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ABSTRACT

Current research and though regarding the relationship of individual difference (ID) factors to achievement in the basic skills is reviewed. Four major categories and nine subcategories of ID factors are defined and serve as the framework for the review: status factors (age, sex, and race, ethnic group, and socioeconomic status); intelligence factors (IQ and specific intellective factors, and perceptual factors); affective factors (attitudes and personality factors); and process factors (cognitive styles and cognitive strategies). Within each section of the paper, an attempt is made to examine research on IDs from the perspective of identifying strategies of instructional intervention that might be employed to accomodate or reduce achievement-related learner differences. The review emphasizes that factors which describe variations in student performance on learning tasks are more useful for the design of adaptive instructional practices than are factors that describe psychometric traits of learners. Accordingly, the promises inherent in continued research on process factors are emphasized. (A bibliography is appended.) (Author/GDC)

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Abstract

The paper provides a survey of current research and thought regarding the relationship of individual difference (ID) factors to achievement in the basic skills areas. Four major categories and nine subcategories of ID factors are defined and serve as the framework for the review: status factors (age, sex, and demographic factors); intellective factors (IQ and specific intellective factors, and perceptual factors); affective factors (attitudes and personality factors); and process factors (cognitive styles and cognitive strategies). Within each section of the paper, the attempt is made to examine research on IDs from the perspective of identifying strategies of instructional intervention that might be employed to accommodate or reduce achievement-related learner differences. The underlying theme of the review is that individual difference factors that describe variations in student performance on learning tasks (IDs in learning) are more useful for the design of adaptive instructional practices than are factors that describe psychometric traits of attributes of learners (IDs in learners). Accordingly, the promises inherent in continued research on process factors are emphasized.

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INTRODUCTION

Research on individual differences is of special importance to practitioners concerned with improving instruction in the basic skills area. Whether one views the "basic skills problem" as a universal decline in literacy or as a condition endemic to urban or disadvantaged populations, the basic challenge is one of correcting deficiencies where they occur and insuring the achievement of minimal competency for all. In other words, the problem seems to be the differential effectiveness of basic skills instruction for different populations and for different people within each population. The fact that some students fail where others succeed seems to make information about student characteristics an essential prerequisite for the success of efforts to improve basic skills achievements.

According to recent studies and reviews of school effectiveness, it appears unlikely that deficiencies in achievement can be explained by variations in school practices alone (Coleman, Campbell, Hobson, McPartland, Mood, Weinfeld, & York, 1966; Jencks, Smith, Acland, Bane, Cohen, Gintis, Heyns, & Michelson, 1972) or alleviated through the adoption or extension of existing intervention efforts (Jensen, 1974). At the classroom level, it appears that no particular classroom practice or set of practices is consistently related to academic achievement (Averch, Carroll, Donaldson, Kiesling, & Pincus, 1974). In all of these analyses, however, student background factors are consistently

and significantly related to achievement. The evidence, albeit indirect, suggests that it is not fruitful to look for a set of universal or even population-specific practices that will result in optimal levels of achievement for all. Rather, the key to the basic skills problem may involve the specification of principles for varying instructional practices within each educational environment according to the needs and learning characteristics of different students.

The view that instruction should be adapted to individual differences cannot be discussed without interjecting a few cautionary notes. For one thing, there is nothing particularly innovative about the notion of adaptive instructional environments; Glaser (1972) traces the proposal to the writings of E. L. Thorndike in the early part of this century. Another reason for caution has to do with the variety of individual difference factors and possible intervention strategies. The questions of what to adapt to and how to be adaptive are complex and to some degree independent. Finally, there is no reason to be overly optimistic about the effectiveness of adaptive environments. Reviews of the research on such practices as ability grouping (Begle, 1975; Goldberg, Passow, & Justman, 1966) and individualized instruction (Gibb, 1970; Schoen, 1976) fail to provide support for the value of adaptive practices, at least as they have been defined and implemented to date.

The position taken in this review is that attempts to adapt instruction to individual differences have been hampered by a reliance on

psychometric indexes and inadequate definitions of instructional treatments (Glaser & Resnick, 1972). The tendency has been to select individual difference variables that are only indirectly related to the cognitive processes required by a particular learning task (e.g., IQ). Moreover, treatments meant to be adaptive (e.g., grouping, self-pacing) are not well-defined enough to match the specific ability, style, and strategy differences that appear to be functionally related to outcome differences on learning tasks.

The Focus of This Review

The purpose of this paper is to provide a review of the research on individual differences that seems to have potential for guiding the alteration of instructional practices in basic skills instruction. Accordingly, the review has a dual purpose: to identify characteristics of students that account for a sizable portion of the variance on learning tasks and achievement tests, especially characteristics that describe variations in students' performance on these outcome measures; and to identify strategies of instructional intervention designed to accommodate, or reduce these achievement-related learner differences.

The scope of the review is limited to research that bears directly on the question of improving basic skills instruction. Basic skills are herein defined as those performance capabilities typically associated with standardized tests of reading and mathematics administered in the elementary school. No attempt is made to provide a survey of

research activities for a particular time period. Readers interested in survey reviews are referred to the prodigious annual reviews of research on reading compiled by Weintraub and his associates (e.g., Weintraub et al., 1971) and the reviews of individual differences in mathematics produced by Aiken (1970, 1971a, 1971b, 1972, 1976). In keeping with the dual purpose of this review and the explicit bias that underlines these purposes, the following kinds of studies were selected for review: studies that explore functional relationships between aspects of learners and aspects of reading and mathematics tasks; formal studies of aptitude-treatment interactions; studies of correlates of reading and mathematics instruction conducted with the purpose of making inferences about instructional practices; investigations of differences between more and less proficient learners, especially investigations that center on strategies and behaviors exhibited by learners during the learning process; training studies designed to reduce individual differences; and studies of instructional practices designed to accommodate individual differences.

Types of Individual Differences in Learning

There are a number of ways of categorizing individual difference variables that relate to learning. The phrase "individual differences" has come to stand for differences between groups of individuals as well as differences between individuals. Group factors, often referred

to as status factors, include age, sex, race, and socioeconomic status (SES). Historically, the major category of individual difference variables has been psychometric factors; cognitive, affective, and perceptual factors defined by performance on standardized tests and factor analyses of these tests.

Recently, there has been a good deal of interest in individual differences that relate to performance characteristics of students. Some of these characteristics refer to generalizable styles of approaching classes of learning tasks, while others refer to specific strategies that students employ on particular learning tasks. The distinction between traits and performance factors has been referred to as attributes vs. process factors (Glaser & Resnick, 1972), genotypic variance vs. phenotypic variance (Jensen, 1967), and individual differences in learners vs. individual differences in learning (Bloom, 1976). The argument presented by these and other researchers is not that IQ, personality characteristics, sex, race, and other attributes of learners do not relate to learning, but that the discovery of such relationships does not lead to either an understanding of the learning process or to an understanding of how performance deficiencies might be alleviated. For the purpose of this review, styles, strategies, and other performance characteristics that relate to basic skills achievement will be covered in a separate section, labeled "process factors."

Before presenting the categorization scheme to be used in this review, it should be mentioned that there is at least one additional class

of individual difference variables that relate to basic skills achievement. Just as there are individual differences in learning (performance) characteristics as contracted with trait differences between learners, there are differences between students in the behaviors and motivational states that give rise to learning. Resnick and Robinson (1975) distinguish between learning-related attributes and motivation-related characteristics. Included in this latter category are differences in aspiration, expectation, and intrinsic reinforcement. Although the distinction is somewhat muddled, motivation characteristics can be considered secondary or support characteristics as opposed to primary learning characteristics, which determine the quality of students' performance. Other secondary or support characteristics might include strategies and dispositions that proficient learners employ to manage their learning activities (Glaser, 1973), dysfunctional behaviors that poor learners exhibit to avoid learning activities (Covington & Beery, 1976) and student-to-student and student-to-teacher behaviors that serve to maximize or reduce learning opportunities (Doyle, 1978). Individual differences in motivation-related characteristics and self-management behaviors will be considered in a separate review (Thomas, 1978).

The following taxonomy will be used to organize the research on individual differences in basic skills learning and achievement:

I. Status factors
   A. Age
   B. Sex
   C. Demographic factors (race, ethnicity, and socioeconomic status)

II. Intellective factors
   A. IQ and specific intellectual factors
   B. Perceptual factors.

III. Affective factors
   A. Attitudes
   B. Personality factors

IV. Process factors
   A. Cognitive style
   B. Cognitive strategies

Modes of Intervention

In any area of research, the process of deriving implications for practice is fraught with difficulties. Problems of interpretation and inference are especially evident in research on individual differences. Although a comprehensive analysis of the distinct classes of problems involved in making inferences from research is beyond the scope of this review, it is important to bear in mind that the prescriptive process is replete with value considerations. It is one thing to judge that a particular research conclusion is valid, generalizable, and unambiguous; it is another matter to decide what a particular research conclusion implies for the alteration of instructional practices. In the context of research, judgments about the validity of hypotheses may stem primarily from interpretations of empirical outcomes. In contrast, because of the number of possible intervention strategies and the lack of experimentally derived principles for matching these strategies to the various relationships found between learner and task characteristics, inferences about instructional implications importantly

involve an investigator's view of the proper means and ends of instruction.

The following example might help to illustrate the independence of interpretation and inference problems. Suppose a study reveals a high correlation between possession of a positive self-concept and mathematics achievement. Aside from questions of validity and generalizability that might be addressed to the study, it is necessary to know the functional significance of the correlation. In this example, there are a number of possible interpretations for the findings: possession of a strong self-concept may facilitate or cause mathematics achievement; successful achievement experiences may lead to increases in self-concept; some other factor may be causally linked to both self-concept and achievement; or the relationship between self-concept and achievement may be a dynamic one such that some minimal level of the self-concept is related to successful performance on learning tasks, which leads to high achievement test performance, which in turn contributes to increased self-concept.

The question of what to do about the observed relationship between an individual difference factor and an instructional outcome measure is not very meaningful unless the functional significance of the relationship is sorted out. However, even when the nature of the relationship has been established, a new set of questions arises. To continue the example, do you treat low levels of self-concept as a deficiency or weakness to be corrected? If so, do you provide special self-concept training, or do you alter features of the instructional environment in order to boost levels of self-concept? Furthermore, do you provide

this training or environmental alteration for all students or just for students with a low self-concept? Alternately, it is possible to view self-concept differences without making judgments about strengths and weaknesses. Instead of providing remedial training or a compensating environment, the appropriate prescription might be one that provides different instructional treatments for students who score at different levels of the self-concept measure. No attempt is made to alleviate or reduce differences between students. Rather, the intervention strategy is designed to accommodate and hence to preserve learner differences.

In Snow's (1976) terminology, the basic distinction is between a capitalization mode and a compensatory mode. In a capitalization mode, the notion is to seek alternative treatments that complement or build on the strengths or preferences of particular learners. In a compensatory mode, treatments are matched to the weaknesses of learners. According to Snow, compensatory treatments "are designed to do for the learner what he cannot do for himself." The application of Snow's distinction to the four types of learner difficulties defined by Wiener and Cromer (1967) suggests that the capitalization mode is appropriate for "defects" and "differences," whereas the compensatory mode is required for "deficiencies" and "disruptions." Wiener and Cromer's definitions for the four types of learning are summarized below.

1. Defects. Defects are relatively permanent malfunctions that affect learning. Students with serious defects fail to benefit from most

instructional experiences. Defects typically require adaptive instruction that is specialized and separate from ongoing practices.

