THINKING AND LEARNING SKILLS

Volume 1:
Relating Instruction to Research
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Currently, two streams of endeavor offer promise for improving school effectiveness in developing students' higher cognitive capacities. One of these is represented by the increased interest of school districts, colleges, and universities in identifying ways to help their students build the cognitive skills that enable them to learn and think effectively. What can be done, they ask, beyond teaching the fundamentals of reading, writing, arithmetic, and subject-matter knowledge, to enable students to use their skills and knowledge for effective problem solving, reasoning, and comprehension? The second stream is apparent in recent scientific advances in the study of intelligence, human development, problem solving, the structure of acquired knowledge, and the skills of learning.

This confluence of renewed educational interest and modern scientific investigation offers a challenging opportunity to attack the problem of "passive knowledge"—knowledge that students receive and express, but cannot use effectively for thinking and learning. Schools have not been well enough equipped for this task. Older theories of learning focused on simpler forms of learning and did not provide understanding of higher cognitive processes. Educational practices based on those theories resulted in improved instruction for fundamental skills; less emphasis was given to exercising thinking and problem-solving abilities in the course of schooling. Today, however, educators, educational researchers, developmental psychologists, and cognitive scientists are designing school programs and conducting investigations on understanding and problem solving in mathematics and science, comprehending and reasoning with text material, study skills and abilities to learn, and the role of memory organization in the acquisition of knowledge. These processes of human cognition and learning are being studied
with particular attention to how conditions that foster them might be built into
the materials, methodologies, and environments for learning and schooling.

In recognition of this potential, scientists at the National Institute of Education
(NIE), Susan Chipman and Judith Segal, proposed the conference on which these
volumes are based. Their goal was to examine educational practices and scientific
investigation concerned with students' abilities to understand, reason, solve prob­
lems, and to learn. The plan for the conference was to bring together cognitive
researchers, program developers, and teachers of cognitive skills to provide
mutual advice and to discuss their theories, findings, and recommendations. In
this way, a rich array of current work could be assembled that would be available
for educators and researchers. In addition, the conference could provide inform­
ation to NIE that would assist in identifying needs for future research.

The conference took place at the Learning Research and Development Center
(LRDC) of the University of Pittsburgh, one of the major research and devel­
opment centers funded by NIE, engaged in both basic and applied research on
the relevant issues. Organizing the conference called for close collaboration
between LRDC and NIE. Chipman and Segal at NIE and Michelene Chi and
Robert Glaser of LRDC formed the initial planning committee. Conference
contributions were carefully structured. Each chapter in these volumes was espe­
cially requested to fulfill a particular function. The aspirations and rationale for
the conference are well described in Chipman and Segal's introductory chapter,
"Higher Cognitive Goals for Education." They point out that whereas schools
appropriately make the basic skills of reading, writing, and mathematics a high
priority, skills in learning, reasoning, and general problem solving—including
the more sophisticated aspects of reading and mathematics—are less emphasized
or neglected. Thus, the burgeoning research on cognition fills an important
need: to understand and describe these skills with the precision that would make
it possible to teach them and assess their acquisition. The related practical require­
ment is to design instructional programs that successfully teach these higher
cognitive skills.

These volumes, like the conference sessions, are organized by a classification
of cognitive skills into three groups: intelligence and reasoning, knowledge
acquisition, and problem solving. Although we recognize that there are features
common to these areas, as well as important relations between them, these
categories serve present purposes in reflecting attention to the three central themes
of conference discussions.

While each of the editors has been concerned with both volumes, Volume 1
is particularly Judith Segal's contribution, and she introduces it. In Volume 1
she attempts to bring theory and practice into close perspective. Programs that
have been implemented in schools are described by their developers. These
programs encompass the range of approaches to cognitive skills instruction from
which practitioners can currently choose. Their diversity offers readers a basis
for exploring the advantages and limitations of different approaches to instruction. The developers describe the theories and assumptions underlying their programs, discuss the specific skills they are seeking to instill, offer examples of typical instructional methods and materials, and discuss the effectiveness of their programs.

In three invited essays, leading cognitive psychologists analyze the instructional programs presented. Their contributions look carefully at the ideas and practices recommended. They examine the assumptions built into the programs about the nature, development, and acquisition of thinking and learning skills; comment on the relationship of these assumptions to research findings and current theory; review evaluation data on these programs and discuss the problems of evaluation; and suggest additional ideas for research and further questions for exploration.

In the final section of Volume 1, we are fortunate to include chapters by educators who have implemented programs of instruction in cognitive skills in different settings. They comment on current efforts and describe impressions and results from their own experiences.

