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INSTRUCTIONAL PSYCHOLOGY

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CONTENTS

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INTRODUCTION

The term "instructional psychology" was originally used to refer to topics emphasized in instructional design, such as programmed learning, behavioral objectives, and modularized instruction with frequent testing. As behaviorism's influence waned, the term "instructional psychology" began to broaden, becoming virtually synonymous with "educational psychology." Current instructional psychology carries over from its behaviorist beginnings a tough-minded empirical approach to education, but it differs from its behavioristic salad days in a stronger emphasis upon theory, a move from external situational variables to internal cognitive variables, closer connections with cognitive theories of motivation, a focus on school tasks, and greater emphasis upon individual differences. In the behavioristic heyday of instructional psychology, individualization was primarily in terms of time spent in achieving goals. Today instructional psychology thinks of individualization in terms of attribute-treatment interactions—teaching methods that interact with student characteristics. Abilities and dominant motives formerly regarded as fixed are now regarded as potential targets for education. Instructional psychology aims for the development of motivation, cognitive structures, and a repertoire of skills and strategies for learning and problem solving.

The four authors of this chapter complement each other in their areas of specialization but exemplify the trend toward cognitive approaches described by Menges & Gerard (1985) in their review of previous *Annual Review* chapters on instructional psychology. Since the 1983 chapter by Gagne & Dick covered the major instructional theories, we have not attempted to review them here. This chapter reflects the dynamic growth of instructional psychology: the increasing interest in the interaction of cognition and motivation, the movement from hardware-oriented technology to issues of technology grounded in instructional theory, and the trend from static variables toward process variables. We begin with the learner—cognitive and motivational characteristics learners bring to instructional situations. We then deal with instructional processes. Finally, we survey research on the tasks and content of instruction.

LEARNER CHARACTERISTICS

The importance of individual differences in the ability to learn and benefit from instruction has long been a theme of educational psychology (Corno & Snow 1986). Rather than static traits, current research emphasizes a more dynamic process-oriented approach to learner characteristics (e.g. Brown et al 1983, Snow & Lohman 1984). Whereas early instructional psychology dealt primarily with instructional designs involving matters of manipulating presentation and pacing of instructional material, it has become clear that learners seek to learn; they transform what they receive from instruction and create and construct knowledge in their own minds. Thus what the learner brings to the instructional situation in prior knowledge and cognitive skills is of crucial importance. Although there is a variety of learner characteristics that influence learning and instruction (cf Corno & Snow 1986), two of the most important are intelligence and motivation.

Intelligence

The classic area of intelligence has probably shown more signs of change in the last decade than in any period since Thurstone and Spearman introduced factorial studies of intelligence. Recent research on intelligence has been revitalized by cognitive approaches. As Gagne & Dick (1983) pointed out in the last *Annual Review* chapter on Instructional Psychology, intelligence tests predict performance in conventional schools and intelligence interacts with instructional methods to affect educational outcomes. But what is intelligence? Undheim (1981a,b,c,d) has made a persuasive case for the proposition that intelligence is achievement—the result of past learning as well as a predictor of future learning. Psychometric theories of intelligence have attempted to define intelligence by focusing on the number of factors or latent traits of individuals that explain performance and the geometric relationships among these factors (Sternberg 1985). Guilford (1982) proposed that there are 150 factors underlying intelligence, while recent adaptions of general *g* theories focus on crystallized abilities, fluid or analytic abilities, and spatial-visualization abilities (Snow & Lohman 1984). Balke-Aurell (1982) has shown that general or fluid intelligence as well as crystallized intelligence and spatial visualization ability are influenced by educational experience. Learners who are involved in educational programs and in work that demands verbal functioning develop verbal, or crystallized, ability, while participation in activities demanding spatial-visual functioning results in greater development of this somewhat more specialized ability. Snow & Lohman (1984) suggest that crystallized abilities are evoked by familiar tasks and environments, and that novel tasks or unusual instructional techniques that require analysis or decontextualization recruit fluid abilities. These differences can result in attribute treatment interactions (ATIs) between instruction and learners.

Information processing approaches to intelligence have stressed the dynamic processes involved in intelligence rather than static traits of individuals. Sternberg (1985) has related four general information processing paradigms to intelligence. The cognitive-correlates approach has focused on performance of simple tasks (e.g. letter matching) in an attempt to uncover the basic cognitive processes involved such as speed of response and speed of lexical access. In contrast, the cognitive-components approach has utilized more complex tasks such as analogical reasoning to explore the higher-level components involved in performance, for example, inference, application, and executive control. The third approach has attempted to train cognitive processes to demonstrate their existence and importance (e.g. Campione et al 1982). Finally, the cognitive-content approach has examined how differences in the structure and content of individuals' knowledge base influence their performance. For example, Anderson (1983) has proposed that individual differences in performance are a function of the flow of information in the mind, with individuals differing in their declarative knowledge (knowing what something is) and their procedural knowledge (knowing how to do something).

Sternberg (1985) has proposed an ambitious triarchic theory of intelligence that attempts to integrate and synthesize most of the research on intelligence. There are three subtheories in his overall theory. The componential subtheory specifies the components of intelligent performance which include: (*a*) metacomponents that exert executive control, (*b*) performance components that execute the plans constructed by the metacomponents, and (*c*) knowledge acquisition components that select, encode, and combine information to create new knowledge. The contextual subtheory deals with how individuals adapt or accommodate to their environment. The third subtheory relates intelligence to experience with a variety of tasks. Regardless of whether this triarchic theory is borne out by future research, it is sure to generate research and provoke discussion.

In contrast to Sternberg's (1985) information processing view, Gardner (1983) suggests that intelligence varies across different domains or symbol systems such as language, music, mathematics, or physical coordination (kinesthetics). He proposes examining the profile of a learner's intelligences in relation to educational goals and matching students with subject matters and teaching methods to develop further intellectual strength. This approach highlights the fact that components measured in traditional intelligence tests emphasize the symbol systems used in schools, which are largely verbal. The current progress in analysis of intellectual functions contributes to an evaluation both of educational goals and educational media. Do we need to be more systematic in facilitating development of aspects of cognition that have been relatively neglected? For example, there is renewed emphasis on the teaching of general problem-solving skills (Frederiksen 1984a) and intellectual skills training (Sternberg 1983) which can be seen partially as a result of the new or cognitive approaches to intelligence. Besides new goals for education, Gardner's (1983) multifaceted approach to intelligence suggests that we reexamine our media of instruction to use other symbol systems.

Motivation

Previous reviews (e.g. Resnick 1981, Gagne & Dick, 1983) have not had separate sections on motivation. In recent years, however, cognitive reformulations of achievement motivation theory (e.g. Weiner 1979, Dweck & Elliott 1983) have revitalized motivational research and suggested productive relationships between research programs in cognition and motivation. The following section focuses on the interactions between motivational characteristics of the learner and cognition and instruction.

ATTRIBUTIONAL MODELS Cognitive approaches to motivation have been strongly influenced by attribution theory (Weiner 1979). Attributional models stress the importance of the role of perceived ability and effort in achievement dynamics. For example, attribution theory and cognitive reformulations of learned helplessness theory (e.g. Weiner 1979, Peterson & Seligman 1984) suggest that individuals who attribute failure to stable internal causes show passivity in learning, anxiety, and lowered self-esteem. There is, however, controversy over the causal nature of attributions for performance (cf Covington & Omelich 1979, 1984, Wong & Weiner 1981, Weiner 1983, Brown & Weiner 1984). In addition, questions have been raised about the ecological validity of attribution theory for classrooms (Blumenfeld et al 1982, Brophy 1983, Eccles 1983), since much of the attribution research has been done in the laboratory. In contrast to a static view of attributional style, Bandura (1982) has suggested a more dynamic construct of self-efficacy, concerning individuals' beliefs about their ability to achieve goals by their actions in specific situations. Harter (1985) also suggests a more differentiated view of the locus of control issue, proposing a concept of beneffectance (accepting internal control for success and external control for failure). These more dynamic and differentiated constructs suggest promising linkages between motivational and cognitive variables to be explored in future research.

A number of studies have found developmental differences in children's understanding of attributional constructs such as ability and effort with younger children having more undifferentiated concepts of ability and effort and, in fact, defining ability in terms of effort or improvement in learning (e.g. Nicholls 1978, Nicholls & Miller 1983, Blumenfeld et al 1985). Both Nicholls (1984) and Dweck & Elliott (1983) propose that students approach instructional tasks differently depending on their concepts of ability. Students who believe ability can change and improve with learning will approach the task with an orientation to learn and focus on the process of how to do the task. In contrast, students who conceive of ability as capacity will focus on comparative performance and outcome.