2. Deficiencies. A deficiency is an absence of some function or prerequisite learning. A deficient child is one who needs to learn something he/she has not learned. Remedial instruction is a kind of adaptive instruction designed to compensate or make up for deficiencies.

3. Disruptions. Disruptions refer to the presence of some behavior or characteristic that must be removed before optimal learning can occur. Special treatments for hyperactive students are adaptations to disruptive factors.

4. Differences. Differences refer to mismatches between a typical mode of responding and a particular instructional treatment. Wiener and Cromer's assumption is that some students would have far less difficulty with reading if the materials, methods, or instructional conditions provided for them were consistent with their behavior patterns. The example the authors use is the discrepancy between the languages presented visually and aurally to lower-class children.

As noted above, the question of how to intervene is not limited to the issue of capitalization vs. compensation alone. As Cronbach (1967) and Glaser (1976b) point out, an adaptive environment can be composed of any combination of the following features: alterations in the duration of schooling, alterations in the duration of instruction, differential instruction goals, differential instructional methods, and differential assessment criteria.

In light of the complexities of the intervention issue, this paper will not only provide a discussion of both interpretation and inference considerations relative to key studies, but also highlight studies within each section that present an experimental test of an intervention strategy. Given these emphases, research on individual differences in basic skills learning and achievement will be reviewed with reference to four major

topics: status factors, intellective factors, affective factors, and process factors. The paper will conclude with a final summary section devoted to the implications for the design of instructional practices.

STATUS FACTORS AND BASIC SKILLS ACHIEVEMENT

Status factors are those student characteristics that correspond to a person's membership in different social groups. With the exception of age, these factors are assigned by reason of birth: sex, race, ethnic background, and socioeconomic status (as defined by parents' status). Although a substantial amount of research is available concerning relationships between such factors and basic skills achievement, only a very small percentage of it will be reported here. This is because student characteristics that relate closely to learning vary almost as much within status groups as they vary between groups. Status characteristics therefore offer little guidance for adapting instruction to individual differences.

As a consequence of the magnitude of variation within status groups, attempts to adapt instruction to gross variables such as age or race have not been very successful, e.g., compensatory education (Jensen, 1969). The utility of research on status factors and achievement may be limited to the discovery of clues to the identity of more specific factors that may be characteristic of, but not identical to, a particular status designation.

Age and Reading

Research on the relationship between age and reading is typically referred to as reading readiness research. It is possible to identify

at least three somewhat independent types of research studies under the heading of reading readiness. These three types of research attempt to discover: (1) the discrete cognitive-development stages through which all children pass and what the stages imply about designing sequences of instruction in reading; (2) the "critical periods" in a child's development and how instructional resources should be allocated to accommodate these periods; and (3) those characteristics (early learnings, abilities, behaviors, status factors) of prereaders that correlate with reading achievement or reading disability and how to accommodate instruction to them.

The current status of research in all three areas is inconclusive. Discussions of maturational factors or cognitive-developmental stages and their relation to reading readiness typically lead to the conclusion that it is foolish to stand back and wait for a child to progress through a stage, yet it is inadvisable to push students if they are not ready (cf. Dechant & Smith, 1977). Although Bloom (1964) emphasizes the importance of catching and teaching students before it is too late, his evidence for this position is based on correlational data alone. Rohwer (1971), on the other hand, cites evidence in support of the relative unimportance of early learning. For example, students who received no formal schooling until ages 11 or 12 were able to catch up with their schooled peers within two or three years. Finally, research on psychological correlates of reading readiness (reported in a subsequent

section on intellective factors) is characterized by Dechant and Smith (1977) as inadequate in that no measure or combination of measures yet exists that is capable of predicting reading readiness.

Implications

Age is certainly an important factor for learning and instruction. As Passow (1974) reports, treatments such as early childhood programs, which are based on age considerations alone, can sometimes have important facilitating effects on subsequent academic achievement. The point to be made here is that it may be a mistake to base instructional prescriptions exclusively on age. As Piagetian research has long emphasized, it is not maturation alone that determines readiness for learning. Readiness is determined by changes in cognitive structures, abilities, and perhaps memory capacity (Case, 1975). The correlation between these changes and age is far from perfect. Consequently, age seems to be an inappropriate unit of analysis.

Sex and Reading

Asher (1977) in his review of sex differences in reading cites the following facts. Boys make up 90 percent of the remedial reading students in some districts. In the middle elementary school years, boys are about one-third to one-half grade behind girls in grade-equivalent reading scores. Results from the 1972 National Assessment

of Educational Progress show that girls do better than boys on reading comprehension tasks throughout elementary and junior high school. By the time students become 17 years old, sex differences in reading disappear. (It is not clear whether this disappearance is real or attributable to a differential dropout rate between the sexes.) Finally, boys tend to be more disruptive and aggressive in class and more negative toward school in general and reading in particular.

Asher discounts the popular hypothesis that sex differences in reading are attributable to the fact that elementary teachers are predominantly female (98 percent of teachers in grades K-3 were female in 1972, according to Asher). He points to comparative studies that show that reading gains made by boys and girls are the same regardless of whether the children have a male or female teacher. According to Asher, other studies show that regardless of the sex of the teacher, girl students are rarely favored; in fact, boys tend to get a disproportionate share of attention from both male and female teachers. Asher favors the hypothesis that the difference between boys and girls in reading achievement is a function of differences in rate of attention toward reading between the sexes, a difference that can be alleviated through changing instructional conditions or materials.

In support of this hypothesis, Asher cites two kinds of studies presumably related to rate of attention. In studies that compare programmed instruction or computer-assisted instruction to traditional classroom instruction, boys tend to do as well as girls

in reading in the experimental conditions. According to Asher, these structured methods are better able to maintain (and equalize) attention. A second line of evidence for the hypothesis comes from a study by Asher and Markell (1974). Fifth grade boys and girls who differed initially on a standardized reading test scored equivalently following exposure to high interest reading materials. In the case of students who were exposed to low interest reading material, girls retained their superiority over boys.

Another perspective on the cause of sex differences is taken by Dwyer (1973) in her review of research on sex differences in reading. Dwyer asserts that the common finding favoring boys in reading achievement is due to cultural expectations associated with the male sex role. According to Dwyer, boys perceive schooling and especially reading as feminine and hence inappropriate for the male sex role. As evidence for this position, she cites a study comparing German and American 4th and 6th graders wherein the American pattern of female excellence and male retardation in reading was reversed in the German sample.

A full explanation of the superiority of girls over boys in reading achievement may require an examination of the reversal often observed for mathematics achievement; in general boys outperform girls in mathematics, especially at advanced levels of the subject. Seewald, Leinhardt, and Engel (1977) examined differences in academic contacts made by teachers to girls and boys in reading classrooms as

compared to mathematics classrooms. Seewald et al. hypothesized that differences in the amounts of time and kinds of contacts teachers devote to girls and boys vary across subject matter areas and, thus explain sex differences in academic achievement between the subject matter areas. The researchers videotaped 33 female teachers during both individualized reading and mathematics sessions. In terms of the total number of contacts, total amount of time spent, amount of cognitive time spent, average duration of contacts or percentage of total time spent that was cognitive as opposed to managerial, the results showed an interaction of student sex and the subject matter of instruction. As expected, girls received more cognitive statements and questions during reading instruction, but the opposite was true, favoring boys, during mathematics instruction. Boys received more managerial statements and questions overall in both subject matter sessions. And finally, girls received a higher percentage of total cognitive contacts during reading instruction; the opposite was true, favoring boys, during mathematics instruction.

It should be noted that all of the studies mentioned above are open to alternative interpretations. The Seewald et.al. study, though provocative, implies but fails to confirm any causal links. The teachers may simply be responding to real or imagined ability differences in their respective subject matter sessions. To confuse the discussion further, Brimer (1969) administered two tests of listening comprehension to large groups of children in grades 5 through

11 and found boys to be superior to girls on both tests in all grades except for one test in grade 5. Brimer was unable to explain these differences on the basis of sampling bias, test bias, or interest bias and concluded that males learn to function more effectively in an auditory context, perhaps as a compensation for their relative retardation in expressive language.

Implications

It would appear from the research cited that sex-related differences in academic achievement and in reading achievement in particular are related to the expectations of both students and teachers. It is possible that an adequate account of sex-linked differences in reading achievement requires an explanatory model that includes all of the factors cited above as well as their interaction effects. It is premature, however, to prescribe corrective action based on the research cited here. No test of the expectations hypothesis has been cited. Such a test would require an experimental manipulation of student and teacher expectation factors or, at the very least, a comparison of the achievement levels of girls and boys who have been taught to read by some sex-blind procedure such as computer-assisted instruction.

Demographic Factors and Reading

Demographic factors include race, socioeconomic status (SES), and ethnicity. These factors, especially SES and race, have generated

a considerable volume of research. Schools serving populations of disadvantaged students, blacks, Spanish-speaking students and/or urban students, for example, tend to produce achievement test results that are consistently and significantly below the mean for the total U.S. population. Moreover, in comprehensive studies of school effectiveness, SES or race is typically found to correlate more highly with academic achievement than any other student characteristic and to account for more of the variance in achievement than any school-related factor.

For a number of reasons, researchers and practitioners have long been concerned with reducing group differences in academic achievement. For one, these differences have been seen as being attributable, either wholly or in part, to environmental deprivation. This assertion implies to most investigators that subsequent changes in the environment can compensate for the deprivation and erase the differences. For example, there is a growing body of evidence to support the view that differences between elementary schools in quality of instruction has a more profound influence on the achievement of blacks and lower SES children than is true for the population as a whole (Jencks et al., 1972; McKeachie, 1975).

Another reason given for reducing group differences is that the differences between racial and SES groups tend to be cumulative in nature. That is, the gap between some of these groups (blacks versus whites, especially) tends to increase with schooling--a phenomenon

that seems to point to a failure on the part of the educational system to be responsive to the needs of racial or SES groups (Jensen, 1969).

Race, ethnicity, and SES are independent factors. All levels of SES are represented within any ethnic or racial group, for example. Yet the fact that these variables are highly correlated in practice has led many investigators to view race and SES, and ethnicity and SES, as interchangeable. Stodolsky and Lesser (1967) administered four tests of mental ability to low- and high-SES students in four ethnic groups: Chinese, Negroes, Jews, and Puerto Ricans. A major finding was that the pattern of performance across the tests of verbal ability, reasoning, number facility, and space conceptualization varied markedly for different ethnic groups. Moreover, these patterns were consistent across SES samples within each ethnic group, despite large SES differences in overall performance level. The authors reject the notion that ethnic differences are better explained as SES differences, and suggest that it might be advisable to teach to the strengths of each ethnic group even at the expense of magnifying differences among the groups.

Socioeconomic status, as the phrase implies, typically refers to a complex of variables which might include any combination of father's or mother's occupation or education, family income, "quality" of neighborhood, even the number of books in the home. Bloom (1964) critizes most indexes of socioeconomic status for their emphasis on status characteristics of the environment rather than on what

is done in the home. Bloom points to an unpublished master's thesis by Alexander which revealed that students' initial scores in reading comprehension were unrelated to the size of their gain in reading proficiency between grades 2 and 8. The factor that seemed to account the most for this gain was parents' occupation. Bloom's interpretation of this finding is that improvement in reading is a function of: (1) the value placed on school learning by parents and students; (2) the amount of reinforcement of school learning occurring at home; (3) the expectation of economic return attached to getting an education; and (4) the morale and training of the school staff (for example teachers in schools serving lower SES students see their role as a less desirable one than do teachers in other schools).