Volume 2 displays the guiding hand of Susan Chipman, who also has written an introduction to it. This volume contains a representative sample of contemporary research on cognitive skills and considers research issues and open questions that indicate future research directions. The papers she has brought together here exhibit the rich variety of theory and methodology currently being brought to the study of thinking and learning by cognitive scientists. Each major topical area—knowledge acquisition, problem solving, and intelligence and reasoning—includes perspectives from developmental psychology and from the study of cultural influences on human learning.

Reflected here is an issue prominent throughout the conference—the question of the generality or domain specificity of problem-solving and learning skills. Early seminal research emphasized the important common characteristics of problem solving in various task environments, but it is not obvious that these common characteristics can be treated as general, teachable skills. General skills may develop slowly and naturally out of much specific experience, and perhaps problem-solving skills can best be taught in the context of the acquisition of particular domains of knowledge. Many other fundamental research issues appear in Volume 2, including questions about the influences of learning, development, and social background on the acquisition of cognitive skills, and about the necessity for adapting instruction to the prior experience, knowledge, and skill level capabilities of students. Developmental differences also receive special attention in this volume.

The conference at LRDC was an exhilarating experience for those who attended, as we hope these volumes will be for those who peruse and study them. We have attempted to address a wide audience, and the conference and the resulting
volumes should help to strengthen a community of interest that cuts across the boundaries separating basic researchers, program developers, and classroom teachers. These volumes should enlarge that community, helping to accelerate an integration of the efforts of all those concerned with guiding students in becoming more independent, effective learners and problem solvers throughout their lives.

Research on the training of cognitive skills is, as these volumes attest, a high priority in education—one supported by growing public interest and scientific advances. Few other educational possibilities beckon us to apply our energies and exploratory talents as much as this one does. Teaching thinking and the ability to learn have been long-term aspirations for schools, and now progress has occurred that brings these goals within reach. Our task is to produce educational environments where knowledge and skill become objects of interrogation, inquiry, and instruments for learning so that as individuals acquire knowledge, they also acquire cognitive abilities to think, reason, and continue learning.

There are many acknowledgments to be made in producing a work as extensive as this, and we would like to express our thanks to all who contributed to the success of the conference and to the production of these books. Karen Locitzer shouldered the responsibility for all the conference arrangements. Michelle von Koch handled the technical editing with Helen Craig’s invaluable assistance. Emilee Luckett at NIE provided vital secretarial support for Chipman and Segal throughout the process of conference planning, writing, and editing. The conference was enriched by others who do not appear as authors, particularly Richard Anderson, Joseph Psotka, and Virginia Shipman, who made important contributions.

Robert Glaser
THINKING AND LEARNING SKILLS

Volume 1:
Relating Instruction to Research
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Higher Cognitive Goals for Education: An Introduction

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In a rapidly changing technological environment, it is difficult to predict what knowledge students will need or what problems they will have to solve 20 years from now. What they really need to know, it seems, is how to learn the new information and skills that they will require throughout their lives. These general skills are prominent among the characteristics employers say they would like to see in the youth they hire (Chatham, 1982). Clearly, much of the value of education for students’ later lives comes from whatever general thinking and learning skills have been acquired along with the specific knowledge that schools impart. Quite appropriately, schools place the highest priority on skills with very general applicability: reading, writing, and mathematics. However, skills in learning, reasoning, and general problem solving—including the more sophisticated aspects of reading and elementary mathematics—are neglected by the schools.

An Evident Need

Even in the earliest grades, teachers direct students to a lesson or reading assignment with instructions to learn information, concepts, or skills. Little is said to the child about how to go about learning. Recent research focused on reading has shown that explicit instruction in strategies for effective thinking and learning rarely occurs in classrooms (Beck, 1983; Durkin, 1984; MacGinitie, 1984). Similarly, it is assumed, or hoped, that repeated attempts to learn or to solve problems will automatically result in improvement of general ability to reason or solve problems; little is taught about ways of going about solving the problems.
The central research problem in this area is still to understand and to describe these skills with the precision that would make it possible to measure them. Nevertheless, Jencks (1978) has argued that it is the complex skills, not the basic skills, that are deteriorating. NAEP (National Assessment of Educational Progress, 1981) does report that the problem with student writing seems to rest in the quality of thinking and organization rather than in the mechanics. There is general agreement that reading comprehension, not decoding, is the most important problem area in reading instruction today. Repeated assessments have shown that students' mathematics problem-solving performance is much less satisfactory than their computational skill (NAEP, 1983). Instructors at the college level, especially in community and open admissions colleges, complain that students have great difficulty managing and evaluating their own learning efforts. Students agree: On the SAT questionnaire (College Entrance Examination Board [CEEB], 1981) students rate study skills as the skill area in which they feel the greatest need for assistance. Not surprisingly, the recent CEEB effort (1982) to define basic competencies for college entrance includes competencies in general reasoning, problem formulation and solution, studying, and general learning skills. Many of these competencies, of course, are not well defined. Current emphasis on measuring competencies and training for the competencies measured may be creating a still more unfavorable environment for the development of these more complex competencies that we do not yet know how to measure.