Covington's self-worth model (Covington & Beery 1976, Covington 1983, 1984) proposes that individuals are motivated to maintain a high self-perception of ability. Effortful strategic behavior may increase the potential for success; however, if failure occurs, these students must conclude that they lack ability. Hence, effort is a double-edged sword (Covington & Omelich 1979) and students may avoid the dilemma by not trying. Covington suggested that changes in instructional methods such as decreasing competition, giving fewer norm-referenced tests, and individualizing instruction would not threaten students' self-worth as much and might lead to more effortful and strategic behavior.

EXPECTANCY-VALUE MODELS Expectancy-value models are derived from Atkinson's (1964) need achievement theory. The expectancy component is directly linked to attributions and self-concept whereas the value component is more affective. Task value has not been included in most attributional models, but has been shown by Eccles (1983) to be an important determinant of achievement behavior. Eccles's (1983) model details relationships among socializers (i.e. family, school, and peer influences) and students' goals, self-concepts, expectancies, attributions, and achievement behavior. Dweck & Elliott (1983) also have proposed an expectancy-value model that stresses the dynamic relationships among students' goals, expectancies, values, and performance. Both the Dweck & Elliott (1983) and Eccles (1983) models are important for their emphasis on task value. This new interest in task value complements the recent emphasis on classroom tasks in process-product research (e.g. Doyle 1983) and the concern for context and relevant tasks in cognitive development research (e.g. Paris & Cross 1983).

TEST ANXIETY Although it is well documented that anxiety often interferes with performance, the mechanisms responsible for this relationship are not yet clear. Morris et al (1981) reviewed the literature on anxiety and found that the more cognitive "worry" component of anxiety seemed to be more highly predictive of performance decrements than the "emotionality" component. Similarly, Wine (1980) suggests that anxiety interferes with performance by inducing self-focused thoughts rather than task-focused thoughts. Information processing approaches (e.g. Benjamin et al 1981, McKeachie 1984) suggest that performance deficits of anxious students may result from problems in encoding the material (i.e. reading the material), in organizing the material (i.e. when studying or reviewing), or in retrieving the information during an exam. McKeachie et al (1985) found support for this view by demonstrating that students high in test anxiety benefited more than other students from a course on learning strategies. Paulman & Kennelly (1984) found that test anxiety and exam-taking skills have separate and interactive effects on performance. This information processing approach incorporates the ideas from both the cognitive-attentional interference model (Wine 1980) and the learning skills deficit model (Culler & Holahan 1980). Clearly, more research is needed on the cognitive and affective interactions among anxiety, learning strategies, and performance.

In contrast to the focus on individuals' cognitive skills or affect, other researchers have focused on the external testing or classroom conditions that foster anxiety. Hill & Wigfield (1984) suggest a number of ways instructional practices could be changed to lessen anxiety including changing reporting practices, decreasing time pressure, preventing continued failure by modifying test difficulty to match skill levels, and changing testing instructions to lessen anxiety and optimize performance. These recommendations parallel those of Covington's (1984) for reducing threats to students' self-worth.

CONCLUSION The future of research on the interactions between motivation, cognition, and instruction is bright. Researchers will begin to integrate motivational and cognitive variables in their work, although they will have to address the methodological issues involved in measuring dynamic motivational and cognitive constructs with essentially static instruments and designs. Affect and task value are likely to play a larger role in future research. Finally, the ecological validity of these models must be improved. As Brophy (1983) aptly points out, "Classrooms are work settings in which students must cope with activities that are compulsory and subject to public evaluation" (p. 201). This is in contrast to play or laboratory settings, where the student has a choice over activities or where the task and evaluation criteria are clearly defined. More research is needed on how students perceive and value classroom tasks and how classroom instruction interacts with students' motivation and cognition.

INSTRUCTIONAL PROCESSES

Perhaps the most significant contribution made by cognitive theory is the common language it provides for a wide range of educational phenomena. Not only are most experimental, motivational, and differential psychologists now using the same paradigm, but so are researchers on educational media, instructional design, and classroom teaching. For researchers on classroom teaching and tasks, cognitive science has introduced theory to an area that has largely been atheoretical; for instructional designers, it has provided a shift from examination of instructional stimuli, learners' overt responses, and reinforcement to concerns about the instructional effects on cognitive structures and strategies; for media researchers, it has resulted in redefinition of media as activities that correspond to required mental operations and as attributes that support these activities. Conceptions of the learner, the task, the medium, and instruction are being reformulated as parallel interacting processes grounded in cognition (e.g. Glaser 1980, Shuell 1980). In this section we examine the impact of information processing theory on media, instructional design, classroom instruction, and testing, leaving educational tasks for the following section.

Media and Technology

Historically, research on media (e.g. radio, TV, computers) has progressed in waves corresponding to the introduction of new technologies. Each wave has compared the impact of the latest technology to some previous one (Saettler 1968), with accumulated studies culminating in a review attempting to make some summary judgment about the value of the medium. Contemporary examples of these reviews include those by Levie & Dickie (1973), Jamison et al (1974), McKeachie (1974), Berliner & Gage (1976), and Schramm (1977). A typical conclusion of these reviews is that for most tests of achievement one medium is about as good as another.

Recent applications of meta-analytic techniques have uncovered significant findings undetected by the less sensitive box-score summaries. The Kuliks and their colleagues at the University of Michigan have systematically analyzed hundreds of studies and have drawn conclusions more favorable to new technologies but varying by content and level. They found a moderate positive impact of individualized instruction on achievement in college courses (Kulik et al 1979) but not in precollege science and mathematics courses (Kulik & Bangert-Drowns 1983). For computer-assisted instruction, however, a moderate positive impact on achievement and attitudes was found for high school and junior high school students (Bangert-Drowns et al 1985) and elementary school students (Kulik et al 1985), but smaller differences for college students (Kulik & Kulik 1985). Small but significant findings also favored programmed instruction (Kulik et al 1980) and visually based instruction (Cohen et al 1981) in college courses. The medium of instruction and method of instruction are often confounded in research (Clark 1983, 1985), but the continued use of meta-analysis may encourage a standard for reporting of experimental procedures in original studies that permits the subsequent statistical disentanglement of media and methods across studies.

A more important concern is media and methods conceptual disentanglement; how media are defined, distinguished from each other, and from method. Salomon (1978, 1979) observes that various media have much in common. As a new technology is developed, it draws heavily from previous media as early film did from theater. Such commonality diminishes any differences between media in effects on learning. However, media do differ in important ways; each is composed of a distinctive but nonfixed set of elements or attributes (e.g. realism, interactivity, etc) and may employ different symbol systems (e.g. iconic, linguistic, etc). Some features of a medium may be imposed (such as the viewing of a film in large groups in a darkened hall) rather than inherent. But even the inherent attributes are capabilities that may or may not be employed. Thus a television presentation not using the more distinctive features of the medium may look more like a lecture than another application of television which does. These different clusters of attributes and symbol systems interact with the message, the task, and the learner. For example, certain attributes of a medium (e.g. a video cut to closeup, to draw on Salomon's 1979 study) may evoke mental operations required by a certain task (e.g. recalling visual details of a story) for learners of certain aptitudes (e.g. those facile at relating details to conceptual wholes) while other attributes (e.g. video zoom) serve to supplant this operation for those less adept. Exposure to this isomorphic operation may result in the acquisition of the corresponding mental skills, as was the case in the Salomon study. This conceptualization of media emphasizes their psychological effects rather than their comparative effectiveness.

Rather than comparing the overall effectiveness of radio versus television, Beagles-Roos & Gat (1983) examined the differences and outcomes. They found that when children were exposed to a television and radio story with the soundtrack in common, those in the television group were better at picture sequencing, recall of details from the story, and making inferences based on actions. Those in the radio group were better at recognizing expressive language, at making inferences based on verbal sources, and on knowledge unrelated to the story (see also Meringoff 1980).

Contemporary media research is also examining attributes of a single medium and their corresponding cognitive effects. For example, Kozma (1985) reviews studies of educational television and the effects of pacing, cueing, modeling, and transformation. Johnston & Ettema (1985) examined research to determine what characteristics of television might make it effective for prosocial learning. Similarly, Tennyson and colleagues (Tennyson 1980, 1981, Tennyson & Buttrey 1980, Johansen & Tennyson 1983) studied attributes of computer-based instruction. One group of students was given control of the amount and sequence of instruction, continuing reports on their progress, and instructional advisement; a second group's instruction was computer controlled; a third group had control of their instruction but no progress reports. The group with personal control and progress reports performed better than the group without progress reports and saved time while performing as well as the computer controlled group.