From the point of view that SES differences need not be accepted as inevitable and can be reduced, Bloom's argument seems to be an important one. Bloom describes a study in which an index of home environment correlated .80 with an entire fourth-grade achievement battery, a result that Bloom contrasts with the typical correlation of .50 using SES or education of the father. Again, Bloom's index is one that emphasizes what happens in the home, and not its cost or its location. Bloom lists six factors that contribute to the index: achievement press; language models in the home; academic guidance provided in the home; the stimulation provided in the home to explore aspects of the larger environment; the intellectual interests and activities in the home; and, the work habits emphasized in the home.

There are, of course, additional characteristics of racial and SES groups that have been linked to reading and other aspects of academic achievement. According to Jensen (1969), differences between racial and SES groups in intelligence account for a sizable proportion of the variance in academic achievement between these groups. For Jensen (1974) there are two levels of intelligence or intellectual functioning. Level I intelligence refers to associative abilities that involve relatively little transformation of input. Level II intelligence refers to abilities involved in conceptual learning, mental transformations, and mental elaboration. Jensen has found an interaction in his studies such that black-white differences in tasks that require Level II abilities are greater than are the racial differences found for tasks that require Level I abilities. With respect to reading, Jensen's model would predict greater SES or racial differences in favor of middle-class or white students on tests of reading comprehension than would be found on decoding tests that require associative abilities rather than reasoning.

Rohwer (1971 and elsewhere) has taken issue with Jensen's model. Rohwer asserts that racial and SES differences in learning do not constitute differences in learning potential or proficiency. Rather, low SES and black children are merely less efficient at learning; they have not learned to provide spontaneously the effective mediators or the elaboration necessary for success on most learning tasks.

When provided with the necessary training, group differences on conceptual tasks disappear (Rohwer, 1971), as do similar group differences on reading comprehension tasks (Rohwer and Matz, 1975).

Entwistle (1971) stresses the importance of language and dialect differences between racial and SES groups as a prominent factor in explaining group differences in reading achievement. Lower SES and black children have a "restricted" language code as opposed to the "elaborated" code used by most middle-SES white students. Teaching reading to a speaker of a restricted code, according to Entwistle, poses the same problem as attempting to teach white or middle-SES children to read using a reading text written in French. Entwistle's view is based on the work of Basil Bernstein and his group in England, a group that has been able to achieve positive results in teaching children from working-class families to use an elaborated code.

Carroll (1971) reports the results of a study by Carver (1969) that is in partial conflict with Entwistle's view. Carver administered a listening comprehension test to low-SES blacks that was constructed to be especially suited to the dialect, interests, and background of this population. Carver found low-SES blacks to show a deficit on this test equivalent to that found on standardized measures of aptitude and listening comprehension. Carroll concludes that the deficit usually associated with low-SES students is not specific to the reading mode.

Attempts to compensate for the deficits evidenced by low-SES black children have been disappointing in the main (Jensen, 1969). Passow (1974) attributes this lack of success to the fact that most compensatory

education programs are composite curricula with multiple and ambitious objectives, which are rarely based on a rigorous examination of the causes of the deficiencies that gave rise to the program. However, Passow mentions three exemplary compensatory education programs: the Perry Preschool Project in Ypsilanti (Weikert et al.), the Learning to Learn Program (Van de Riet & Resnick), and the Beginning Reading Project (Goldberg). All three have produced training effects in reading and prereading skills. For example, preliminary results from the Beginning Reading Project show that students who participated in the project in kindergarten had a significant advantage in later reading achievement over their peers who began reading at later points in time.

Early training in perceptual skills may represent a valuable adjunct to instruction in reading. Elkind (1970) reports that black children who were trained in perceptual strategies such as exploration, reorganization, and schematization made more progress than control students who received an equivalent amount of regular reading instruction. Chall (1967) reports that lower SES black children seem to benefit more from a highly structured code (phonics) approach to reading than they do from a meaning or "look-say" method.

Implications

As noted previously, to be useful to practitioners, research on status factors must investigate specific variables associated with membership in a particular group. The failure of compensatory education programs to produce the benefits that were once anticipated may serve as a

catalyst for the abandonment of the notion that all blacks or all disadvantaged students are alike in some way and will benefit from a single treatment. Comprehensive programs that do seem to benefit disadvantaged students (Becker, 1977; Passow, 1974) seem to be based less on the notion that these students need some special environment to compensate for one or another weakness and more on the view that low levels of achievement are a function of inadequate instruction and learning.

Three studies mentioned in this section seem to merit special mention. First, the research conducted by Bloom on the specification of home and family variables that correlate with achievement is of interest because it implies that the relationship between SES and achievement is subject to manipulation. As long as SES is defined by such fixed variables as father's educational level, the high positive correlation between SES and achievement (.90 in some studies) presents a gloomy picture. Bloom's point seems to be that the functional or causal variables are the perceptions, expectations, and stimulation provided in the home environment. One implication is that parental training programs or, at the least, consciousness-raising attempts, might have a significant influence on those cognitive and motivational characteristics of students that have a direct bearing on learning and achievement.

A second interesting line of research is the one taken by Rohwer and his colleagues. Here, the attempt is not to boost abilities or achievement per se, but to identify the learning strategies used

spontaneously by proficient learners in order to teach them to other learners who for one reason or another have not acquired such strategies. One of the assumptions behind this research is that poor learners perform the way they do not because they are disadvantaged or have low IQs, but because they have not learned certain strategies for learning and self-management. Making such strategies available to all students through special training and environmental prompts should reduce individual and hence group differences in learning.

The finding reported by Chall (1967), in which lower SES black children benefit more from a structured program of phonics than from a meaning approach to reading, seems to call for an intervention strategy that is adaptive to racial-SES differences. A complementary finding is reported by Berliner and Cahen (1973). In a review of aptitude-treatment interaction research, the investigators cite the preliminary finding that programmed instruction is more effective for children from a lower SES background, whereas higher SES students appear to do better with regular classroom instruction. Again, the criticism of such findings is that they are based on an inappropriate measure of individual differences. It is not membership in a particular SES group that determines one's need for one kind of treatment or another, but some as yet undetermined learning characteristic that is unevenly distributed in different populations.

Age and Mathematics

For some time, there has been speculation regarding the implications of research on cognitive development in children, especially Piagetian research for designing instruction in early mathematics. Piagetian research is concerned, for the most part, with the development of an understanding of basic logical principles. As Piaget has pointed out, these principles, such as invariance of quantity and reversibility, form the basis for arithmetic and geometric reasoning as well as scientific thought.

An extreme view of the implications of Piagetian research is expressed by Rohwer (1971), who suggests that negative attitudes towards school apparent in adolescence (e.g., mathematics) may be due in part to the tendency for schools to make cognitive demands that students are not ready for. Rohwer suggests that formal instruction in complex skills (e.g., arithmetic reasoning) be delayed until the onset of what Piaget refers to as the stage of formal operations--age 11 or 12 for most students. For Rohwer, it is easier for students to catch up later than it is for them to overcome the deleterious effects of early failure.

Copeland (1970) calls for a drastic change in the mathematics curriculum, especially the requirements for grade 1. He cites research that reveals that most children cannot grasp number conservation concepts until a year or more after numeration is introduced

in school. Other trouble areas, according to Copeland, are the use of symbolic notation for simple computation as in the new math, and spatial reasoning concepts required for learning simple measurement operations. Copeland suggests that first grade, like kindergarten, should be devoted to readiness activities and not formal instruction.

Despite these claims and hypotheses, as Callahan and Glennon (1975) point out in their review of research in mathematics education, it is unrealistic to think of "magic points" that define readiness for all students for all concepts. There are great variations among students with respect to the age at which mathematics-related operations are attained, as well as variations within students in their readiness for varieties of mathematic learnings.

Sex and Mathematics

As noted in the section relating sex to reading, it is not uncommon for studies to find sex-linked differences in mathematics ability and achievement. In two of the most comprehensive analyses to date, Tyler (1956) and Anastasi (1958) found that girls outperformed boys on tests of verbal and linguistic abilities, whereas boys tended to outperform girls on tests of numerical and spatial aptitudes and on tests of arithmetic reasoning. Husen (1967) looked at sex differences (among other variables) in achievement-related abilities at the secondary school level across twelve countries. Although he expected to find differences favoring girls on verbal

problems in mathematics, boys consistently scored higher than girls on both verbal problems and computation problems in all twelve countries studied.

Fennema (1974) reviewed a large number of post-1960 studies on sex differences in mathematics and found no consistent significant differences between the mathematics performance of boys and girls in grades 4 and 9. However, when differences did appear in those studies they tended to favor girls on tests of mathematics computation while favoring boys on tests of mathematics reasoning. Also, differences favoring boys were more apt to appear in studies using high school students than in studies using younger learners. Both Fennema and Husen attribute the differences they found to sociocultural factors and/or sex-role expectations.

Studies that involve differential instruction or remediation on the basis of a students' sex are rare. Glaser and Resnick (1972), in their review of research on instructional psychology, cite an interesting study by Brinkman (1966). Brinkman administered a special, programmed instructional course which stressed perceptual rather than formal-logical aspects of geometry. Presumably as a result of this brief course, girls performed on par with boys on the Space Relations subtest of the Differential Aptitude Test, a test that typically favors boys.

Implications

The idea that special training might reduce sex-related differences in achievement is an intriguing one. Providing differential

instruction on the basis of sex differences seems to fly in the face of current trends, but such training may serve to reduce the tendency for girls to avoid courses in advanced levels of mathematics. That is, whether the observed differences between girls and boys in mathematics is due to cognitive or expectation differences, special training may have a positive effect on girls' confidence in their mathematical prowess.

Demographic Factors and Mathematics

The relationship between socioeconomic status and mathematics achievement favors children in middle and upper SES categories over children from lower SES backgrounds. This difference appears to be consistent across varieties of mathematics tasks (Callahan & Glennon, 1975), to be evident at a very early age (Dunkley, 1972), and to persist through high school (Husen, 1967).

Husen, who found a consistent relationship between fathers' educational level and mathematics achievement in all twelve countries studied, concluded that "the educational achievement of the students in mathematics is influenced by SES through its effects on the educational plans of students" (cf. Bloom, 1964). Keeves (1972) considers such correlates as father's education and occupation to be "proxy variables involving inherited traits, attitudes and the practices of the home."

Conclusions

A criticism presented earlier deserves to be repeated here. For educators, a primary goal of research on individual differences is to devise instructional strategies that will adapt to (accommodate, remediate, compensate for, capitalize on) these differences. To the extent that this goal is accepted, research on status differences such as age, race, and sex must be regarded only as first steps. For example, knowing that girls score below boys on tests of arithmetic reasoning will not help practitioners to design instruction for all girls, or even for a particular girl, since it is unlikely that it is sex per se that contributes to the observed difference. If that were so, no girls would score higher than any boy on tests of arithmetic reasoning. What seems to be necessary as a second step in research on group differences is to identify the psychological (cognitive, affective, motivational) correlates of success in reading and mathematics that seem to be differentially represented across status groups.

In one sense, however, status differences are real and not reducible to other variables. When expectations are placed on individuals based purely on their membership in a particular group, these expectations, especially when shared by students and teachers alike, have a way of affecting learning and opportunities to learn. Compensatory programs, grouping, and exclusion rules based on age, sex, and racial characteristics may tend to exacerbate these expectation effects and do more harm than good.