Research (Dansereau, Long, McDonald, & Actkinson, 1975) indicates that even good students know very little about techniques they might use to remember better the material they are studying. Nonetheless, one way successful students and more educated persons differ from the less successful and less educated is that they are likely to know and use learning techniques more sophisticated than rote repetition (Weinstein, 1978). For example, only good readers at the 12th-grade level are able to adjust their style of reading to the purposes for which they are reading (Smith, 1967). Although it would be difficult to set minimum competency standards for learning skills, it is clear that there is room for improvement: Even good students have a limited repertoire of such skills, and others have fewer still.

There is good reason to try to improve the characteristics of individual students as learners. Most commonly, educational research attempts to improve instructional techniques in general or in specific subject matter areas. Dansereau (1978) points out, however, that research at the college level indicates that truly different methods of instruction—lecture, discussion, reading, computers—have negligible effects on student performance, whereas there are large individual differences in student performance. Although carefully developed and researched instructional materials may enhance achievement of particular educational or training goals, such materials will never be available to meet all the needs of individuals. Only a few high priority subjects are likely to receive the necessary
research and development investment, and learning about developing topics such as the frontiers of technology requires an independently active learner. It does make sense, therefore, to invest in the alternative strategy of improving learners, rather than simply improving instructional materials.

An Opportunity for Genuine Improvement

Because explicit instruction in thinking and learning skills has received little attention in the schools, it is likely that large improvements are possible. It is much easier to improve instructional outcomes in a new or neglected area than to achieve significant improvements in instructional methods that have undergone decades or centuries of evolutionary improvement by trial and error. Furthermore, there is reason to believe that increased efforts in this area hold promise for ameliorating the persistent problem of unequal school success for the diverse social and ethnic groups that make up our society. A recent investigation of the delivery of study skills instruction (USDE, 1982) indicated the rarity of serious school programs of study skills instruction and revealed that students, parents, and school staff all believe that these skills are learned primarily in the home. Unlike teachers and school administrators, however, most parents and students were unable to explain what is meant by study skills. Educational practice has evolved in relation to the surrounding culture, particularly the subcultures from which both educators and those participating most fully in schooling traditionally have come. Therefore, educational practice is grounded in tacit assumptions about the skills and knowledge students bring to school and about the supplementary assistance and training provided at home. Detailed observations are beginning to show that the forms of help with school work available at home vary dramatically in quality and quantity (Chall & Snow, 1982; Varenne, Hamid-Buglione, McDermott, & Morison, 1982). Obviously, students whose parents know what is meant by study skills are advantaged.

There is some evidence from cross-cultural psychological research that techniques for learning schoollike material are culturally influenced. For instance, Westerners and non-Westerners differ in the use of rote, associative forms of learning typical of less successful students here as opposed to the use of a more complex, organized, and strategic form of learning typical of more successful students (Scribner & Cole, 1976). Within our own society, parallel ethnic or socioeconomic differences in the use of such strategies may exist (Glasman, 1968; Jensen, 1969). In laboratory studies, parents’ ways of directing children’s behavior vary among social classes and ethnic groups (Wertsch, 1978). A plausible form of parental guidance—nonspecific encouragement to figure out reasons for events—has been shown to produce moderately lasting effects on the systematicity of problem solving in young children (Richards & Siegler,
One suspects that such guidance would be differentially distributed across social groups and that its compounded effects over many years could be substantial.

Furthermore, parents cannot transmit skills that they themselves have not had the occasion to develop and practice in their own occupational and social situations (Ogbu, 1978). Consequently, there is reason to suggest that the omission of explicit training in thinking and learning skills from the school curriculum may be one reason why social class and cultural backgrounds are now so strongly predictive of school success. Among the research papers of Volume 2, some represent nascent efforts to examine the relation in our society between culture and cognitive function.

New Conceptions of Intellect

Cross-cultural cognitive research has been one influence contributing to a re-conceptualization of human intelligence that is now in progress (Hunt, 1983; Sternberg, 1979, 1982). What in the past has been seen as innate cognitive ability or aptitude for learning may turn out to be largely a matter of opportunity to acquire skills critical for success in the school environment. Most people recognize that traditional measures of “intelligence” or IQ reflect experience and environmental opportunity as well as other factors. However, the fact that these measures were designed to classify individuals and to predict school performance has hindered progress in understanding either what was important in school performance itself or what really is important about differences in environmental experience. For example, many people would define intelligence as ability to learn. Most intelligence tests, in fact, measure how much people have learned from their general experience. Therefore, it has long been a puzzle in differential psychology why individuals with high IQs show little superiority in basic ability to learn (Tyler, 1965). It may be that the critical differences in intellectual functioning rest on the organization and management of our basic learning ability. Although it is likely that there are constitutional aspects to individual intellectual differences, Pellegrino and Glaser (1982) have found that both specific knowledge relevant to the test items and memory management strategies that might be learned or trained are important determinants of performance on intelligence test items.