Lepper (1985) describes the ability of computer games to evoke challenge, curiosity, and personal control in learners, potentially increasing learning. If motivational enhancements result in mindful engagement in the task, learning will be facilitated. Comparison of television and print showed that learners who perceive a medium as "hard" invest more mental effort in processing its messages (Salomon 1974, 1983). Krendl & Watkins (1983) found that learners who were told that a subsequent televised presentation was educational were more able to make inferences and generalizations about the story (i.e. learn at a deeper level) on posttests than viewers who were told the same presentation was for entertainment. Baker et al (1981) found a negative correlation between the use of instructional games and basic skills achievement in reading and mathematics. Some motivational enhancements in computers and other media may actually depress the use of effective cognitive strategies or reduce time on the learning task.

A related question is the presumption that learning to program computers can transfer to higher cognitive skills. Whereas Clements & Gullo (1984) found that children taught computer programming for 12 weeks scored higher on measures of reflectivity and divergent thinking than students taking computer-based instruction in reading and mathematics, Pea & Kurland's (1984) review found little support for this contention. The transfer of programming skills may depend on extensive practice, on explicit efforts to decontextualize them, and on motivation for their transfer (Salomon 1984). Thus the question becomes not whether transfer will take place, but under what conditions are learners likely to transfer what kinds of programming skill.

Instructional Design

Instructional design has taken on a new aura of respectability as the result of a call for a "science of the artificial" (Simon 1981) and a renewed call for the development of a "linking science" between psychology and instructional practice (Glaser 1982b). The design of instruction that fosters the acquisition of performance based on our knowledge of how learning occurs is central to a theory of instruction (Glaser 1982b). Between the previous review in this series (Gagne & Dick 1983) and a recent book (Reigeluth 1983), 14 different instructional design models have been described. Though as many as seven of these models share a common notion that instruction must support the learner's cognitive processing, the models tend to be idiosyncratic in terminology. Clearly, integration is needed (Reigeluth 1983).

A dominant model seems to be emerging from information processing theory. This theory is already strongly reflected in the design of complex human-computer systems (Schneiderman 1980, Card et al 1983, Rubenstein & Hersh 1984) and is debuting in instructional design literature (Brezin 1980, Bovy 1981, Winn 1982, Bruning 1983, Kozma 1985). From information processing constructs such as perception, limitations of short-term memory, organization of long-term memory, and metacognition, these authors draw implications, though not yet design principles, related to stimulus cuing, the use of images and visuals, schemata modification, and cognitive monitoring. Similarly, measures of individual differences are shifting to a description of variation in learners' present knowledge and schema structure, in cognitive strategies or styles, and in basic cognitive processes (e.g. channel capacity, reaction time, etc). Correspondingly, adaptive instruction (Shuell 1980) builds on learners' strengths (capitalization), performs functions the learners are unable to perform (compensation), or provides them with cognitive skills or knowledge needed to learn (remediation).

While research on aptitude-treatment interactions has failed to identify the number of consistent relationships one would need to construct an extensive set of design principles (Cronbach & Snow 1977), this research has shown that those learners scoring high in general ability and prior knowledge do especially well under instruction that is significantly incomplete, because it affords opportunities for them to elaborate and organize learning themselves (Snow & Lohman 1984). On the other hand, less able students benefit from explicit, structured instruction. Simultaneously, these students should also receive instruction aimed at developing their learning strategies and skills. These conclusions parallel those of Tobias (1982) and complement the antagonistic relationship between effective and enjoyable instructional treatments described by Clark (1982). These recommendations, however, amount to design heuristics rather than the specific principles initially anticipated from this line of research. They suggest additional research and development on computer-based instruction with learner-control and advisement along the lines of Tennyson's work (Johansen & Tennyson 1983).

CONCLUSION: MEDIA AND METHODS Clark (1983, 1984, 1985) contends that research on media attributes and effects continues to confound media and method. Zooming, for example, is a method of directing attention that may be performed just as well in other ways, such as by using static arrows in photographs. Attributes and symbol systems are only correlated with media and should not be considered media variables. Clark (1983) concludes that "media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition," (p. 445). He recommends that researchers refrain from producing additional studies exploring the relationship between media and learning.

We contend that research on media variables is still important. Each medium is composed of a characteristic, flexible cluster of attributes (some of which are shared with other media, some not) and this cluster may, but need not be, employed to create a presentation other media are incapable of creating. To the extent that this presentation supports (i.e. cues, supplants, etc) cognitive processes necessary or sufficient for learning a particular task, the medium makes a unique contribution to learning. As Salomon & Gardner (1984) point out, researchers need to study the effects media can be made to have, rather than those they may typically have. The trend in technology development is toward an integrated media form that draws together the most distinctive attributes of various media (i.e. computer-based interactive video). While this integrated medium makes comparative studies less meaningful, it increases the importance of attribute studies. We need to decide which attributes we want in this new, synthesized medium, how they interact with methods, and when they will be most useful. This warrants continued research on the relationship between media and learning. Research on technology not only can help us understand the role of media and methods in learning but increase our understanding of learning processes (Greeno 1985).

Classroom Instruction and Teaching

The previous section focused on instructional design as a link between cognitive psychology and instruction. The current section adds ecological validity to the discussion by reviewing central themes regarding actual instruction in classrooms. The best source for a review of this area is the forthcoming third edition of *The Handbook of Research on Teaching* (Wittrock 1986). Although there is a variety of research programs on teaching (Shulman 1986), three of the most central for instructional psychology are the process-product, the classroom management, and student cognition programs.

PROCESS-PRODUCT RESEARCH PROGRAM The process-product program has been the most popular and productive paradigm in research on teaching in the 1970s and into the 1980s (Shulman 1986). The program has focused on correlational relationships between teacher classroom behavior and student achievement (Brophy & Good 1986), highlighting the importance of engaging and maintaining student involvement with school tasks. The concepts of student time-on-task, academic learning time, and other variations of the time variables are seen as mediators between teacher behavior and achievement (Shulman 1986). A recent edited volume (Fisher & Berliner 1985) provides a comprehensive history and review of instructional time. Process-product research also stresses the importance of an active, direct instructional role for the teacher. Although the findings are probably most generalizable to basic skills instruction in the elementary grades, they also have relevance for instructional practice in general.

For example, Rosenshine (1983, Rosenshine & Stevens 1986) has described six teaching functions that are important for effective instruction. These functions include: 1. daily review and checking previous day's work with reteaching if necessary; 2. presenting new content or skills, proceeding in small steps but at a rapid pace; 3. providing initial student practice with the teacher monitoring student understanding; 4. providing instructional feedback and corrections to students; 5. providing independent student practice with a high rate of success (90–100%); and 6. weekly or monthly review.

Besides these general teaching functions, Brophy & Good (1986) summarize the research on teacher behaviors during a lesson by breaking them into categories of (*a*) giving information, (*b*) asking questions, and (*c*) providing feedback. Structuring the material by using overviews or advance organizers is important in introducing a topic (Mayer 1979, Luiten et al 1980), and although clarity of instruction is important, other positive teacher presentation behaviors (i.e. challenge, enthusiasm) do not seem to be related to student engagement (Brophy et al 1983). The effect of asking questions depends upon the level of difficulty or lesson context (Winne 1979, Brophy & Good 1986). In terms of feedback, Brophy (1981, Brophy & Good 1986) suggested that to be effective, praise should be contingent, specific, and informative for the student, including acknowledging correct and incorrect responses as such but not involving personal praise or criticism of the student.

The process-product tradition has generated a corpus of knowledge about classrooms, teachers, and students that describes the reality of classroom instruction and serves as the foundation for teacher preservice and inservice programs. However, interest in the strictly correlational studies has waned, replaced by experimental studies of teacher behavior and student achievement (e.g. Good & Grouws 1979) and an interest in the context effects of task content, classroom structure, and student characteristics.