INTELLECTIVE AND PERCEPTUAL FACTORS

The label "intellective factors" is sometimes used to cover a wide assortment of cognitive, perceptual, and style dimensions (cf. Aiken, 1971a). For the purpose of this review, however, "intellective factors" will be limited to ability or aptitude variables as measured by standardized tests. In keeping with the distinction between individual differences in learners vs. individual differences in learning, specific performance factors (factors that can be observed or measured during learning) will be considered in the section on "process variables."

IQ and Achievement

Intelligence has long been considered a measure of the ability to learn and to apply what has been learned. Since competence in both reading and mathematics is judged by how easily and fast a student learns the required skills, as well as how well the student is able to apply these learnings to novel items on achievement tests, IQ continues to be a major factor of interest in research on basic skills achievement.

The IQ test is certainly the most controversial of educational measures. Proponents of IQ testing point to the predictive validity and durability of the tests (Glaser & Resnick, 1972; Vernon, 1964). McNemar (1964) concluded that the worth of multitest batteries for predicting academic achievement had not been demonstrated and that tests of verbal reasoning (combined with numerical ability in the

case of mathematics achievement) predicted grades as well or better than any other test or combination of more specific ability tests.

Opponents of IQ typically point to the prevalence of abuses in IQ testing. IQ tests are considered to be culturally or racially biased and are wrongly interpreted as setting a biological limit on the achievement of an individual or group.

Recently, however, the supremacy of tests of general intelligence has come under a different kind of attack. Stevenson and Odom (1965), for example, found that variations in children's performance across a variety of cognitive tasks were neither highly interrelated nor significantly correlated with IQ. Different tasks require different abilities, according to Stevenson and Odom. According to other investigators, the important inference from studies such as this one is that is inaccurate to define intelligence as the ability to learn (Fleishman & Bartlett, 1969; Glaser & Nitko, 1970).

McClelland (1973) states that the adage that intelligence is what intelligence tests measure is "uncomfortably near the whole truth and nothing but the truth." To McClelland, the commonly touted fact that IQ tests predict academic achievement is of spurious importance, since the validity coefficients that are used to support this "fact" are based on correlations between IQ scores and achievement indexes, measures which are essentially variants of IQ tests. This issue is an important one to keep in mind, because the importance

of IQ for predicting academic achievement may be better explained by the similarity of achievement tests to IQ measures than by a failure of alternative instructional treatments to make a difference in learning outcomes. A related point is that the similarity between IQ and achievement tests is in no small measure based on the idea that what IQ tests measure should serve as the model for definitions of academic achievement. Alternately, it is possible to define reading and mathematics competence without relying so heavily on inferential and deductive reasoning.

IQ and Reading

Lohnes and Gray (1972) studied the effectiveness of ten reading projects as part of a research program supported by the USOE Co-operative Reading Studies. Their analysis of the data revealed that 45 percent of the redundant (overlapping) criterion variance could be accounted for by an intelligence factor in the reading readiness tests. Moreover, Lohnes and Gray found significant intercorrelations among the various achievement tests used to compare the effectiveness of the ten programs. The authors concluded that IQ is not only the principal factor in reading readiness and the best predictor of growth in reading achievement, but general intellectual development may well be the best criterion for assessing the effects of instruction.

Harris (1969), in his review of research on reading, reports that the correlation between IQ and reading achievement typically

clusters between .40 and .60. Among the tests that have good predictive power according to Harris are the verbal and reasoning subtests of the Primary Mental Abilities and the WISC.

An early study by Gates and Bond (1936) continues to be cited in the literature as a comprehensive correlational study of reading readiness. Gates and Bond found a moderately high correlation between IQ and reading achievement. They also found a verbal measure of mental age to be a better predictor of achievement than a nonverbal measure. However, the highest correlations with achievement were found for measures of the general quality of students' oral comprehension and for the amount of a student's previous instruction in reading. Almost forty years later, Golinkoff (1975) reported the same finding: IQ tests are helpful in predicting reading achievement, but "other aspects of language development and beginning reading knowledge are more closely related to success in learning to read."

There is some evidence that the predictive power of the IQ test is dependent on the age of the student tested. Gates and Bond (1936) found that the correlation between a measure of general ability and reading achievement increases with age. Despite the fact that these correlations were taken concurrently at each grade, the authors concluded that mental age becomes a better predictor of achievement as the child grows older. Likewise, Dechant and Smith (1977) report the typical correlation to be on the order of .35 or lower in the first grade; by the time students reach the sixth grade,

this correlation may reach .65 or higher. Dechant and Smith conclude that mental age is "a more basic determinant of reading success when children have reached the stage at which they read to learn than it is when they are learning to read."

Again, it is important to remember McClelland's (1973) charge that achievement tests are essentially variants of IQ tests. If achievement tests are more loaded with IQ-like items at higher than at lower grades, which is likely given the stress on comprehension at higher grades, the trend toward higher correlations with increasing grade levels could be simply an artifact of changes in test design. Until this question is settled, it is not particularly meaningful to speak of IQ as a "determinant of reading success."

The correlation between IQ and reading achievement varies with other factors as well. Gates and Bond (1936) found the correlation to vary according to the method of reading instruction such that a higher correlation was evident for students who took part in reading programs that were tailored to fit individual needs. Among the possible interpretations for this finding is that an adaptive program allowed students to learn at a level which more closely approximated their potential than was true in a program that treated everyone in the same way.

The relationship between IQ, method of treatment, and reading achievement was investigated by Chall (1967). One of the conclusions she reports from her reanalysis of studies comparing the phonics

method to the meaning approach was that bright children seem to be less affected by methods than other children. Whereas bright children tend to learn well irrespective of the method used, slow and average children tend to do better with the more structural phonics approach.

The idea that the correlation between IQ and reading achievement may be different at different levels of the IQ distribution is also offered by Vernon (1977). Vernon distinguishes between two types of reading deficiency, "reading backwardness" and "specific reading retardation." Reading backwardness is defined by a positive correlation between IQ and reading achievement. Backward students score low on both measures. Students who exhibit specific reading retardation read worse than their IQ scores would predict. Vernon cautions that reading failure is not a unitary phenomenon and IQ is in no way a sufficient index of reading disability.

Implications

There appears to be a danger in placing so much importance on the IQ test. The reliance on IQ testing as a preinstructional measure and on achievement test results as the primary outcome measure for assessing learning tends to obscure the differential effectiveness of alternative instructional environments and the differential influence of other student characteristics on learning. As Golinkoff (1975) suggests, part of the problem is that practitioners use

achievement tests with the intent of learning how much of what has been taught has been learned, yet these tests are heavily loaded with items that are more sensitive to aptitude differences than to differences in learning. Many of the items, especially reading comprehension items call for inferences and deductions, are relatively insensitive to instruction. One result is that, depending on the aptitude of the students in the sample, achievement testing can constitute an unwarranted endorsement or condemnation of an instructional program. Another consequence is that the unswerving predictive power of premeasures, whether ability or achievement tests, across variations in instructional methods may lead to unwarranted despair regarding the effects of schooling.

Perceptual Abilities and Reading

The relationship of perceptual abilities to reading is most apparent on tests of reading readiness (Dechant & Smith, 1977; Gates & Bond, 1936). In his review of research relating to readiness, Livo (1972) cites a number of studies, which taken together suggest that visual-perceptual factors have more weight than either intelligence or total reading readiness scores in predicting first grade reading success. For example, the Bender Visual Motor Gestalt Test correlates .50 with first grade reading achievement.

It appears that the correlation between visual perception abilities and reading achievement declines as grade level increases

(Livo, 1972). Nevertheless, reading is an information-processing task at all levels. It is likely that perceptual as well as language factors are implicated in the reading deficiencies of some students at all grade levels. Sabatino and Hayden (1970) administered a psycho-educational test battery to 472 children identified as failing in grades 1-6. The data showed that there are specific perceptual information processing problems characteristic of underachievers "which appear as receptive, central and expressive language, auditory perceptual, auditory and visual perceptual memory, and perceptual integrative difficulties."

A factor analysis of the eight subtests included in the battery revealed that perceptual abilities are independent of cognitive and language abilities. That is, children may show perceptual impairments with or without language or conceptual problems. The authors concluded that more attention should be devoted to perceptual behaviors in the primary grades. They found that children were often able to hide perceptual defects from their teachers by relying on their language skills. Teachers' inability to make appropriate diagnoses was further implicated by the finding that a diagnostic measure filled in by teachers for each student in the study showed no relationship to other independent measures in the factor analysis of the measures. The authors concluded that teachers need specific training in the identification and interpretation of student deficiencies.

There is a tendency to view perceptual abilities as innate and not suitable for training. But the visual discrimination tasks that correlate most highly with academic achievement appear to be classifiable as early reading skills as easily as measures of perceptual ability. Dechant and Smith (1977) include being able to discriminate, recognize and name letters, match words, copy a sentence, and discriminate vowel sounds, as well as to copy patterns and match shapes, in their list of the best predictors of achievement. It is possible that the most productive approach to early reading instruction is one that trains reading skills and perceptual abilities simultaneously. A study by Williams (1977) lends support to this notion. She found visual discrimination training to be effective to the extent that the stimuli used were letters and words.

Auditory discrimination abilities are also closely related to reading readiness. According to Livo (1972), cumulative evidence suggests that auditory discrimination is the single best predictor of reading success, ahead of visual discrimination, range of information, and mental age, respectively. According to Silverston and Deichman's (1975) review of perceptual factors and reading, auditory ability precedes visual discrimination as a prerequisite to reading and language arts acquisition.

Implications

The full complement of intellective factors that researchers

have related to one or another aspect of reading achievement could not possibly be listed here. Oral language competency (Livo, 1972), performance on Piagetian tasks (Halpern 1970), and rate of oral reading and quality of motivation (Packman, 1970) are among the many factors mentioned in the literature as correlating positively with reading achievement.

The problem does not seem to be one of finding cognitive and perceptual correlates of reading readiness or reading achievement. The problem is one of describing how these factors interact to contribute to particular performance difficulties (Vernon, 1977).. Vernon describes four areas where the majority of deficiencies can be found: (1) the capacity to analyze complex, sequential visual and/or auditory linguistic structures, (2) the linking of visual and auditory linguistic structures, (3) the establishment of regularities in grapheme-phoneme correspondence, and (4) the grouping of words into meaningful phrases. An alternative approach to the use of correlational techniques is one that begins with the assumption that the majority of reading difficulties are directly caused by inadequate learning. Comprehensive analyses of students' errors on a set of tasks should reveal what the student has failed to master so that remedial instruction can be prescribed. Whether or not these errors reflect a child's low IQ or poor visual discrimination abilities, diagnoses that are made on the basis of such psychometric constructs rather than directly on reading tasks do not lead as

readily to a remedial strategy and tend to implicate a training approach too far removed from the reading process (Williams, 1977).

Intellective Factors and Mathematics

Mathematics achievement tests call for a variety of specific skills, general abilities, and knowledge of mathematics information. It is not surprising, therefore, that both a positive correlation between general intelligence and mathematics achievement (Romberg, 1969; Aiken, 1971b; Cathcart, 1974), and between specific factors and mathematics achievement (Aiken, 1971b) are common findings in research on mathematics education. Among the specific abilities that contribute to the prediction of success on mathematics task and tests are verbal comprehension, deductive reasoning, spatial ability, algebraic manipulative skill, and number ability (Aiken, 1971b).