We are not the first to suggest that there might be a need for systematic training to improve learning and thinking skills. Indeed, efforts to train and strengthen mental powers have a very long history (Mann, 1979). In 1706, John Locke said: “The business of education is not to make the young perfect in any one of the sciences, but so to open and dispose their minds as may best make them capable of any, when they shall apply themselves to it.” Alfred Binet (1909), whose theoretical investigations of intellectual functioning initiated the
technology of intelligence measurement, was himself convinced of the possible benefits of "mental orthopedics." In these volumes, we sample the curricular and theoretical research resources that are now available to work toward those long-standing educational goals.

At this descriptive level, it may sound as if we are talking about facts that have always been known. Because we are talking about the importance of self-knowledge and self-control of learning and problem-solving strategies, that is partially true. If an analysis is correct, skilled learners should recognize it as corresponding reasonably well to their own thinking. The critical difference is that modern research techniques take the descriptions to a level of precision and detail that is making it possible to communicate these strategies to those who do not already know them as well as to those who do know them. For example, there is little use in instructing students to identify the main ideas in material they are studying and to concentrate on them—a commonsense strategy—if students are unable to identify the main ideas. In fact, even many college students find it difficult to isolate the important points in texts (Brown & Smiley, 1978) and therefore cannot profit from study skill advice at that level. Training that is informed by current research, however, can overcome that obstacle (Brown & Day, 1983; Day, 1980). Rereading an earlier effort to summarize what was known about "learning about learning" (Bruner, 1966), one is struck both by the constancy of the general descriptions of intellectual skills and by the great progress in applicable specific knowledge of cognition.

A Renewed Challenge for Educators

In summary, the development of higher cognitive skills that enable students to be independent learners and independent, creative, problem-solving users of their knowledge has always been a very important goal for educators. There is evidence, however, that explicit instruction in these skills is rare and that students' mastery of them is frequently inadequate. Furthermore, there is reason to believe that improved instruction in such skills might help to overcome persistent socio-economic and cultural differences in the outcomes of education. Today, our long-standing aspirations for education can draw upon new resources provided by the recent, rapid growth of research into cognitive function, including developing reconceptualizations of intelligence or intellectual ability. Today, educators are being challenged to strive for excellence in their students' development—the higher goals of learning, thinking, and problem-solving skills as well as basic computational and decoding skills (National Commission on Excellence in Education, 1983). The cover article of the January, 1983, New York Times Education Supplement, "Teaching to Think: A New Emphasis," (Maeroff, 1983) illustrates the widespread concern and the growing educational response to this challenge.
In these volumes, we have brought together a rich sample of the resources that educators may call upon to meet this renewed challenge. They are resources of two kinds. There are educational programs that have already been developed to teach learning, thinking, and problem-solving skills. The first of these volumes samples such programs, discussing both their relation to research understanding of cognitive functions and issues of practical implementation. A second kind of resource is the rich and growing body of modern cognitive research that will provide the foundation for new approaches to the teaching of cognitive skills. The remaining volume samples this research, touching upon both the analysis of the major skills and key open questions that surround the teaching of cognitive skills.

Research on cognitive skills and practical educational efforts to teach cognitive skills interlock in a complex way. Educators’ goals are frequently more ambitious and broader in scope than the topics on which researchers have focused their analytic efforts. Yet, educators’ conceptualizations of the skills they are attempting to teach are frequently derived from the efforts of previous generations of researchers. Both draw upon their own and others’ introspective intuitions about the nature of learning, thinking, and problem-solving skills as one source of inspiration for their work. Thus, educational programs embody both the practical wisdom of gifted teachers and the theoretical understanding of intellectual functioning that prevailed at the time they were developed. New theoretical understanding of cognitive skills may suggest a reformulation of educational goals and provide considerable guidance for instruction, but the artful contributions of gifted teachers and curriculum developers also are needed to realize those goals. An important feature of Volume 1 is the set of analysis papers that were designed to foster the relationship between research and educational practice in cognitive skills training, drawing out the lessons that each enterprise has to offer the other. The authors were asked to analyze the presuppositions and educational activities of the programs in relation to research understanding of the skill domain in question, but they were also asked to identify important educational goals that seem to have been neglected as subjects of research.