CLASSROOM ORGANIZATION AND MANAGEMENT RESEARCH PROGRAMS The classroom management program of research is closely related to process-product research but has a distinctly ecological flavor (Doyle 1986, Shulman 1986). The central assumption of this approach is that classrooms are characterized by certain features of group settings regardless of the particular teachers and students. These features (such as the publicness of events, multiple events occurring simultaneously, the immediacy and unpredictability of events, and the fact of a shared history) create pressures and demands (the environmental press) to which both teachers and students must respond (Doyle 1986). A key component of classroom organization is activity structure. Activities such as group lectures, small groups, or seatwork have different functions, rules, and norms that can prescribe both teacher and student behavior (Berliner 1983). For example, presenting a lesson in a recitation instead of using a small group or seatwork requires the teacher to control student behavior more to maintain the lecture or discussion and limits student-student interaction (Bossert 1979, Doyle 1986). Another important component of structure is the nature of the academic tasks students confront in the classroom (Doyle 1983, Blumenfeld et al 1985). For example, filling in a worksheet on Christopher Columbus makes very different cognitive demands on students than writing a report requiring library research. This focus on the nature and use of classroom tasks currently is a major area of interest for classroom researchers and links them to developments in cognitive psychology and curriculum developers' concern with content (Doyle 1983, 1986).

THE STUDENT COGNITION RESEARCH PROGRAM The student mediating or cognition program of research is a fairly recent development. Partially in reaction to the simple correlational strategies of the process-product tradition and their treatment of the student as an empty black box, many researchers have attempted to examine how students process, interpret, and make sense out of all the information presented to them in the classroom (Shulman 1986). Researchers interested in academic outcomes of schooling have attempted to move beyond simple notions of time-on-task to explore student information processing while they are engaged in actual school work (e.g. Corno & Mandinach 1983). For example, using a stimulated recall technique, Peterson et al (1982) found that, independent of student ability, students who used specific cognitive strategies (e.g. relating information being taught to prior knowledge) performed better on an achievement test. Peterson et al (1984) also found that student self-reports of attention, understanding, and affect mediated the relationship between instruction and achievement and that these student cognitions were better predictors of student learning than observers' ratings of time-on-task. Obviously, time-on-task is a necessary condition for learning, but it is not sufficient; it depends on the cognitive and motivational processes engaged in by the student during task performance.

Besides this "technical" socialization, other researchers have examined how student perceptions mediate social outcomes of schooling (Blumenfeld et al 1983, Weinstein 1983). For example, Brattesani et al (1984) found that teacher expectancy effects were mediated by students' perceptions of differential treatment by the teacher. Although this program of research must struggle with problems in measuring student cognitions, it promises to be one of the most active and exciting areas in research on teaching and learning over the next several years.

CONCLUSION Classroom research provides the context for the application of cognitive psychology to instruction. As Glaser (1982a) points out, researchers in the substantive domains of reading, math, science, and writing are examining the micro processes of learning and instruction while classroom researchers are exploring the macro processes or general principles of teaching and learning relevant to classroom ecology. These general principles of classroom instruction and management may be seen as necessary, but not sufficient, conditions for improved instruction. Obviously, we need collaborative research on both the micro and macro processes of learning and instruction. The interest in student mediating cognitions and academic tasks by classroom researchers and the current interest in school tasks by cognitive psychologists suggest that much useful research will emerge in the future on how to both manage a classroom and teach the content of the curriculum that will improve student learning in all areas.

Testing and Instruction

Testing issues that have recently captured public attention include debates about bias in testing, the role of minimum competency testing, and the decline of scores on standardized achievement tests (Glaser & Bond 1981, Haney 1984). Although the outcomes of these debates will certainly affect educational practice, they tend not to inform instructional design. On the other hand, there is a quiet revolution going on in the field of testing that shows considerable promise for linking testing and instruction (Tyler & White 1979, Burstein 1983). The twin goals of this revolution are to enhance (*a*) the validity of educational tests, and (*b*) the sensitivity of these tests to the processes and outcomes of learning. Interest in instructionally relevant testing has been fueled by the inadequacies of traditional achievement tests as instructional instruments (see Koslin et al 1979, Tyler 1979, Frederiksen 1984b, Johnston 1984). In this section we review several developments that should benefit the design and assessment of instruction.

TEACHER-MADE TESTS An important source of information about how to measure learning processes and outcomes is the testing practices of teachers. The strength of teacher-made tests is that they are closely related to the realities and needs of teaching. "These methods—quizzes, essay tests, discussions, exercises, lab problems, etc.—may not always be 'scientific,' but they often have a great deal to recommend them" (Calfee 1985, p. 3). On the other hand, teachers may overlook sound principles of test construction. Calfee (1985) describes how teachers and researchers working together were able to develop a computer-based assessment procedure for writing instruction that informed classroom practice, met state-mandated minimum competency requirements, and was technically sound. Schwartz & Taylor (1978, 1979) discuss a similar effort where researchers and teachers worked together to develop valid measures of quantitative skills such as measurement of length. They validated their measures in part by demonstrating convergence between an ecologically valid measure and a test-like measure (e.g. performance in a game and performance on a test) of the same quantitative skill, and in part by asking teachers to assess the similarity between the measures and the skills actually taught in classrooms.

COGNITIVE PSYCHOLOGY AND TESTING Cognitive psychology has proved to be a valuable resource not only for improved formulations of thinking and learning but also for methods for assessing these processes (Glaser 1981, Schoenfeld 1982, Messick 1984a). For example, Curtis & Glaser (1983) discuss how recent advances in reading theory can inform the assessment of reading achievement in four areas: decoding, accessing semantic word information, sentence processing, and discourse analysis. Although reading is seen as an interactive process involving all of these components, Curtis and Glaser point out that current instructional and testing practices address only the lower level processes at the expense of the higher order processes and the interactions between them. The authors offer concrete suggestions for modifying reading achievement tests.

Another example of the impact of cognitive psychology is found in the work of Brown & VanLehn (1980, 1982). They describe a computer-based system for diagnosing the faulty rules—or "bugs"—that produce children's arithmetic errors. A major feature of this work is the finding that most errors do not result from ignorance, but from use of systematic rules that are partially correct. Once a bug has been accurately diagnosed, an instructional prescription follows naturally. Similarly, Glaser (1981) reviews research by Bartholomae (1980) which shows how to analyze writing samples for systematic errors, thereby providing information about the "bugs" students have in their "intermediate system" for producing the meaning and intent of the writer through the written code.

DYNAMIC ASSESSMENT Testing is and should be an integral part of instruction. Nevertheless, traditional psychometric practices do not directly address the dynamic nature of the testing, teaching, and learning cycle (Feuerstein et al 1981). However, dynamic assessment procedures based upon the work of Vygotsky (1978) should prove valuable in this regard. Two features of Vygotsky's theory are relevant to dynamic assessment. First, Vygotsky recognized that learning and development occur in a social context, with students receiving guidance and feedback about their performance. This view adds another dimension to learning, for learning is measured not only by the amount of knowledge gained, but also by the extent to which mastery can be demonstrated independently of social support. Second, based upon this "scaffolding" view of learning and development, Vygotsky advocated assessing students' propensity for learning by measuring their "zone of proximal development." This zone is defined as the difference between a student's current level of performance—what he or she can achieve independently—and potential level of performance—what he or she can achieve with support.

Brown and her colleagues (Brown & French 1979, Brown & Ferrara 1985) have begun to investigate the utility of dynamic assessment procedures. In one study (Campione et al 1984), learning efficiency and near- and far-transfer were assessed in addition to static predictors of learning (i.e. IQ). Learning efficiency was measured by the number of hints required for successful performance, an indicator of the amount of "scaffolding" required by the learner from an adult assistant. The dynamic measures were better predictors of the children's gains between pre- and post-test than were the static measures.

CONTEXTUAL ASSESSMENT The role of context in assessment has received extensive treatment recently (Scarr 1981, Messick 1983, 1984b), and these considerations have important implications for the validity of educational testing. The current emphasis on cognitive measurement at the expense of metacognitive, motivational, and attitudinal measurement provides researchers and teachers with an incomplete educational profile (Paris et al 1985). Messick (1983) discusses treating the child as context, so that rational choices can be made among variables (i.e. cognitive, personal/social, and health/physical) that are theoretically important determinants of learning. Messick also discusses measurement of characteristics of the researcher, teacher, classroom, school, peers, family, and the larger cultural community in which they are imbedded as illustrated in Mercer's (1979) System of Multicultural Pluralistic Assessment (SOMPA), which systematically utilizes physical, personal/social, and cultural information in the assessment of child characteristics.

EDUMETRICS If testing is going to inform instruction, there must be a testing technology that parallels the technology available for measuring stable individual differences. Carver (1974) has provided a felicitous term for this new technology—"edumetrics." The goal of edumetrics is to provide instructionally useful information about students: their educationally relevant characteristics, their potential for learning, and a sensitive evaluation of what they have learned or failed to learn. A fundamental difference between traditional psychometrics and the upstart "edumetrics" is the latter's emphasis on the measurement of change.