Aiken (1971a, 1971b, 1972) provides comprehensive reviews of the relationship between mathematics achievement and intellective factors, verbal factors, and language factors. According to Aiken, the high positive intercorrelations found between reading ability and mathematics achievement (r= .45 to .55, Aiken, 1971b); between tests of reading achievement and arithmetic reasoning (e.g., Harris, 1969); and among numerical reasoning, the ability to discern verbal meaning and mathematics achievement (e.g., Romberg, 1969), cannot be completely explained by the overlap of these variables with general

intelligence ("g"). For Aiken, the diagnostic problem in mathematics is far more complex than for any other content area. Mathematics achievement seems to depend not only on a combination of general and specific intellective factors, but on perceptual abilities and previous instruction in reading as well.

Aiken (1971b) cites two studies which provide evidence for the importance of reading competence for mathematics achievement. A study by Gilmary (1967) compared arithmetic instruction to instruction in reading and arithmetic in a six-week remedial program for elementary school students. An analysis of covariance, controlling for IQ, revealed an increment in gain of one-half grade on the Metropolitan Achievement Test for the combined instruction condition compared to arithmetic instruction alone. A similar result was obtained by Call and Wiggin (1966) with junior high school students. A[illegible] (1972) suggests that specific training in syntax and vocabulary would provide the best complement to mathematics instruction.

Other factors mentioned in the literature as predictive of mathematical competence include performance on Piagetian tasks, especially conservation and class inclusion tasks (Romberg, 1969; Cathcart, 1974) and listening ability (Cathcart, 1974). The complexity of the picture is amply revealed in the study by Cathcart. Cathcart administered a battery of ability and achievement measures to second and third grade students. For the second grade students, listening ability, conservation ability, and IQ were significantly related to

mathematics. For the third grade students, IQ, SES, age, listening ability, and vocabulary, but not conservation ability, were related to performance. One finding that appears somewhat curious considering that mathematics was the criterion performance was that listening ability showed the highest correlation with achievement at both grades.

Implications

The importance of reading and language ability for mathematics achievement suggests a number of possible changes in instructional practices. For one, mathematics instruction could be delayed, at least for some students, until such time as minimal reading competency is achieved. Such a strategy would probably not seriously affect ultimate levels of mathematics achievement and might serve to alleviate some of the frustrations that accompany mathematics learning (Rohwer, 1971). Alternately, reading and mathematics instruction could be linked in such a way that progress in mathematics could be tied to progress in reading as well as attainment of prerequisite mathematics skills. A third possibility would be to use mathematics content, such as word problems, for reading instruction.

Perceptual Abilities and Mathematics

Rosner (1973) argues that primary grade reading and mathematics proficiencies are differentially related to perceptual skills, with

reading competence calling for auditory abilities and mathematics requiring visual abilities.

Callahan and Glennon's (1975) review of the research on specific learning disabilities in mathematics provides support for the importance of perceptual factors in mathematics achievement. Callahan and Glennon list the following symptoms of learning disabilities:

1. Disturbed horizontal position of number sequences
2. Disarray of the vertical allignment of numbers
3. Transposition of numbers
4. Auditory memory problems--frustration in oral drills
5. Visual spatial organization; difficulties in quickly distinguishing different shapes, sizes, amounts
6. Difficulty in learning motor patterns for writing numbers
7. Inability to identify quickly the number of objects in a group
8. Difficulty in the perception of sequences and patterns
9. Perseveration; continual practice or drill in one process makes transfer to another process difficult.

Implications

The importance of visual discrimination abilities in mathematics suggests a number of intervention strategies. One possibility is to provide specific training on visual tasks prior to or concurrent with mathematics instruction. Another possibility is to provide special materials that would compensate for the visual perceptual deficiencies of selected students. Lesser (1972) cites

support for this latter strategy in his review.

Adaptive Instruction: Research on ATIs

In the absence of experimental tests, inferences regarding how students might benefit from one kind of instruction or another according to their scores on intellective or perceptual tests are little more than strong guesses. Endorsements of diffential instructional practices based on characteristics of students require research that tests simultaneously the differential effects of two treatments on one or more individual difference variables. Such tests are provided through the use of the aptitude-treatment interaction (ATI) model (Cronbach & Snow, 1977).

The phrase aptitude-treatment interaction refers to an experimental outcome where one instructional method (or level of a single method) is superior to another for students who can be placed at some point on an individual difference dimension (or set of dimensions), wheras an alternative instructional method (or level) is superior for students at another point on the individual difference dimension (or set of dimensions). Although Tobias (1976) refers to ATI research as attribute-treatment interactions, and Berliner and Cahen (1973) prefer trait-treatment interactions, there is universal agreement that personality characteristics, status variables, attitudes, interests, and styles, as well as abilities, are candidates for interactions with instructional treatments.

Jensen (1967) was one of the first to draw attention to the fact that some studies that failed to find significant differences between experimental treatments were characterized by large amounts of within treatment variance. Jensen's inference was that if students were assigned to treatments according to task-related individual difference variables instead of by random assignment, significant treatment differences might have occurred.

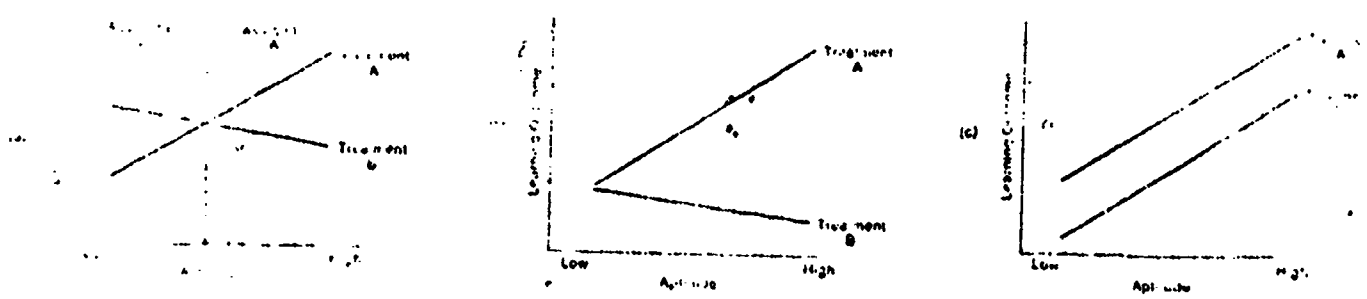

Figure 1. Regression lines showing three kinds of outcomes in ATI research.

Figure 1 shows the possible relationships between an aptitude variable and a learning outcome variable obtained under different instructional treatments (Snow, 1976). Figure 1a shows a classic disordinal interaction; disordinal interactions provide a principle or decision rule assigning students to different instructional treatments. Figure 1b illustrated an ordinal interaction. In the example, only high aptitude students were differentially affected by the treatments. Levin (1973) points out that ordinal interactions often

serve to highlight the importance of a particular instructional manipulation for a minority of students. In Figure 1a, the traditional experimental approach would have concluded without qualification that Treatment A is no better than Treatment B and in Figure 1b, that Treatment A is better than Treatment B. However, only in Figure 1c merits the unqualified generalization that one treatment is best.

ATIs in Reading: Intellective and Perceptual Variables

Cronbach and Snow (1977) review the research on ATIs in reading and conclude that no convincing conclusions are apparent. However, there is some preliminary evidence that general ability interacts with reading method. Differences between ability levels, favoring high ability students, are more in evidence in both a linguistics approach and a combined phonics and linguistics approach than they are in a whole-word approach.

For example, a study by Stallings and Keepes (1970), reported in Berliner and Cahen's (1973) review, found that scores on a measure of initial reading ability, the Illinois Test of Psycholinguistic Abilities (ITPA), interacted with method of reading instruction. Students who scored below 15 on the ITPA did better with the whole-word approach; students who scored above 15 benefited more from a linguistic approach to reading. On the other hand, Chall (1967) re-analyzed nine experimental studies of phonics versus whole-word (meaning) instruction that included a breakdown by IQ. She found

the superiority of phonics instruction to hold for all IQ ranges studied. She also concluded that there is some evidence for the superiority of systematic phonics over a less structured, more inductive phonics approach, especially for low-SES students.

Another popular interaction in reading research is one between preference or strength and reading instruction. The hypothesis is that students who show a weakness in the auditory mode should do better in a "look-say" (whole-word) approach to reading than in a phonics approach, while the opposite would be true for students who are weak in visual abilities. Lesser (1972) concluded as much in his review of research in this area. Rosner (1973), though he did not test the interaction, provides evidence for the possibility that the interaction might be an ordinal one such that students who are deficient in the auditory mode would be more likely to be at a disadvantage irrespective of the reading approach employed.

Robinson (1972) tested 248 students for modality weakness and found only 5-6 percent that could be identified as either visually or aurally deficient. In an experimental test Robinson failed to find an interaction between method of reading instruction and modality weakness. Robinson's conclusion was that adapting instruction to individual differences in this area is not warranted.

Oakan, Wiener, and Cromer (1971) provide some evidence that level of reading achievement and instructional mode may interact in determining comprehension. They found that poor readers

comprehend more when they listen to stories than when they read them themselves; for good readers, the opposite is true. This finding is consistent with research conducted by Sticht (1971) using adults as subjects.

ATIs in Mathematics: Intellective and Perceptual Factors

The only consistent conclusion found by Cronbach and Snow (1977) regarding ATIs in mathematics instruction concerns a relationship between general ability and the meaningfulness of instruction. High ability students, including students with high ability and low achievement, are better able than low ability students to benefit from treatments that involve explanations and rules or that lead the student to organize material intellectually.

Rosner's research (e.g., 1973) suggests the importance of visual abilities for mathematics learning. Lesser (1972), in his review, cites three dissertations which lend support to the view that students who are strong in space conceptualization (visual) abilities or number facility should be matched to a complementary program. By comparison, the mismatching of students to programs results in insignificant gains.

Conclusions

It seems evident that more research on aptitude treatment interactions is required before adaptive instruction according to intellective and perceptual abilities can be prescribed with confidence.

The advantage of ATI research is that, to a greater degree than any other research design, the results of ATI studies lead directly to implications for practice. ATI studies effectively circumvent many of the interpretation and inference problems mentioned earlier.

Yet, there are some difficulties associated with ATI studies and with the inferences they engender. Tobias (1976) lists four such problems: (1) it is not clear whether alternative instructional methods can be designed to rely conclusively on one set of abilities; (2) traits may show a different relationship to the outcome variable at different stages of the learning process; (3) ATIs may be highly specific to a particular task and not generalize from one curriculum area to another; and (4) it may not be practical to prepare complementary alternative instructional tracks.

A possible solution to the problems associated with ATI research is indirectly suggested by Wittrock (1973): "The reason that ATI research has not often produced significant results is probably because we have not often chosen to study the relevant processes that the learner engaged in when he learns a given subject matter." Again, this suggestion seems to call for the specification of individual difference factors exhibited during learning as a more "relevant" substitute for psychometric factors and other traits.

Studies with children reported by Chall (1967) and Cronbach and Snow (1977), and with adults by Snow (1976), seem to point to the conclusion that students low in general ability benefit more from highly structured programs than they do from programs not as highly

structured. According to Snow (1976), students low in general ability show a depressed performance as compared to able students when the instructional treatment:

1. Places information processing burdens on learners;
2. Uses elaborate or unusual explanations;
3. Is a "new" curriculum;
4. Includes discovery or inquiry methods;
5. Encourages learner self-direction;
6. Is relatively unstructured or permissive;
7. Relies heavily on verbiage;
8. Is rapidly paced;
9. Provides only the minimal essentials through programmed instruction; and
10. Provides advance organizers.