Defining and Describing the Higher Cognitive Skills

For both research and practice, the issues of definition and description of complex learning, thinking, and problem-solving skills remain absolutely central. Past and present research focuses on these problems of definition—for example, on identifying the processes and strategies that good text comprehenders, good students, and effective problem solvers use. In educational practice, better understanding is needed so that we can measure the presence of these skills, set them as goals for instruction, devise reasonable methods of training, and evaluate the
effectiveness of training. As our discussions of educational programs show, current understanding is generally insufficient to permit convincing evaluation of programs with respect to their claims to develop complex cognitive skills. Although the emphasis in Volume 1 is on the discussion of programs intended to develop general cognitive skills, the same problems in measuring efficacy exist for the more ambitious goals of traditional curricula. Today, striving to develop complex cognitive skills requires an element of faith from educators, but the price of excessive skepticism is likely to be the certainty of limited educational accomplishment.

As yet, there is no comprehensive and universally accepted theory capturing complex human intellectual functions in a single conceptual framework. For purposes of discussion, we have divided the general thinking and learning skills that are the subject of these volumes into three major areas: (1) knowledge acquisition, (2) problem solving, and (3) such very basic cognitive skills as approaching tasks in an organized, non-impulsive fashion, or drawing simple logical conclusions. Nevertheless, we recognize that there are common features to all these skills, and important relations among them. This can be seen in even the briefest of descriptions. In discussing knowledge acquisition, A. Brown (1980) characterized the key cognitive skills as: knowing when you know, knowing what you know, knowing what you need to know, and knowing the utility of taking active steps to change your state of knowledge. In problem solving, these skills include analyzing the problem, searching related knowledge, planning possible attempts at solution, keeping track of progress, and checking results against the overall goal or more immediate goals. The distinction between acquiring knowledge and making flexible use of that knowledge to confront new situations is helpful, but it cannot be sharply drawn. Especially when it comes to taking steps to improve one’s state of knowledge, there is a problem-solving aspect to learning. And operational methods for problem solving are a kind of knowledge that one must acquire. In our third category, we have risked grouping together very disparate mental functions—elemental mental processes that form a part of many complex skills (cf. Sternberg’s chapter) and very general self-control or self-management strategies that are also applicable in a wide range of situations (cf. Baron’s chapter). Most of human experimental psychology contributes to our understanding of elemental mental processes. For the readers of these volumes, a relatively new research focus—metacognition, the study of individuals’ knowledge of, awareness of, and control of their own cognitive processes—is most critical. Metacognitive sophistication—the deliberate and reasoned deployment of cognitive resources and strategies—is the goal of much cognitive skills training. Whether that is a reasonable goal and, if so, what instructional process is likely to achieve the goal is something we may learn from research on metacognition.

In the preceding paragraph, we provided first steps in the characterization of the elusive general cognitive skills that are the subject of these volumes. As a
further introduction, we provide only brief summaries of the understanding of these skills that is emerging from research. These themes are elaborated throughout these volumes, first in the analysis chapters of Volume 1 and then in the research chapters of Volume 2, each of which gives a detailed view of some aspect of cognitive skill.

Knowledge Acquisition

How people acquire and add to complex bodies of knowledge is poorly understood, in spite of recent dramatic advances. Many years ago, Bartlett (1932) demonstrated that what a person remembers from a text or a drawing depends on previous general knowledge as much as on the material itself. More recent research in both cognitive psychology and artificial intelligence (Schank & Abelson, 1977; Winograd, 1972) has demonstrated that general knowledge is required to make sense of even simple sentences and texts; careful analysis shows that a great deal is left out, taken for granted. Anderson (1978) and others have been very active in showing the many ways that the reader's background knowledge or general expectations for a text affect its interpretation and what is remembered. Work towards explaining more precisely how such knowledge affects understanding and memory for information continues.

In addition, readers have knowledge about the general form of texts themselves—about, for example, the parts that can be expected in a story. Bartlett also demonstrated that such knowledge is part of our cultural heritage, that stories drawn from an unfamiliar culture are extremely difficult to recall. Although simple stories have received most attention from researchers, it is obvious the same point applies to literary genres in general. In addition, researchers are beginning to recognize and analyze the characteristic forms of other kinds of texts such as science textbooks or popular science articles.

Understanding the Skills of Comprehension. The crucial question about the skill of comprehension is how the reader makes use of such knowledge in comprehending a text. One interesting conjecture (J. S. Brown, Collins, & Harris, 1978) is that comprehension of a story involves divining the plan and purpose behind the actions in the story. We understand the actions in a story because they fit plans that we ourselves might be able to generate. Brown and his colleagues suggested that a wide range of comprehension skills have this common characteristic—seeking to place the elements into a plan or purpose that makes sense for the whole. Another example they gave is comprehending a mathematical proof: To make sense of it you have to know that particular sequences of steps are intended to do something. That is, they form a larger conceptual unit that has a particular function in the proof.