A major goal of this section was to show that the edumetric technology is already substantial, including collaborations between teachers and researchers (Schwartz & Taylor 1978, Calfee 1985), the tasks of cognitive psychologists (Glaser 1981, Schoenfeld 1982), the principles of learning research used in dynamic assessment (Brown & Campione 1985), and the assessment of context (Messick 1983). Furthermore, many useful ideas—such as using criterion groups to select items that are maximally sensitive to learning—can be found in other papers by Bereiter (1962), Hambleton et al (1978), and Lipsey (1983).

TASKS, CONTENT, AND OUTCOMES

In this final section of the review we turn our attention to the tasks, content, and outcomes of instruction. In the first part we review instructional research in the major content areas: reading, writing, mathematics, and science. The second part is devoted to research on the instruction of generalizable problem solving skills and learning strategies.

Reading

As befits the centrality of reading to functioning in a literate society, there continues to be an enormous research effort devoted to the processes of reading and their instruction. The most direct entrance to the voluminous literature on reading is via edited volumes (e.g. Anderson et al 1984, Mandl et al 1984, Waller & MacKinnon 1984, Whitehurst 1984, Besner et al 1985, Carr 1985, Orasanu 1985), although there are other recent works of special note. Among these are the *Handbook of Reading Research,* edited by Pearson (1984a), which has sections on methodological issues in the study of reading as well as sections on basic processes and instructional practices. In addition, there is a chapter on reading by Calfee & Drum (1986) in the new *Handbook of Research on Teaching*. Finally, a lacuna in the reading literature has been filled by a new graduate level text (Downing & Leong 1982).

Resnick (1981) concentrated her review on comprehension, because comprehension research was the focal topic of the 1970s; in this review we take a step up the ladder of cognitive processes to research on reading strategies and their instruction, reflecting a major interest of researchers during the past five years (Paris et al 1983, Pressley & Levin 1983a,b, Baker & Brown 1984).

STRATEGIC READING Reading is not a linear process proceeding from written text to comprehension, but is rather a series of complex interactions between the reader, text, and context of reading. These interactions require strategies such as rereading in response to comprehension failure (Garner et al 1983, 1984), skimming ahead to establish an organizational scheme, using context to process unfamiliar words (Potter 1982), and summarizing text to ensure understanding and remembering (Brown et al 1983, Winograd 1984).

Comprehension monitoring (Wagoner 1983) has received substantial attention because this metacognitive skill is essential for competent reading. According to Paris & Myers (1981), "Reading comprehension involves many perceptual and cognitive skills, but a major component is the ability to monitor one's level of understanding while reading. This kind of mental pulse-taking is important because it is a measure of progress toward a reading goal and a signal for comprehension failures. Checking comprehension thus provides a link between the reader's purposes, progress, and behavior" (p. 5).

What do we know about the development of comprehension monitoring? First, we know that mature readers monitor their comprehension as they read, although there are substantial intra- and interindividual differences in the actual strategies used (Baker & Anderson 1982). Second, we know that better and/or older readers monitor their comprehension more effectively than poor and/or younger readers (Harris et al 1981, Paris & Myers 1981).

Other research has attempted to refine these basic findings. For example, Markman & Gorin (1981) found that 8- and 10-year-old children performed better when they were provided exemplars of the problem types (i.e. falsehoods or inconsistencies) than when they were provided with no information other than "some of the essays have problems with them." Furthermore, Markman & Gorin found that these children were able to adjust their standard of evaluation according to the instructional set. In a related study, Baker (1984) found that children 5, 7, 9, and 11 years old were able to use multiple standards of evaluation (i.e. lexical, internal consistency, and external consistency) when instructed to "find the mistakes." Although the older children in Baker's study outperformed the younger ones, all of her children performed better than same-aged children in uninstructed studies. In addition to age differences, Baker found task differences: the internal consistency standard was used least effectively, although even the youngest children were able to use it. In summary, these studies show that (*a*) school-aged children can effectively monitor their comprehension when instructed to do so, (*b*) they can adjust their standards for comprehension monitoring, and (*c*) they can use multiple standards simultaneously.

READING INSTRUCTION Corresponding to the growing knowledge base about reading are efforts to translate this knowledge into a model of instruction (Pearson & Tierney 1983, Duffy et al 1984, Beck 1985). Ideally, these models should be based not only on knowledge about basic processes but also on information gained from process analyses of learning and instruction (e.g. Calfee & Piontkowski 1981, Omanson et al 1984), as well as the evaluation of instructional programs (Mezynski 1983, Johnson & Baumann 1984, Tierney & Cunningham 1984). Here we review two instructional approaches, direct instruction and reciprocal teaching, that reflect emerging trends in the design and implementation of reading instruction. Again, our emphasis on strategic reading will be apparent.

An effective model of direct instruction was discussed earlier in this review (see Classroom Instruction and Teaching). Research on teaching reading has also shown that students learn to read most efficiently when they receive direct, systematic instruction from their teachers (Pearson 1984b, Rosenshine & Stevens 1984). For example, Hansen (1981, Hansen & Pearson 1983) has successfully implemented and evaluated a program designed to increase children's inferential comprehension skills through direct instruction. The major features of this program were pre- and postreading group discussions that emphasized inferential comprehension. Before reading, the discussions focused on making predictions based on the children's prior knowledge about the topic, and after reading the teachers asked questions requiring inferences (e.g. after reading "Charlotte's Web," the teacher asked: "What kind of person do you think Templeton (the rat) would be if he were human?").

Paris (Paris et al 1984, Paris & Jacobs 1984) has implemented a similar but more ambitious program—Informed Strategies for Learning (ISL)—for direct instruction of strategic reading skills. The training included lessons designed to increase children's awareness of reading goals, plans, and strategies, as well as instruction about comprehension skills (i.e. kinds of meaning, inferential and critical reading, summarizing) and how to evaluate and monitor one's own comprehension. The classrooms receiving ISL showed greater gains than control classrooms on a variety of reading tasks.

Reciprocal teaching methods, although embodying the principles of direct instruction, in addition explicitly adopt a Vygotskian (1978) perspective on instruction. Teachers scaffold budding reading skills through prompts and examples and then foster individual control of reading by gradually removing social supports (Au & Kawakami 1984a, Brown et al 1984). Au & Kawakami (1984b) proposed a model of comprehension instruction with two major phases: a scriptal phase where teachers and students access background knowledge and specify initial predictions, and a text phase where teachers and students evaluate their predictions, clarify text ideas, and make inferences among text ideas. Au and Kawakami's results show that whereas first grade discussion groups spent most of their time in the scriptal phase, third grade groups spent most of their time in the text phase. Furthermore, the third grade groups spent less time in teacher-initiated, teacher-cued discussion than did the first grade groups. Hence, there was a developmental progression toward greater student control and higher-level processing of the text.

Pallincsar & Brown (1984) discuss a reciprocal teaching program where seventh grade poor comprehenders were taught comprehension-fostering and comprehension-monitoring activities (i.e. summarizing, questioning, clarifying, and predicting). As was the case in the Au and Kawakami study, a major goal of the instruction was to foster self-regulated comprehension, in this case by having the students take turns in leading a dialogue centered on pertinent features of the text. The program was more successful than typical classroom practice using both tutors and small group discussions, as indicated by measures of gain, transfer, and generalization.

Finally, Pearson (1985, Pearson & Gallagher 1983) outlines an approach to reading instruction that provides explicit steps for the release of task responsibility from the teacher to the student. Instruction proceeds through three phases: (*a*) modeling, where the teacher is solely responsible for task performance; (*b*) guided practice, where the student performs the task with help from the teacher; and (*c*) application, where the student performs independently of the teacher. According to Pearson, this approach meshes well with direct instruction emphasizing the processes of reading, where teachers model reading strategies such as predicting or summarizing and then pass responsibility for these activities on to their students. The research on reading instruction reviewed in this section provides many exemplars of this process-oriented approach to direct instruction and parallels recent developments in writing, mathematics, and science instruction.