These findings suggest an intervention strategy that capitalizes on (accommodates) learner differences rather than a compensatory, remedial approach.

AFFECTIVE FACTORS AND ACHIEVEMENT

The label "affective factors" will here be used to group research on attitude, self-concept, and personality as they relate to achievement in reading and mathematics. Affective factors can be viewed as traits that determine students' disposition to engage in learning. Affective factors are presumed to relate to achievement in the sense that they determine the extent to which students approach or avoid learning tasks. Although the dynamics of the relationship between affective factors, motivation to learn, and achievement are complex and bidirectional, the majority of studies in this section are based on simple correlational models. The reader is referred to a companion paper by Thomas (1978) for a more comprehensive and theoretical treatment of these dynamics.

Attitudes and Reading

Attitude can be defined as a state of readiness for becoming motivated and for persevering on a learning task (Matthewson, 1976). According to Dechant and Smith (1977), attitudes are general dispositions. Specific "interests," on the other hand, are viewed as the manifestation of attitudes.

Matthewson reviewed a number of studies linking attitudes to the reading process and concluded that attitude (or interest) may have a positive facilitating effect upon reading comprehension performance, a conclusion supported by Carroll (1971). According to Matthewson, the

correlation between a student's attitude toward reading as a school subject and reading achievement appears to be of the magnitude of .20 to .35.

In one study reviewed by Matthewson (Healey, 1965), an attempt to change students' attitude toward reading resulted in a long-term improvement in reading behavior. Healey used a combination of instructional strategies to improve fifth grade students' attitudes toward reading. Two years later, these students scored higher in reading achievement and read a greater number of books in their first year in junior high school than control students who had not received special treatment. Zimmerman and Allebrand (1965) found that good readers, as opposed to poor readers, have attitudes that are more favorable toward achievement in reading, no matter whether achievement is defined by parental approval, academic evaluation, or self-knowledge.

Implications

The essential problem in research on attitudes and learning is a variant of the "chicken and egg" issue. Does the possession of a positive attitude toward reading lead to increased benefit from instruction, or does successful performance in reading produce a positive attitude toward the subject? From an intervention point of view, does it make more sense to provide materials or a method of instruction designed to elicit positive attitudes, or is it better to insure success experiences for all students with the hope that positive

attitudes will follow. Clearly, Healey might subscribe to the former position, whereas Bloom (1976), in his book on the Mastery Learning Model, explicitly supports the latter view. Both positions may ultimately be correct. The possession of some minimum interest in or attitude towards mathematics may be required in order for students to benefit from instruction. The maintenance of these interests and attitudes may depend upon subsequent success experiences. Further, high levels of achievement in the discipline may be accompanied by a heightening of attitudes and interest.

Self-Concept and Reading

Cole (1974) examined correlations between achievement motivation and school achievement as well as between self-concept and achievement. Except for the correlation between self-concept and spelling, all were positive and significant. Two facts about this study must be pointed out: the highest correlation was only .312, and the students were drawn from a very narrow IQ range (96-103). The correlation observed would seem to have been attenuated due to the restricted IQ range of the sample.

Wathenberg and Clifford (1964) performed a study relating self-concept to reading achievement that seems to get around the "chicken and egg issue" that is characteristic of much of the research on self-concept, attitudes, and other measures of affect. In order to determine whether possession of a positive self-concept contributes to reading

proficiency or whether a positive self-concept derives from successful experiences with reading, the authors measured the self-concept of kindergarten children along two dimensions, competence and self-worth; these scores were then related to reading achievement performance 2 1/2 years later. The results showed that, in contrast to a test of mental ability also administered during the students' kindergarten year, the self-concept measure was predictive of subsequent reading achievement.

Implications

As elaborated in the Thomas (1978) paper mentioned earlier, although premeasures of self-concept are useful for predicting achievement in a variety of areas, it is a misconception to view self-concept as a trait that determines the level of achievement a student is likely to attain. Self-concept appears to be the product of a student's history of success and failure experiences and is related to the causal attributions students use to evaluate their successes and failures. According to this analysis, self-concept is readily affected by environmental factors, especially the reward structure employed in the classroom. In addition, an appropriate intervention strategy might be one that both provides success experiences and links successes and failures to effort and task difficulty rather than to ability and luck.

Personality Factors and Reading

Grimes and Allinsmith (1961) found an interaction between a

personality characteristic and teaching methods. In their study, they found that highly anxious and/or highly compulsive children benefited more from a structured phonics program than from an unstructured reading program. Both of these interactions, for compulsivity and for anxiety, were ordinal in nature.

Research relating personality factors to reading achievement is quite sparse. Judging by the literature, students do not develop a personality or anxieties until they become college freshman. The reason for the lack of research on children is probably at least twofold. For one thing, childhood personality tests are notoriously unreliable, and for another, the measurement of personality and anxiety is a highly sensitive, sometimes tabooed enterprise. Dechant and Smith (1977), in their review of research on personality factors in reading, describe the research that exists as inconclusive. Most of this research is concerned with the relationship between gross emotional maladjustments and reading achievement, a relationship that the authors describe as circular in nature. Insofar as some of the most promising research on aptitude treatment interactions involves adapting instruction to personality differences (Cronbach & Snow, 1977) and to differences in trait anxiety on adult subjects (McKeachie, 1975), there seems to be a need to discover to what extent these variables relate to differential learning situations for children.

Affective Factors and Mathematics Achievement

Conventional wisdom has it that affective variables are more closely related to achievement in mathematics than to achievement in most other areas. That is, students who do well in mathematics are the ones who tend to like the subject; students who do poorly tend to dislike the subject. Mathematics is a rule-bound and relatively difficult subject area. Also, unlike any other subject, mathematics does not have concrete topics or content areas. The content in mathematics is an abstract symbolic system. Most adults who progressed through elementary arithmetic into the more specialized courses introduced in junior high school can probably recall finding mathematics more difficult, more demanding, and perhaps less interesting than other courses. Yet, research on the relationship between attitudes and mathematics achievement lends only partial support to the view that student achievement in mathematics is strongly related to student attitudes toward mathematics. Aiken (1976) in his review of the topic concludes that the correlation between attitude and mathematics achievement appears to be significant and positive but relatively low.

Neale (1969) found correlations ranging from .20 to .40 across a number of studies in the area and described the relationship as "modest." In one of the studies Neale examined, factor analysis was used to separate factors that relate to mathematics achievement. The results showed that attitude, personality, and ability each accounted for 25 percent of

the variance in academic achievement. Malpass (1953), however, found that attitudes toward school, teacher, classmates, and achievement in mathematics were unrelated to scores on the Stanford Achievement Test.

In a recent review, Aiken (1976) provides a summary of research on attitudes as they relate to mathematics achievement. Among Aiken's conclusions are: (1) the late elementary and early junior high school grades are especially important for the development of attitudes toward math; (2) the correlation between attitude and achievement varies with sex as well as grade level, the correlation being higher for girls; (3) no clear inference can be made whether or not a poor attitude is a function of poor ability in mathematics (Neale, 1969, concurs); (4) personality characteristics related to a positive attitude toward mathematics include a greater sense of responsibility, high social standards, high academic achievement motivation, and a greater freedom from withdrawal tendencies; and (5) students who have a positive attitude toward mathematics, compared to those with a negative attitude, tend to be more conforming and more obedient, and their parents tend to be more possessive.

Callahan and Glennon (1975) review a number of studies that relate self-concept to achievement in elementary school mathematics. Their conclusion is similar to Aiken's and Neale's with respect to attitude: this relationship appears to be a "two-way street." For some children, a poor concept of self may cause underachievement; for other children, failure at mathematics may cause a poor self-concept (cf. negative attitude, lack of interest). Finally, Aiken (1970)

makes the point that attitude toward mathematics operates as a moderator variable such that only very positive or very negative attitudes affect achievement. Aiken also suggests that there may be a relationship between teacher attitude toward mathematics and student achievement.

In a study of extroversion, Trown (1970) found that in original learning, retention, and transfer of an algebra lesson, extroverted boys outperformed introverted boys although the opposite was true for girls. An additional interaction emerged regarding introversion-extroversion and the placement of rules and lessons within the lesson. Introverted students performed better when rules were placed before examples; extroverted students benefited from the placement of examples before rules.

More attention seems to be devoted to research on personality correlates of mathematics achievement than was true for reading. A brief look at some of the reviews of research in mathematics education reveals a substantial list of personality and behavioral correlates including aggression, social interaction, autonomy, dominance, masculinity-femininity, total MMPI score, introversion-extroversion (Aiken, 1976), need for appreciation, popularity, and intimacy of friendships (Baraheni, 1962).

Conclusions

The summary and conclusions presented for the relationship between affective characteristics and reading achievement hold equally well for mathematics. The relationship between affective characteristics and

academic achievement is probably best thought of as a "two-way street," in Neale's (1969) terms. Accordingly, the most appropriate intervention strategy might be a "two-way" approach involving direct attempts to improve self-concept or attitude "deficiencies" (compensatory mode), combined with adaptive instructional methods and/or materials designed to match students' affective characteristics (capitalization mode).

Research concerning the role of affective factors as moderating or intervening variables should probably be pursued. One possibility is that affective variables such as self-concept or personality factors moderates the relationship between ability and differential instructional treatments. For example, the differential effectiveness of programmed instruction vs. a teacher-centered approach may depend on a students ability level and a student's concept of his/her abilities.

PROCESS VARIABLES AND ACHIEVEMENT

Process variables are those that relate directly to performance differences exhibited by students during the learning process. Two classes of process factors are covered here: styles and strategies. Research on process variables in learning is an offshoot of the cognitive approach to the study of learning. According to Wittrock (in press), the "cognitive approach implies that learning from instruction is scientifically more productively studied as an internally, cognitively mediated process than as a direct product of the environment, people, or factors external to the learner" (p. 1). The extension of this argument is that individual differences are more profitably studied by investigating what it is that learners do or do not do during learning and instruction than by studying what learners "are" as defined by status characteristics or as measured by psychometric tests.

Cognitive Style and Reading

According to Messick (1972), cognitive styles are information-processing habits- characteristic modes of operation that define an approach to learning across a variety of content areas. Messick lists nine examples of cognitive style dimensions:

1. Field independence versus field dependence;
2. Scanning;
3. Breadth of categorizing;
4. Conceptualizing styles;

5. Cognitive complexity versus simplicity;

6. Reflectiveness versus impulsiveness;

7. Leveling versus sharpening;

8. Constricted versus flexible control; and

9. Tolerance for incongruous or unrealistic experience.

Research on cognitive style factors and learning is fairly recent, but has grown at a rapid pace over the course of the last ten or twelve years. One of the reasons for this interest is that many researchers believe that students' learning styles are every bit as important for successful learning as their general cognitive abilities. Moreover, a student's style of approaching a learning task may be more malleable than his/her abilities either through direct instruction or through alterations in the individual environment. In a review of research on aptitude treatment interactions, Snow (1976) offered the following conclusion about research in higher education:

> The generally capable, independent, divergent thinking, analytic type of student will do best in both achievement and creative performance if given his preferred style, namely a teacher who encourages independent thinking and initiative. The conforming, non-divergent, field dependent, less capable student will also show his best achievement in his preferred treatment, a teacher who requires conformity.

The impulsivity-reflectivity dimension of cognitive style studied by Jerome Kagan and his associates is perhaps the most popular style variable, at least in research on children. Kagan (1965) found that reflective children make fewer errors in decoding words than do impulsive children.