These researchers are making progress in explaining what it is to “know what it is you know and what it is you need to know.” You could know that you have
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to come up with a plan behind a text that makes it reasonable for everything that is there to be there. You could know that if certain things don't fit, then you still have a need to find some hypothesis that will make them fit. In the case of a simple story, it has been possible to observe skilled readers formulate a general plan for the entire story even before the main narrative begins (Olson, Duffy, & Mack, 1980). A surprising statement is recognized immediately as the introduction to the climactic event, and readers are able to predict that it will involve the character who has not been mentioned since the beginning of the story. (Otherwise, why would he have been there?)

Aids to Comprehension and Memory. Much less is known about the process of acquiring complex knowledge, like that presented in school and college textbooks, than is known about the comprehension of simple stories. As for stories, there may be characteristic expository patterns that good students can use to structure the information being presented, to identify the important points, and so on. Rather extensive attention (Mayer, 1979; Reder, 1980) has been given to the effect of such devices as advance organizers, interpolated questions, and elaborations of content upon memory for texts. The results of this research have been sometimes positive, sometimes negative, apparently because it was not founded on a theory that could describe the relation between particular questions, for example, and the content of the text. Techniques for characterizing the structure and content of texts in a reliable, consistent, and detailed manner are now available and may lead to more reliable techniques for assisting students' learning. On the other hand, the demonstrated important effects of the reader's prior knowledge on both comprehension and memory suggest limits to what can be achieved with an approach based on the text design alone.

Traditional Study Techniques. Traditional study skills techniques seem to have been informed by the same ideas that led to the instructional research on text design, with the important difference that the student is to supply the questions and elaborations and to derive an advance organizer from a quick skimming of the text. In effect, the student is asked to act as his or her own instructional designer. It is not at all obvious that we should expect students to be able to do this, or that their efforts would be any more consistently effective than those of instructional researchers. Indeed, evidence for the effectiveness of traditional study techniques is limited (Anderson, 1980). Not surprisingly, extensive training in supporting skills such as the identification of main ideas seems to be required in order to achieve success with a study technique such as outlining (Barton, 1930). Brown (1980) has observed that underlining key points is an effective study technique for those who use it spontaneously, but not for others who are induced to use it. It seems likely that traditional analyses of study skills are too superficial and insufficiently detailed to be instructionally useful. Although research to date suggests that time-consuming study techniques like elaboration and imagery,
self-questioning, and outlining are no more effective than simple reading and rereading (Anderson, 1980), more serious investigation of the relationship between these techniques and the rapid, seemingly automatic comprehension processes of skilled readers is needed. Obviously, the quality of what students are doing when they read and reread varies a great deal. Research should be done to determine whether overt study techniques can be used to improve the quality of covert processes in students’ later reading to study.

Characterizing States of Knowledge. A current trend in research on human knowledge is detailed description and contrasting of the knowledge of experts and novices in a particular field of endeavor. The scope of investigation in this research is much greater than that concerned with the mastery of and memory for brief passages of text. It has been facilitated by systems of notation in which concepts and their relations are represented as complex networks in a computer memory. The hope is that such systems may help us analyze students’ states of knowledge, diagnose problems, direct instruction, and evaluate the effect of instruction upon the state of knowledge. Perhaps such work will lead to sensitively adapting computer-tutors. Characteristic patterns of information—of relations among concepts—can also become learning tools for the student (see chapters by Dansereau, Rissland, Jones).

Nevertheless, the formulation of a theory concerning the way in which knowledge develops from the novice to the expert form remains an important challenge for the future. Norman (1978) has provided an evocative, intuitively appealing description of the changes in knowledge as learning occurs: accretion, restructuring, tuning. By analogy to comprehension, one might speculate that the restructuring of knowledge involves an attempt to achieve an organization that conforms to some as yet unarticulated ideal.

The first stage of systematic analysis—introspective analyses of the process of learning new subject matter—is just now beginning. At this time, research on the learning of realistically complex bodies of knowledge demonstrates the incredible detail and complexity of relationships in the specific subject matter knowledge that experts have (cf. Rissland’s chapter) and the importance of previous knowledge to the acquisition of new knowledge. But there are also tantalizing hints of more general tactics and strategies in learning that more effective students may use. The image of the student as instructional designer may have some value for suggesting the nature of learning and study skills that facilitate mastery of entire domains of knowledge, entire college courses.

Problem Solving

A Characterization of Problem-Solving Processes. The scientific study of problem-solving behavior began early in this century when Gestalt psychologists undertook systematic descriptive and experimental studies. They found that
sometimes a problem solution appears to be a sudden event, which Kohler (1927)
called insight. By studying people trying to solve very difficult problems, how­
ever, these researchers were able to see and describe steps in the problem-solving
process: First, the problem is recognized and defined; then there is a phase of
exploration in which the elements of the situation and their relationships are
examined; next the problem is analyzed, the information gathered is organized
and structured, and a plan is formulated; and finally, the problem is attacked
and an overall solution occurs. Obviously, much is unexplained in this account.
What is meant by analysis? How does solution occur? The Gestalt psychologists
thought of the information gathered as making up a perceptual field with built-in
structural stresses and strains. As relations are considered or interpretations
are varied, the perceptual field will suddenly restructure, they concluded, leading
to a solution.