Writing

In her 1981 review, Resnick pointed out that psychologists were just beginning research on written composition. Since then there has been a surge of interest in this area. A new journal, *Written Communication,* has been started, and the *Handbook of Research on Teaching* has a chapter on written composition

(Scardamalia & Bereiter 1986). In addition, there have been a number of recent books on research in written composition (e.g. Frederiksen & Dominic 1982, Whiteman 1982, Mosenthal et al 1983, Beach & Birdwell 1984). Reflecting the interest in writing by several disciplines, there are multiple paradigms employed by writing researchers (Bereiter & Scardamalia 1983, Mosenthal 1983). However, with increased attention from psychologists, research in this area is focusing on the cognitive processes involved in producing text, in contrast to the finished product (cf Resnick 1981, Bertram et al 1982). The psychological models (e.g. Sommers 1980, Flower & Hayes 1981a, 1984) have departed from the classical rhetorical linear model (planning, composing, and editing) to suggest a more interactive and recursive writing process. This section focuses on: 1. the cognitive processes of the writer as a producer of text and 2. writing instruction and technology.

COGNITIVE PROCESSES OF THE WRITER Although recent psychological models of the composition process argue against the mapping of a single linear model onto the cognitive processes of the writer, the categories of planning, composing, or translating, and reviewing or editing are useful divisions for summarizing research in this area (e.g. Hume 1983; cf Scardamalia & Bereiter 1986, however). Cognitive models of writing suggest that planning includes the cognitive processes of accessing knowledge in long-term memory or from external sources, drawing inferences, organizing the information, and setting goals (Flower & Hayes 1981a, 1984). Research shows that good writers, in comparison to poor writers, produce better, more elaborate goals and spend more time in planning, especially in global planning in contrast to sentence-level planning (Hume 1983). In addition, research on in-process planning, which examines the pauses made during a writing session for evidence of planning, shows that good writers spend more time in long planning pauses and pause more to consider substantive thematic issues than sentence-level, grammatical issues (Flower & Hayes 1981b, Hume 1983).

A central issue in writing research concerns the nature of the planning process and how plans are translated into text. Or, more colloquially, how do ideas become prose? Flower & Hayes (1984) proposed a multiple representation thesis to clarify the relationship between planning and composing. They suggested that writers create a variety of internal and external representations of meaning (e.g. images, schemas, propositions, notes, drafts) which are then instantiated in text. Scardamalia & Bereiter (1982) suggest that plans are instantiated by assimilating them to knowledge-telling strategies for novices and young children and reflective-planning strategies for experts. Flower & Hayes (1984) also suggest that finding analogies and accommodating general problem-solving skills to prose constraints are used in translating plans to text. Hume (1983) summarized the research on translating or composing by noting that this subprocess creates a large cognitive demand as the writer copes with the global issues of instantiating goals and plans, as well as with organization, clarity, grammar, spelling, punctuation, handwriting, etc. As some of these skills (i.e. handwriting and spelling) become automatized through practice and experience, the writer can spend more time on substantive issues. More research is needed on this process of translating in general, and in particular, on how certain skills become automatized in young or novice writers.

The subprocesses of reviewing and revising have received somewhat more empirical attention than translating. Novice writers, even children, do review their texts, but they often focus on surface level issues such as spelling, grammar, and punctuation rather than on global issues such as style or purpose (Hume 1983). Novice writers often make only minor corrections, not substantive changes, in revisions (Bridwell 1980, Sommers 1980, Faigley & Witte 1981). Thus, as in the planning process, we see the problems of limited processing capacity, lack of knowledge, and executive control preventing sufficient allocation to substance.

WRITING INSTRUCTION AND TECHNOLOGY Just as there are a number of writing research paradigms, programs in writing instruction are even more diverse (Scardamalia & Bereiter 1986). Rhetoric theory has evolved from stressing Aristotle's topoi as strategies for generating text to emphasizing the topoi as exemplars for a finished product (Applebee 1984b). Surveys of writing instruction in public schools suggest that instruction does not occur often, tends to focus on word and sentence level skills, and involves mainly recitation of previously learned material (Graves 1978, Applebee 1984a). However, with the popularity of the cognitive process movement, writing instruction is beginning to focus on how to teach students cognitive strategies for planning, organizing, translating, reviewing, and revising their text. Scardamalia & Bereiter (1986) summarize the various direct instruction approaches to teaching strategies for writing as well as procedural facilitation methods where the teacher supports the students' efforts in a collaborative manner. As in reading instruction, these developments focus on explicit instruction and process-oriented approaches.

Another aspect of writing instruction and research concerns the impact of the microcomputer and of word processing programs. There have been numerous articles in the popular press about the transformations and improvements this technology will have on writing. Unfortunately, the research necessary to support this enthusiasm is lacking (Bridwell et al 1984). Several developments, however, are worthy of note. Frase (1984) describes three modes of computer intervention (advisory, emulation, tutorial) and elaborates on an advisory system, *Writer's Workbench,* that was developed to provide writers with a detailed analysis of their compositions. Providing writers with information on word use, readability, and complexity, as well as spelling and punctuation, the program leaves the revision decision in the writer's hands. In an evaluative study of this system, Kiefer & Smith (1983) found that students who used *Writer's Workbench* for a semester improved their editing skills, compared to students who used word processing without *Writer's Workbench*. In evaluating the effectiveness of word processing programs, we are reminded of Clark's (1985) warning against confounding media and method effects. While *Writer's Workbench* is focused on analysis and revision of the writing process, other computer-based writing programs focus on structure and argument. Programs such as WANDA, QUILL, SEEN, and PREWRITE are designed to facilitate the early, invention phase of the process. Although the verdict is still out on the effects of these programs, it is encouraging to see the development of software based on cognitive process models.

Mathematics

Research interest in the psychology of mathematics has remained strong since Resnick's (1981) Instructional Psychology chapter, as is evident by the number of new edited books in this area (Brainerd 1982, Carpenter et al 1982, Ginsburg 1983, Lesh & Landau 1983). In addition, there are the published proceedings of a major conference on mathematical education (Zweng et al 1983) and a chapter in *The Handbook of Research on Teaching* (Romberg & Carpenter 1986). Finally, Resnick & Ford's (1981) integrative review still provides a contemporary view of psychological thinking about mathematics learning and instruction. The major themes of the current instructional psychology of mathematics are reflected in several recent papers devoted exclusively to mathematics instruction. These themes emphasize in turn models of teaching, research, cognitive processes, and development.

Shavelson (1981) outlines an approach to teaching mathematics that links psychological knowledge about (*a*) subject-matter structure, (*b*) student cognitive structure, (*c*) teacher decision making, and (*d*) instructional context. Shavelson's integration of information from diverse fields of inquiry is facilitated by his consistently cognitive approach to the problem of mathematics education.

In a novel paper that emphasizes the close relationship between teaching and researching, Cobb & Steffe (1983) introduce the notion of the teaching experiment. Teaching experiments have two critical features: first, teaching experiments consist of either long-term or short-term instructional interactions between teachers and students (macroschemes or microschemes); the goal is to observe the learner's dynamic passage from one state of knowledge to another. The second feature of teaching experiments is that the teacher's actions are guided by explicit models of the students' mathematical knowledge: "From this perspective, the activity of teaching involves a dialectic between modeling and practice" (Cobb & Steffe 1983, p. 86).

In an application of cognitive learning theory to the process of doing mathematics, Gagne (1983) divides the problem-solving task into three phases: (*a*) translating from a verbal problem statement to a mathematical expression, (*b*) carrying out an operation on the expression, and (*c*) validating the solution. Although there is little controversy about his performance model, the instructional implications Gagne draws require clarification (Wachsmuth 1983) or rebuttal (Steffe & Blake 1983).

Whereas Gagne (1983) presents an adult performance model of mathematical problem solving, Resnick (1983) presents a developmental model of number understanding tracing the development of number concepts and skills through three periods of development: (*a*) the preschool period, during which counting and quantity comparison abilities emerge; (*b*) the early primary period, during which children invent mental procedures for addition and subtraction and master simple story problems; and (*c*) the later primary period, during which children acquire the structure and notation of the decimal system. In a later paper, Resnick (1985) discusses the processes by which children construct mathematical knowledge and thereby pass through these three developmental periods. Taking this work a step further, Resnick (1982, Resnick & Omanson 1985) investigates instructional procedures that specifically build on knowledge of children's constructive processes.

In the remainder of this section we review empirical research on mathematics learning and instruction. This brief review reflects researchers' current interest in the mathematical accomplishments of young children.