First grade children were assigned to a reflective or an impulsive group based on their performance on the Matching Familiar Figures (MFF) task. In the experimental task, students in both groups were shown cards which had five words printed on them; for each card, students were directed to point to the word read aloud by the experimenter. The results of this study showed that, in general, reflective students, students who took more time on the MFF task, were better able to recognize accurately the words on the cards than were the impulsive students. This relationship was found to hold true even when mental ability was controlled. Moreover, the relationship was stronger for girls than for boys and stronger for high verbal than for low verbal students. Wittrock and Lumsdaine (1977), in their review, conclude that reflective children do better than impulsive children on tasks that involve analysis. When a global or holistic approach is required or acceptable, impulsive children do as well as reflective children. They suggest that instruction be designed in relation to a student's cognitive style by either complementing that style or by compensating for it.

Another cognitive style dimension that appears to offer a promising area of investigation for research on reading is the field independence-field dependence dimension. Field independent people have an analytic rather than a global way of perceiving, which allows them to see figures as independent of their background or context. Stuart (1967) found an inverse relationship ($r = -.75$) between level of reading achievement and performance on the Embedded Figures Test (EFT). Good readers took less

time to find the embedded figures. Wittrock and Lumsdaine (1977) consider field dependence to be a handicap, since schools typically demand a field independent and analytic style for success. With respect to the field independence-dependence dimension, they suggest that the cognitive style not the task, should be modified.

Cognitive Style and Mathematics

Success in mathematics usually requires patience as well as ability. Performance on a mathematics problem typically demands understanding of the requirements of the task, the recall of the appropriate rule, the application of that rule, and often a final check to make sure that a careless error was not made. The premium that is placed on being methodical and careful in mathematics tasks should favor children who are reflective rather than impulsive. According to Callahan and Glennon's (1975) review, this seems to be the case. The authors cite Kagan, who has suggested that the major cause of reflectivity is anxiety over making a mistake.

The correlation between cognitive style factors and mental ability is typically low. Nevertheless, performance decrements that are sometimes associated with a particular style can be easily mistaken as a sign of low ability (Cathcart & Liedtke, 1969). Schwebel and Schwebel (1974) hypothesized that impulsive respondents "underuse their capabilities." The authors hypothesized further that if impulsive students were restrained from making an immediate response, that is, if they

were required to be reflective, they would perform like reflective students.

Schwebel and Schwebel formed three groups using 49 second and third grade children drawn from lower and middle SES populations. Acting on the assumption that lower SES children would be more apt to respond impulsively, they divided the students into an experimental group and a control group made up exclusively of lower SES children, and a second control group made up of middle SES children. The tasks consisted of two Piagetian class inclusion problems and a number conservation task. The experimental group was restrained from making an immediate response; the control groups were not. The restrained lower SES group significantly outperformed its unrestrained counterpart and even outperformed the middle SES unrestrained group, though this latter result was not significant. In addition, across the two control groups, students who answered correctly took significantly more time to produce their answers. The authors suggest however, that training children to internalize reflective habits may be a more productive avenue than forced restraint.

Adaptive Instruction: ATIs and Cognitive Style

Research on cognitive style dimensions shows promise for providing relatively stable aptitude-treatment interactions. Moreover, since many of these interactions involve environmental or classroom process variables rather than task characteristics, they may well provide principles for matching students to treatment in both basic skills areas, reading and

mathematics (Spitler, 1971). Among the tentative interactions mentioned in the previous section on cognitive style are the interaction between impulsivity-reflectivity and the analytical vs. holistic nature of the task (Wittrock & Lumsdaine, 1977), and the interaction between this same style dimension and the tempo of instruction (Schwebel & Schwebel, 1974).

In addition, teacher's cognitive style may interact with that of students (a trait-trait interaction). Witkins, Moore, Goodenough, and Cox (1977) found that field independent teachers were more apt to rate their field independent students more satisfactorily than their field dependent students. The same tendency to rate like students more satisfactorily was also found for field dependent students. No conclusion regarding the effect of this interaction on achievement could be drawn from this study. Yando and Kagan (1968) tested the hypothesis that reflective teachers would have a stronger impact on the reflectivity of their students than would impulsive teachers. Among other results, they found an interaction between teacher experience and teacher tempo. The largest gains in student reflectivity were made in classrooms taught by experienced, reflective teachers.

Implications

The selection of an intervention mode with regard to differences in cognitive style seems to depend on the nature of the style variable. There is some suggestion that the impulsivity-reflectivity style dimension is amenable to a compensatory mode of intervention. Direct training, restraint of some kind, or the provision of models might be used to

encourage a more reflective style where appropriate. With respect to the field dependence-field independence or analytical-global dimension, on the other hand, it may be more appropriate to provide instructional practices matched to a student's style than to try to change that style.

Wittrock (in press) suggests that the field dependence-field independence dimension should be used as an index of the extent to which students will benefit from a structured vs. a more permissive environment. According to Wittrock, field independent students learn better from a situation where they are permitted to set their own goals, provide their own motivation, and determine their own reinforcement. Field dependent students are more comfortable and learn better with externally defined goals, external reinforcement, and a clearly delineated structure. The alleged low correlation between cognitive style and ability would seem to suggest that a test needs to be performed (ATI) delineating the relationship between structured vs. unstructured instructional treatments of varying kinds and both levels of ability and cognitive style dimensions.

Cognitive Strategies

Whereas cognitive styles represent relatively deep-seated approaches to learning and problem solving, strategies refer to characteristic performances exhibited by learners during learning that are wholly under conscious control. Strategies are learned skills that people employ during a learning task in order to manage the demands of that task and

make it easier to complete. In Resnick's (1976) terms, strategies have a propaedeutic function as opposed to a prerequisite function in learning; that is, strategies are helpful rather than necessary for attainment of the terminal task. To take a familiar example, in order to multiply 12 x 13 in your head, the ability to apply basic multiplication rules is a prerequisite. If you give this task to a number of students, most everyone will know how to compute the answer and be able to provide it in time. But a few students will be able to provide the answer immediately. The key to proficiency on the task is the use of a strategy (e.g., adding a 12 to the familiar square of 12).

Research on cognitive strategies has its roots in the cognitive psychological analysis of memory and problem solving and in an information-processing view of learning. Dansereau, Actkinson, Long, and McDonald's (1974) definition of strategies reflects this tradition: "ways of selecting, storing, manipulating, managing, and outputting information" (p. 11). Recently, the notion that differences in performance between students can be analyzed at the strategy level has spread to research on motivation, attention, behavior modification, comprehension, and creativity (Anderson, in press; Dansereau et al., 1974; Richardson, 1978; Wittrock, in press).

There are two research models that have been used to investigate the role of learning strategies in the basic skills areas. One such model is the performance analysis. A performance analysis is similar to a task analysis. Whereas a task analysis is conducted in order to determine the prerequisite skills needed for successful attainment of some criterion

task, a performance analysis focuses on what students do when confronted with a learning task. Included within the domain of behaviors investigated by performance analyses are learning sets, self-management behaviors, plans, and all of the covert and overt responses, including errors, that learners make while carrying out a task. Performance analyses designed to identify individual differences in learning commonly focus on what proficient learners do or do not do when confronted with a learning task. A related approach is to focus on errors made by poor learners on a learning task. The assumption behind these kinds of research studies is that one of the major sources of individual difference variation in learning has to do with differential preferences for and employment of effective learning tactics or strategies on a learning task (Glaser, 1976a).

The second research model can be called the "optimization" approach (Glaser, 1976a). The goal of optimization research is to insure that all students come to employ the most efficient strategies on a particular task. Moreover, the goal is to insure that students learn to use these strategies in an autonomous fashion. The intervention technique may involve special training, the provision of special prompts to induce the use of particular strategies, or a combination of these methods (Glaser, 1976b; Rohwer & Levin, 1971; Williams, 1977).

Performance Analyses in Reading

Most of the research in the area of reading aimed explicitly at identifying strategy differences is in the area of comprehension. This

situation is due, in part, to the fact that research on memory and information processing forms the basis of much of the strategy research. Another reason for the prevalence of comprehension research is that strategies tend to be differentially implicated depending upon the amount of freedom a student has in performing a cognitive task. Paragraph comprehension is less rule-bound than decoding; hence, there are more differences between students in the way they approach and perform the task. According to Williams (1977), good comprehenders are hypothesis testers. In Goodman's (1976) terms, reading is a "psycholinguistic guessing game."

Golinkoff (1975) reviews some of the characteristic behaviors of good and poor decoders and comprehenders. The following is a partial list of her conclusions:

- The best decoders read in syntactic chunks.
- Good comprehenders recognize less frequent words quickly. Poor comprehenders have difficulty decoding unfamiliar words.
- Good comprehenders exhibit fewer meaning distortion errors and correct a higher proportion of these errors.
- The decoding errors of poor compr ders are less likely to decrease when given advance infor on about a passage than is true for good comprehenders.
- Poor comprehenders are relatively unable to use sentential cues to select the correct pronunciation of ambiguous words.
- Good comprehenders do not actually read each word but use context features to speed up recognition. They exhibit fewer and briefer fixation pauses.
- Poor comprehenders are unable to use interword redundancy to help them read single words.

- As evidenced by their poor performance on close tests, poor comprehenders may not be processing the meaning of sentences.

Perfetti and Lesgold (1977) explored possible individual difference factors between good readers and poor readers in discourse comprehension. The authors speculate that the source of poor readers' difficulties in discourse comprehension could be in (1) their use of discourse structure, (2) short term memory capacity, or (3) verbal coding speed. The authors conclude that it is coding speed that accounts for the major differences between good and poor readers and that this factor is further accented by differences in short-term memory functions. Referring to the problem as the "double whammy," the authors conclude that less skilled readers are poor at verbal coding; that is, they are slower at naming a word stimulus and at retrieving semantic information in response to a name. Also, they are not proficient at retaining the exact wording of sentences they hear. In other words, not only are poor readers slower at getting to the point in the comprehension process where exact wording is not necessary, but their poorer short term memories handicap them when they do reach that point.

Olshavsky (1976, 1977) identified ten reading strategies exhibited by tenth grade students. She found strategy usage to be related to interests, proficiency, and style of materials. Readers apply more strategies when they want to comprehend (interest), when they are most able to comprehend (proficiency), and when they need to comprehend (abstract materials). Examples of strategies that Olshavsky referred to as problem-solving

strategies include the use of context to define a word, rewording, inference, and synonym substitution. In contrast to other analyses, Olshavsky found no differences between proficient and nonproficient learners in the kinds of strategies employed; rather, the difference she found was in the frequency of their use. A related finding is reported in a review by Carroll (1971). Carroll concludes that there is an important interaction between rate of comprehension and power of comprehension. Good readers show a high rate of comprehension on easy material and slow down on difficult material. Poor readers exhibit the same rate regardless of difficulty level. In both the Olshavsky study and the study reported by Carroll, differences between students in the disposition to employ strategies are implicated.

Brown and Campione (1977) reviewed studies that traced the development with age of the use of strategies on simple memory tasks. They report that characteristic deficiencies in strategy usage among younger children are best labeled as production deficiencies rather than mediational deficiencies; that is, when these students are provided with effective mediators or induced to use effective strategies, they are able to do so. The source of younger students' deficiencies as compared to older students is in their failure to generate spontaneously the mediators or strategies. With respect to reading, Brown and Smiley (1977) report that as children mature they become increasingly able to identify the organizing features and crucial elements in textual materials and become progressively aware of their own thought processes. They begin

to know that there are strategies that can be brought to bear on a task and discover when and how to use them. Brown and Campione (1977) refer to this emerging perception of reading as a task that the student has some strategic control over as "metacognitive behavior."