This is a rather vague theory. Nevertheless, these researchers were able to
demonstrate that there were internal mechanisms of thought—even when problem
solvers could report only sudden insight—that could be affected by various factors
that the experimenter manipulated. Maier (1931), for example, influenced the
likelihood of insight by delivering various verbal or visual hints. Other research
showed that people could become stuck on the idea that a particular object had
only a certain function—"functional fixedness." Similarly, a history of success
with one method of solution tends to blind the problem solver to simpler approaches
that would work in a particular case and would be seen by someone without that
history (Luchins, 1942).

Instructional Implications. The research did make major advances in the
understanding of problem solving. Many of the findings could be translated into
advice for problem solvers: for example, telling them to attempt redescriptions
of situations, to break down fixed ideas about the form that must accomplish a
given function, or about the function of particular objects or materials. Indeed,
this research is the basis of most current attempts to teach problem solving.
Research did not advance beyond those rather general descriptions, however,
and consequently there was a lengthy fallow period in problem-solving research.

A New Theoretical Approach. Research on problem solving revived with
the pioneering work of Newell, Shaw, and Simon (1957), who began to work
with computer simulations of problem-solving processes. When you can write
a computer program that explores a problem, analyzes the relation between the
goal and the present state, evaluates means of solution, and forms a plan, then
your theory is no longer vague. The problem-solving performance of such pro­
grams can be impressive, and they are being developed to model human per­
formance in an increasing number of subject matter domains like geometry
(Greeno, 1982). Models of expert and novice problem solvers have been used
to gain insight into the underlying difference in their skill (Simon & Simon,
One interesting suggestion of this line of study is that novices in a field may show more evidence of control and general problem-solving skill than experts, for whom solutions seem to come automatically. Perhaps general problem-solving knowledge is most important during the acquisition of new skills and knowledge.

Efforts to simulate the performance of problem solvers at differing stages of learning resulted in a class of computer models called production systems (Simon & Newell, 1971). Productions consist of conditions of application, and of operations that occur if the appropriate conditions are met. The conditions of application are altered as a result of experience. Productions can be combined as a result of successful experience to yield more complex productions, and thus the appearance of automatic solution. One can easily see how fixation on a particular method of solution, as well as other observed features of problem-solving behavior, would develop in such a system.

_New Instructional Implications._ The influence of this theoretical approach to problem solving is now appearing in practical instructional efforts. In science and mathematics instruction, we are discovering that too little attention has been given to instruction in the conditions of application, to identifying when it is appropriate to apply a method of solution. Production system models tend to highlight the importance of specific knowledge and specific practice with particular kinds of problems, as opposed to general problem-solving skill. On the other hand, they also hint at the way experience might be designed to produce "general" problem-solving behavior, as a result of long experience. Research computer simulations have provided a set of concepts and a vocabulary that makes it possible to talk about problem solving in more concrete and better defined terms: control processes, memory capacity, conditions of application, etc. These concepts are beginning to influence the design and content of instruction.

Computer simulation studies of problem solving have concentrated on puzzle problems that can be described and worked out in symbols. Whereas, recent efforts to understand problem-solving in physics have begun to point out the importance of other representations of problems. Appropriate uses of schematic drawings or images—and skill in translating between verbal descriptions, drawings, and mathematical expressions—are critical to successful problem-solving performance. Perhaps this work is providing a more systematic version of the Gestalt theorists' exhortations to look at problems in new perspectives, a new explication of some instructional goals in problem solving.

**Metacognition: Skills of Cognitive Control and Management**

In both knowledge acquisition and problem solving, the vital importance of control of cognitive activities, of self-awareness, and self-management of cognitive activity is evident. The student must be alert to failure of comprehension
in order to take corrective action. The problem solver must monitor progress

toward a goal. Baron (1978) has suggested that there may be a number of very
general “central” strategies that are desirable in the intellectual functioning of
both children and adults. As possible examples of such strategies, he suggested:
imposing limits, defining tasks into chunks that are appropriate to the person’s
capacity; subject organization, appropriate grouping, categorization, etc., of
materials; checking, the use of multiple solution techniques to verify problem
solutions. Although these strategies sound general, much specific knowledge
may be required to display them. Considerable familiarity with a task may be
required in order to judge its demands on capacity. Checking with multiple
methods of solution requires knowing multiple methods of solution.