Gelman (1980, Gelman & Gallistel 1978, Starkey & Gelman 1982) has documented the impressive quantitative accomplishments of preschoolers, which include the numerical representation of small arrays, arithmetic reasoning about numbers they can accurately represent, and some knowledge about infinity. In a related effort, Fuson (Fuson et al 1982, Fuson & Hall 1983) reviews research on preschoolers' acquisition of the number word sequence as the linguistic counterpart to their numerical skill. Although early number word sequences are merely rote strings, these soon develop into flexible and meaningful sequences that can be applied to concrete problems. These early skills—numerical and linguistic—form the foundation for later arithmetic and problem-solving learning in school.

The development of addition is being worked out in some detail. Houlihan & Ginsburg (1981) reported that the first graders in their study used only counting procedures such as counting-all and counting-on; however, the second graders used both counting and noncounting methods (e.g. addition by place value). If the older children used a counting procedure at all, it was the more efficient counting-on procedure. Secada et al (1983) were able to identify a set of three subskills that appeared to account for the transition from counting-all to counting-on. Third grade, according to Ashcraft (1982, Ashcraft & Fierman 1982), is the time when children begin retrieving arithmetic facts from memory, with the transition from a counting model to a retrieval model being mostly complete by the fourth grade. However, the representation of the factual memory store is still being debated, with Ashcraft favoring semantic-based storage (1983, Ashcraft et al 1984) and Baroody (1983, 1984) favoring stored procedural knowledge. Finally, Brainerd (1983) suggests that a major facilitator of development in addition is improvement in short-term memory functioning.

Carpenter & Moser (1982, 1983) have studied the informal problem-solving abilities of first graders and found that they were able to analyze and represent the structure of simple word problems in order to solve them. Building on this work and the work of others (e.g. Nesher 1982, Vergnaud 1982), Briars & Larkin (1984), and Riley et al (1983) have constructed formal models of children's skill in solving elementary word problems.

Kintsch & Greeno (1985) have taken these efforts one step further by combining principles from a theory of text processing (van Dijk & Kintsch 1983) with hypotheses based on the Riley et al (1983) model for understanding word problems, in an integrated model of problem comprehension. Kintsch and Greeno report that model predictions based on processing requirements for different problems are generally consistent with existing results.

Studying performance on multiplication and division word problems, Fischbein et al (1985) found that primitive intuitive models (e.g. repetitive addition in the case of multiplication) seemed to influence the choice of a numerical procedure even after children have had formal algorithmic training. Since these intuitive models correspond to the way in which the corresponding concept (e.g. multiplication) is usually taught, teachers face the dilemma of introducing a concept through a method that will later conflict with the formal concepts that are ultimately the goal.

Science

Science research is similar to research in mathematics because of the forceful impact that cognitive psychology has had on the methods and focus of research. However, unlike the field of mathematics instruction, and certainly unlike reading, there has yet to appear an edited volume devoted entirely to science. Nevertheless, there are several book chapters and journal articles that are useful entries into the literature on science learning and instruction.

An excellent starting point is White & Tisher's (1986) *Handbook of Research on Teaching* chapter on Natural Science which reviews most of the science education research of the 1970s. The hallmarks of their chapter are emphases on learning and the dynamic aspects of acquiring knowledge on the one hand, and the affective (e.g. student attitudes) and contextual (e.g. classroom management) aspects of instruction on the other. Another major reference is a special issue of the *Journal of Research in Science Teaching* devoted to a set of meta-analyses directed toward science education research questions (see Anderson et al 1983). The questions addressed by this multi-institutional effort include the effects of curricular programs, instructional systems, teaching techniques, and teacher and student behaviors on outcomes in science.

Other trends in science instruction research parallel those mentioned elsewhere in this review. For example, Maehr (1983) provides a motivational analysis of lagging science achievement that suggests a different set of policy prescriptions than do traditional cognitive analyses of this national problem (e.g. more time on task). Maehr's major conclusion is that science instruction should be designed to foster continuing self-guided achievement.

Based on a large-scale naturalistic study of elementary and secondary science classrooms, Hacker (1984) describes profiles of intellectual skills actually practiced by students in science lessons. The science teachers in Hacker's sample had definite preferences for teaching strategies, and their instructional behaviors were matched to changes in the student profiles. The importance of teacher behavior in science education is further underscored by Walberg et al's (1982) secondary analysis of the National Assessment of Educational Progress data. Walberg et al found that the quality of instruction and the social psychological climate of the classroom were the only unequivocal and potentially manipulable causes of science learning. Other variables, such as socioeconomic status or amount of homework, were found not to be causal agents of science achievement. As a final example of this sort, research by White (1984), who has designed a computer microworld for learning Newtonian mechanics, demonstrates the power of technology as an instructional tool.

Arguably the strongest influence of psychology on research in science instruction has been the influence of cognitive or information processing psychology (Gentner & Stevens 1983, Larkin & Rainard 1984). As was the case at the time of Resnick's (1981) chapter, physics has received most of the attention from psychologists, in part because the instructional difficulties are most persistent in the case of physics learning (Champagne et al 1982). Nevertheless, the impact of cognitive psychology can now be seen in diverse areas of science instruction, including elementary science (Ross & Maynes 1983), biology (Brumby 1982), chemistry (Gabel et al 1984), genetics (Smith & Good 1984), and geology (Champagne et al 1981).

In the case of physics, research can be divided into three areas: descriptive, prescriptive, and instructional. Descriptive research on physics knowledge has been either developmental (e.g. Siegler 1981, Wilkening 1981, Acredolo et al 1984) or has compared experts and novices (e.g. Chi et al 1981, McClosky & Kohl 1983, Anzai & Yokoyama 1984). The developmental research has focused on the ability of children to integrate information about different variables (e.g. distance and weight in a balance scale task), whereas the research with adults has focused on differences in the knowledge representations and problem solving strategies of experts and novices. A major conclusion of this research is that novices are not merely "empty headed," i.e. they lack information, but that they are "wrong headed," i.e. they have already formed preconceptions (e.g. heavier objects fall faster than lighter objects) that interfere with the learning of truly scientific concepts (Champagne et al 1982).

Reif & Heller (1982) have attempted to improve on the performance of experts by prescribing the kinds of knowledge and procedures that are conducive to effective problem solving in physics. Their formal model of problem solving includes components for (*a*) describing and analyzing a problem so as to facilitate its subsequent solution, (*b*) decomposing a problem into manageable subparts and searching for a solution, and (*c*) assessing the correctness and optimality of the resulting solution. In later work, Heller & Reif (1984) have shown that their formal model can be used to guide accurate problem representations in controlled learning situations, improving the problem solving performance of students who have already taken a physics course. In contrast to the carefully controlled conditions of the Heller & Reif (1984) study, Hewson & Hewson (1983) have implemented a conceptual change model in a more realistic instructional context that deals directly with students' "wrong headedness." Hewson and Hewson's model prescribes instructional strategies for replacing or differentiating the alternative conceptions that students have prior to formal instruction.

Space limitations prevent us from discussing research on other subject areas. However, the cognitive revolution is having an impact in the areas of geography (e.g. MacKenzie & White 1982), social studies (e.g. Armento 1986, Voss et al 1985), art (e.g. Jones & McFee 1986), music (Whitener 1983), motor skills (e.g. Shapiro & Schmidt 1982, MacKenzie & Marteniuk 1985), and military training (e.g. Kyllonen & Alluisi 1985, O'Neil et al 1986).

Generalizable Skills and Strategies

Current cognitive and instructional research stresses the role of prior knowledge in learning. The previous sections on reading, writing, mathematics, and science reflect current interest in the relationship of knowledge to learning and thinking. Although content knowledge is important, it may not be sufficient for effective problem solving. Educators at all levels have been increasingly concerned about generalizable cognitive skills such as problem solving, reasoning, and learning strategies. The following review focuses on research on teaching problem solving and learning strategies.

PROBLEM SOLVING Research on problem solving and general thinking skills has a long history in psychology. There are several recent books and articles that provide good entry points to the current issues in the field. Chipman et al (1985) and Segal et al (1985) edited volumes that address both thinking and learning skills. Frederiksen (1984a) provided an overview of theories of cognitive psychology related to instruction in problem solving. Glaser (1984) highlighted the problems in applying current knowledge-based structural cognitive theories to the teaching of general problem solving and learning skills. Finally, the entire Winter 1984 issue of *Review of Educational Research* was oriented to issues in the teaching and learning of reasoning skills.