Anderson (in press) presents a model of skilled reading which divides the reading process into three stages of prereading, reading, and post-reading activities. Although Anderson's model is based primarily on research conducted with older children and adults and is oriented toward learning from reading rather than learning to read, the model provides an interesting analysis of strategic aspects of the reading process. According to Anderson, in the prereading state, skilled readers engage in activities such as browsing, skimming, and surveying the text. Skilled readers may also generate orienting questions during this stage concerning the reasons for reading or studying a particular text. During reading, the skilled reader has a number of strategies at his/her disposal. Strategies that can be employed whenever a meaning problem occurs include: rereading, jumping ahead, consulting an outside source, recording the questions, and thinking about the problem. Postreading or study strategies include rehearsal, outlining, and paraphrasing.

Optimizing Instruction in Reading

Rohwer and Levin (1971) distinguish between learning efficiency and learning proficiency. A consideration of learning efficiency refers to variations in instructional conditions that can facilitate or prompt

optimal learning. Learning proficiency refers to differences between subjects in the skills and strategies they bring to bear on a learning task. According to this view, the most valuable instructional interventions are those that insure that all learners are using the most effective learning strategies they are capable of employing and are disposed to use these strategies autonomously.

Not all deficiencies are strategy deficiencies. Effective optimization methods require diagnostic procedures capable of distinguishing between different kinds of deficiencies. Levin (1973) distinguishes between deficit poor readers and difference poor readers (Wiener and Cromer, 1971). Deficit poor readers have problems at the decoding level; they have failed to learn prerequisite decoding skills. Difference poor learners have mastered decoding skills but have problems at the comprehension strategy level. Levin hypothesized that instructions to use imagery should facilitate the performance of difference poor readers; results from the study confirmed this hypothesis. No comprehension differences were found between the two types of readers in the control condition.

Levin (1976) reports that the ability to benefit from instructions to use imagery on tasks of prose comprehension is dependent also on the pictorial ability of learners. Some students learn well from both pictures and words, some learn poorly from both pictures and words, and others learn well from pictures but poorly from words. Presenting a prose passage with and without instructions to use imagery to high

pictorial students and low pictorial students results in an ordinal interaction between ability and instructional conditions. Both ability groups perform at equivalent levels under standard comprehension instructions. With instructions to use imagery, high pictorial students significantly outperform low pictorial students. Pressley (1977) suggests that diagnostic measures be developed to separate students who learn well from pictures and students who do not.

Wittrock (in press) suggests that comprehension can be facilitated by having students generate sentences or line drawings designed to link information and concepts presented in prose passages to what the students already know. Wittrock cites an unpublished study that showed that asking students to generate relational sentences for each of a series of paragraphs boosted both comprehension and retention as compared to an uninstructed control group. Davidson (1976) suggests that students can be taught to generate their own concrete metaphors or pictorial representations to help understand and remember abstract material.

Other strategies that show promise for facilitating reading performance include covert verbalizing, finger tracing, and the use of vocalization (Ghatela & Levin, 1976); using context clues to facilitate decoding (Golinkoff, 1975); self-speech (Glaser & Resnick, 1972): self-management strategies (Glaser, 1972); and highlighting, notetaking, underlining, paraphrasing, and other study strategies (Anderson, in press).

Performance Analyses and Optimization in Mathematics

Mathematics seemingly provides a wealth of tasks and high-level skills that lend themselves to a performance analysis. Yet, very little strategy research can be found in the literature on mathematics education. As noted earlier, mathematics may be a more rule-bound discipline than reading, or at least comprehension. When successful performance depends exclusively on the use of a set of fixed rules and algorithms, there may be no latitude for learner-generated strategies. On the other hand, word problems and reasoning tasks typically provide considerable latitude for alternative approaches.

Glaser (1976a) cites an interesting example of a performance strategy from the field of mathematics education. Given a single-digit addition problem, some children automatically add the smaller number to the larger one rather than vice versa no matter whether they were asked to add, for example, 6 + 8 or 8 + 6. These children have discovered that they have a choice concerning how they define the task. Groen and Resnick (1977) found that even preschoolers were able to discover the choice model on their own without explicit instruction.

Resnick (1976) concludes that the implications from studies like these and others is that "we ought to abandon the routines suggested by rational task analysis." Instead, educators ought to find out what routines skilled performers use and teach these routines to all students.

Implications

Research on the role of strategies in learning suggests a number of intervention tactics:

1. The development and use of diagnostic instruments to determine what strategies or routines students use across a variety of reading and mathematics tasks; the development of such measures depends on thorough performance analyses for these tasks.

2. The use of special training materials to teach students to use the more efficient strategies used by proficient learners.

3. The redesign of instructional methods and materials to encourage or induce the use of the more efficient strategies.

4. The design of special methods to promote the continued use of efficient strategies by students who exhibit a deficiency at the production or disposition level. (Dansereau et al., 1974, suggests behavior modification procedures).

Glaser (1976a) presents an important qualification on the promise of such an intervention strategy. Glaser suggests that strategies that are discovered may be more enduring and usable than strategies that are trained or induced. This suggestion would imply that a training program that treats strategies as rules to be learned (algorithms) would be less effective than one that encourages students to improve on existing rules or one that gives students a choice among potentially helpful rules (heuristics).

It is evident that additional research on strategies in the area of mathematics education is required. As Mayer (1977) suggests, some of the early research on Gestalt psychology may provide the ground work for such research. In addition, suggestions for possible mathematics strategies

can be found in Polya's (1957) book on mathematical problem solving and in an instructional program entitled Problem Solving in Mathematics: Understanding Problems developed by Robinson and Evans at the Ontario Institutes for Studies in Education.

CONCLUSIONS

Research on individual differences is undergoing a very significant revolution. The gradual change from a strict stimulus-response view to a cognitive view of learning has elevated the individual and his/her volitions, expectations, styles, and strategies to a central place in the analysis of learning. Whereas previous attempts at constructing theories of learning and instruction tended to ignore the learner and learner differences, cognitive theory posits that the learner and his or her characteristics serve as intervening variables between external factors and responses made within a learning situation.

The basic theme of this paper is that research on learner differences has moved from a focus on differences between learners, as measured by a psychometric or trait analysis, to a concern for differences that learners exhibit during the learning process. This trend toward investigating process factors (internal variables, intrinsic factors, performance factors) not only serves the construction of theory building, but has potential for providing practitioners with the principles required to provide adaptive instructional environments.

Deriving definitive conclusions from the research presented here is difficult. Research on status factors seems moribund. Research on intellective factors has identified few specific factors that interact with instructional treatments. Research on individual differences in

affective factors is suspect in light of recent models integrating affect, motivation, and achievement (e.g., Wiener, 1972). Research on process factors, especially on basic skills tasks, has only just begun. And finally, aptitude-treatment interaction research, though less than successful to date (Snow, 1977), may not emerge as a major source of information for the design of practice until process factor research reaches maturity.

Despite these cautions, there are a few conclusions that might be offered for the design of research and practice. The reader should note that more specific and perhaps more useful conclusions than these were included at the ends of previous sections and subsections.

Implications for Further Research

In 1957, Cronbach presented a presidential address to the American Psychological Association wherein he called upon the research community to discover principles for governing the matching of students to instructional environments. The search for these principles is still a major objective of educational research. Apropos of this continuing need, possible avenues of investigation suggested by the research reported above, include:

- The discovery of what Glaser (1976b) refers to as "new aptitudes"- performance-related characteristics such as styles, strategies, and self-management behaviors which interact with different learning environments.
- The investigation of learner differences that relate to the peer

re onships and student-to-teacher relationship in a classroom. (Do 1 1978). Classroom learning is a matter of opportunity to learn and time on task. An investigation of learner differences at the classroom level would seek to identify characteristics that inhibit or increase perseverance and the opportunity to learn.

- The investigation of the possible moderating, role of attitude, personality characteristics, and motivation. Recent research (see Thomas, 1978) suggests that such factors as self-concept and a sense of agency affect the relationship between ability and task conditions on the one hand and achievement on the other.

- Further expansion of ATI research to include process factors and affective and motivational factors, possibly in combination with one another.

- The development of a model for facilitating strategy acquisition, which might include principles for determining what strategies are appropriate for what students, and when to use training, prompts a discovery approach to strategy acquisition.

- An investigation of the durability and transferability of training in learning strategies. As Brown and Campione (1977) suggest, the true tes of strategy training is its generalizability to new settings and tasks.

- Further research designed to identify the specific characteristics that may serve to explain the correlations found between SES or race and achievement. Although ability differences are implicated, from the point of view of designing interventions, more attention might be paid to strategy differences (Rohwer, 1971), style differences (Wittrock, in press), and differences in achievement motivation (Weiner, 1972).

- Extension of performance analysis research in order to identify the strategies and behaviors that distinguish more proficient learners from less proficient learners. The end product of such research might include comprehensive diagnostic instrument for all school tasks.

Implications for Practice

As noted in the Introduction, there is nothing particularly innovative about the notion of adaptive instructional environments.

Yet the emerging picture from research on learner differences is that truly adaptive environments have not been attempted on a large scale. Individualized instructional programs were essentially single-treatment programs that allowed for variations in pacing and preference for types of materials. Glaser (1976a) identifies four types of individualization: a learning achievement model that provides differential prescriptions based on information about past achievements and difficulties; a model which makes allowances for variations in the rate, pace, and rhythm of learning; a model that provides for variations in the amount and type of environment support (e.g., guidance, feedback) needed by learners; and a model that individualizes according to the degree to which children can manage their own instruction. The research reported here would seem to provide a beginning for the task of building instructional environments and learning systems that are adaptive to learning difficulties (e.g., the Mastery Learning Model described by Bloom, 1976), differential needs for environmental support (e.g., Chall's, 1967, conclusion regarding the interaction of SES and reading method), and differences in the benefit associated with self-management procedures (e.g., Wittrock's, in press, suggestion concerning the interaction between cognitive style and focus of classroom control).

Additional conclusions from the research reported in this paper include the following:

- Low ability and disadvantaged students seem to benefit from a highly structured, well-controlled classroom environment.

- The importance of reading ability for mathematics achievement seems to suggest that for some students achievement in mathematics will require some form of compensatory reading instruction. Alternately, it may be salutory to delay the onset of mathematics instruction in order to concentrate exclusively on reading.

- There is some preliminary evidence for the value of compensatory approaches for low SES students that emphasize instruction in learning strategies and other optimization techniques (Rohwer, 1971; Rohwer & Matz, 1975).

- Remedial programs designed to affect the perceptual abilities thought to be prerequisites for reading and mathematics readiness would seem to be most effective to the extent that they use content-related training materials (Rosner, 1971; Williams, 1977).

- There is some evidence that at least some cognitive style factors can be altered through special training and modeling.

- Indirect evidence is provided from some of the research on learning strategies (Dansereau et al., 1974; Resnick, 1976) that an emphasis upon one and only one method or routine for learning and problem solving may be less appropriate than an approach that allows students some flexibility to choose or select the strategy with which they are most comfortable.

Finally, it must be concluded that the design of instructional practices that are adaptive to learner differences is a complex enterprise. There are a variety of differences between learners. This review has not even touched on the importance of differences in previous learning and motivation, nor has it considered in depth the enormous differences in task demands between and within reading and mathematics. Clearly, additional theoretical work is required to construct models that integrate learner characteristics with task demands and classroom processes.

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