledge should be designed and used. Also, summative assessment methods should be established to supplement these improved formative measurements and identify more accurately how students differ with respect to subject-matter achievement. With this additional information at hand, course supervisors and instructors will be in a better position to remediate students as well as assign them to follow-on training or job-related tasks.

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