Sternberg (1983) has suggested that general intellectual skills training programs should satisfy the following eight criteria: 1. be based on an information processing theory, 2. be culturally relevant for the individuals involved, 3. provide direct instruction in the desired skills, 4. give attention to motivational components and individual differences, 5. have relevance to real-world behavior, 6. show empirical evidence of its effectiveness, 7. be particularly durable, and 8. transfer. Although most current instructional programs in problem solving cannot meet all of these criteria, several are worthy of note. Venezuela's Project Intelligence was designed to enhance the thinking skills of seventh graders. Evaluation data showed that the experimental group, in contrast to the control group, performed better on the specific thinking skills taught in the course, general intelligence tests, and realistic problem-solving tasks (Herrnstein et al 1983, Adams 1984). Feurstein's Instrumental Enrichment Program (Feuerstein et al 1980) also has shown positive results after two years of training in general intellectual skills for mentally impaired children (Narrol et al 1982). Other studies (e.g. Graham 1981, Haywood & Arbitman-Smith 1981, Yitzhak 1981) have shown less positive results but have involved much less training time than Feurstein's original program. Savell et al (1984) provided a review of the research on Feurstein's program, highlighting the gains on tests of nonverbal intelligence, but concluded that there is little evidence to support changes in self-concept, transfer to general school achievement, or nonschool cognitive tasks. A variety of other training programs, such as de Bono's (1985) CoRT program, Whimbey & Lockhead's (1980) course in analytical reasoning, and Wales's Guided Design (Wales & Stager 1977), attempt to teach general thinking or problem solving skills for college students or adults, but more research that follows Sternberg's (1983) suggestions is needed in order to determine their effectiveness.

The content and procedures of all of these programs differ, yet some commonality emerges. Most programs use a variety of concrete problems or exercises that are assumed to foster higher-order cognitive skills. They also attempt to engage students in discussion of the concepts and principles involved so that thought processes are made explicit. This focus on discussion parallels Glaser's (1984) recommendation of the Socratic method as a means of effective instruction. Collins & Stevens (1982) and Gal'perin (1982) both have found that interactive inquiry methods are effective in teaching general thinking skills. As Glaser (1984) points out, there seems to be little doubt that there is no substitute for extensive experience and knowledge in the problem solving domain in which a problem lies. A problem which is ill defined and difficult to comprehend for the novice may require no creativity from the expert who recognizes several possible approaches to a solution. Nevertheless, two individuals with comparable amounts of experience in problem solving may still differ in their ability to transfer problem solving skills to new problems. Educators can probably facilitate transfer by directly teaching general executive and metacognitive strategies as well as the specific procedures and knowledge involved in solving a set of problems.

LEARNING STRATEGIES AND STUDY SKILLS Tobias (1982) has defined learning strategies as macroprocesses such as reviewing, note-taking, and comprehension monitoring that complement the more microscopic processes of intelligence. As in the problem solving area, there is controversy about whether or not learning strategies can be taught at a general level. Here, however, the research provides more convincing evidence that learning strategies generalize beyond the context in which they were taught. For example, courses designed to enhance study skills have long been successful (Kulik et al 1983). In addition, as we saw in our section on reading research, extensive studies of learning strategies have dealt with teaching reading to children. This research is well represented in the volumes edited by Pressley & Levin (1983a,b). Weinstein & Mayer (1986) provide a review of research on learning strategies. In this section we focus primarily on university level courses attempting to teach generalizable skills in learning along with metacognitive strategies for the use of those skills.

Weinstein & Underwood (1985) included both basic concepts of cognition and specific training in such strategies as elaboration and self-monitoring in a training course for college students. The most striking result from their research was an increase in reading comprehension; reported use of effective learning strategies increased, anxiety was reduced, and grades in later courses also improved. McKeachie et al (1985) compared gains of students in their "Learning to Learn" course with those of students in other introductory psychology courses and obtained results similar to those of Weinstein. The McKeachie and Pintrich course was developed with an underlying premise that skills would be more likely to be used effectively and transferred if students understood the cognitive theories about why particular strategies work. This parallels Paris et al's (1983) idea that students need not only declarative and procedural knowledge, but also conditional knowledge or an understanding of why a strategy works. This conditional knowledge should result in more motivated used of strategies.

A number of researchers have used Marton & Säljö's (1976) distinction between deep and surface processing to develop their courses. Biggs & Rihn

(1984) evaluated a course, "Effective Learning Skills," which attempted to teach students to take a deep, rather than surface, processing approach to study, resulting in the desired achievement gains plus an increase in intrinsic motivation for learning. Casteñeda et al (1984), however, found that hierarchial elaboration strategies imposed demands beyond the capacities of students and were less effective than linking, grouping, and repetition strategies. For technical, well-structured text and students lacking prior knowledge, the strategies of deeper processing involving constructing hierarchies of constructs or paraphrasing were less effective than strategies of repetition or grouping concepts. This highlights the interaction between the learner and the task and reinforces the notion that strategies are only strategic for some individuals and some tasks.

Dansereau's (1985) interactive learning strategy system makes distinctions between strategies that have a direct primary impact on information (i.e. elaboration) versus support strategies (i.e. reviewing). Strategies can be either algorithmic or heuristic, for a specific or for a general purpose, and either large or small in scope. Dansereau (1985) reported that his course in learning strategies produced improved academic performance and self-reported changes in strategies. More recently, he and his colleagues have found that cooperative learning of strategies carries over to more effective learning individually (Larson et al 1984, Yager et al 1985).

Learning and problem solving strategies are of no avail if the learner is not motivated to use them. As we have already seen, the apparently obvious positive effects of increased competence on motivation turn out not to be obvious. Motivation and self-concept are influenced by many variables outside an instructional program in learning and problem solving. Thus, instructional strategies need to deal explicitly with motivational retraining as well as cognitive skills and strategies. McCombs (1984) has developed programs to enhance student motivation through teaching self-awareness, personal control, and positive self-evaluation. Attribution retraining programs (e.g. Dweck & Licht 1980) also may be useful, but only as part of a larger program that focuses on skill training. Changing attributions without changing actual skill and performance may be misleading by convincing students they have needed abilities when in fact they do not.

CONCLUSION One of the hopes of educators has been to adapt instruction to individual learners; learning strategy research suggests that we may also improve learning by adapting learners to teaching and the tasks. At elementary, secondary, and post-secondary levels, training in learning strategies and problem solving seems to be effective. Students change from the beginning to the end of a course, and in some cases transfer their learning beyond the training situation. Unfortunately, random assignment, appropriate controls, follow-up to determine long-term transfer of skills, and analysis of which components of the training are of most value—these desirable features of research—are difficult to achieve and provide ample scope for further research. Future research needs to address which strategies are effective for whom in what situations. In teaching both learning strategies and problem solving, there seem to be no quick, cheap, cure-alls. Explicit attention to these skills and strategies through direct extensive training and practice is needed for improved performance. Moreover, motivational and cognitive training components need to be synthesized in these programs.

FINAL THOUGHTS

It is over a decade since McKeachie's (1974) chapter on instructional psychology. What changes have occurred! The growth and progress of the field in just a decade is quite impressive. Despite the fact that educational research in 1974 was relatively much better supported by the government and foundations, today there are more journals, more articles, and more fields of research. Particularly noteworthy is the greater internationalization of the field. As our citations indicate, European, Asian, Australian, Latin American, and other researchers are making interesting and substantial contributions.

Substantively, local and middle-range theories and an overall cognitive approach give the field a much richer conceptual flavor. We now have a substantial corpus of ongoing research on the learning and teaching of school subjects, particularly reading and mathematics. Similar efforts are now going forward in writing, science, social science, music, physical education, and other fields. Product-oriented research oriented primarily to input and outcomes has merged into process-product research which in turn is beginning to be integrated with content-knowledge research. This offers hope for greater use by educators by providing them with the knowledge of how to teach content as well as how to run and manage a classroom. As research becomes more useful to teachers, they in turn are more likely to become teacher-researchers, creating local theories and testing the validity of concepts in their own day to day teaching.

As the field develops, global constructs are being looked at more analytically. Static conceptions of learners are evolving into more dynamic process-oriented theories. For example, "intelligence" and "motivation" are giving way to more componential, process descriptions of learners. Similarly, general principles of instructional design such as "Minimize learner errors," are yielding to more complex analyses of a learner's prior experience, strategies, information processing characteristics, the task demands, and a consideration of the levels of outcome.

What is the relationship of instructional psychology to instructional practice?

Some of the older prescriptions such as active learning are even more clearly indicated. A new one—direct teaching for metacognitive understanding of procedures, skills, and strategies—is emerging. At the same time, the increased complexity of analyses makes it more and more difficult to come up with simple prescriptions. Rather, the theories and results of instructional research form the schemata that will help teachers to interact effectively with unique students in unique classroom settings.

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