Indeed, Brown (1980) has suggested that metacognition—conscious aware­
ness of and control of cognitive processes—emerges only as knowledge and
skills in a particular domain become quite well developed. Perhaps it is not
surprising, then, that developmental psychologists who study universal novices
have given the most explicit research attention to people’s awareness of thinking
processes and to their knowledge about the workings of their own and others’
minds. Some developmental theorists, working within the Piagetian tradition,
postulate a fifth stage of intellectual development occurring in adulthood that
would incorporate general, overarching comprehension of one’s own intellectual
functions (Arlin, 1975; Commons, Richards, & Kuhn, 1982; Fischer, 1980).
Unfortunately, most research on metacognitive development is focused on rote-
learning skills in quite young children (Brown, 1980; Flavell, 1977). It has not
been common, for example, to query adults about their knowledge of problem­
solving strategies in concert with investigations of their problem-solving per­
formance. Gradually, the developmental research is broadening to examine the
metacognitive aspects of a wider range of cognitive functions such as compre­
hension of instructions (Markman, 1979), selective attention (Miller & Weiss,
1982), or simple problem solving (Richards & Siegler, 1981).

Despite the limited scope of this research, it provides a number of observations
that are important for cognitive skills training. Both children and adults may
verbally display knowledge of effective learning techniques that they do not
apply when confronted with a learning task (Brown & Barclay, 1976). It is
equally true that they may not be able to articulate knowledge that they can
readily put into action at appropriate times (Brainerd, 1973). Obviously, those
who articulate insights about the way they go about solving problems or inventing
mathematical proofs (Polya, 1945), or who describe the characteristic structure
of literary genres, are exceptional individuals. This casts doubt on the prevalent
approaches to cognitive skills instruction that rely heavily on verbal descriptions
of strategies. Verbal instruction may be useful for older persons who already
have the implicit knowledge to understand what is meant by the strategies, but
not useful for those who need to learn them. On the other hand, children can
learn to talk to themselves to pace their actions at critical points (Meichenbaum,
1978). Markman (1979) has found that first- to third-grade children’s ability to evaluate inconsistencies in instructions was improved by asking them to demonstrate the instructions or by having them view others’ partial demonstrations. This is another encouraging indication that it may be possible to teach these metacognitive skills.

OPEN ISSUES

The discussion of metacognition touched upon three unresolved issues that are of critical importance for anyone interested in education of the higher cognitive skills. These are the final 3 topics of Volume 2.

The Generality or Specificity of Cognitive Skills

The idea that there are very general learning or problem-solving skills is an attractive one. In essence, it is the idea that these volumes are meant to explore. It holds the promise of greater efficiency and longer lasting value for our educational efforts. It gives us an alternative view of what we might mean by general intelligence. But it is an unproven idea. General skills may not exist. That is, even though we might characterize an individual as using a particular strategy such as means–ends analysis in a variety of different problem domains, it might be that the individual must learn that strategy separately for each domain. There may be no deep psychological unity to the strategy across domains. A more likely hypothesis is that general skills must be built on the foundation of skills that have developed to an advanced state in at least one and probably more than one specific domain. The significance of this issue for the theory of human intellectual functions is obvious, but its practical importance is equally great. Some advocate teaching general cognitive skills and strategies as a separate school subject. Others believe that this is an emphasis that should be incorporated into the teaching of specific school subjects.

The Teachability of Cognitive Skills

Even if learning, thinking, and problem-solving strategies, whether general or specific, are shown to exist, it might not be possible to teach them directly. Perhaps they must spontaneously emerge as a consequence of substantial experience. At the very least, it should be possible to select and design experience to result in a more rapid and complete emergence of such skills. Probably more explicit instruction can be helpful as well. For example, we need to understand more about the value of verbal labels for cognitive activities and of conscious, deliberate control of cognitive activity. On the other hand, we need also to understand how verbal labels can be made meaningful to a wide range of students.
so that they evoke the desired cognitive activities. We need to understand how
effortful, conscious, and deliberate patterns of cognitive activity can be taught
in such a way that they will be transformed into efficient, automatic patterns.
Volume 2 samples work that provides a promising beginning to the enterprise
of teaching complex cognitive skills.

Developmental Differences

Whether young children and adults are fundamentally different learners remains
an open theoretical question. Certainly, complex learning and problem-solving
skills are found predominantly in older individuals. Some believe, however, that
very sophisticated cognitive skills can be developed by quite young children in
domains that they happen to know well or that are restricted in the content that
must be mastered. Such domains might serve as a foundation for the development
of widely applicable general cognitive skills.

It is more likely that older individuals will have developed the implicit con­
cepts needed to understand abstract, verbal approaches to cognitive skills instruc­
tion. On the other hand, both older students most in need of help and younger
children probably have similar needs for more concrete, intensive instruction.
They may need training to develop the mental processes that make up strategies,
not simply training to use processes that they have already mastered. They may
need to learn to recognize and distinguish among their own mental processes as
well as to learn the verbal descriptions that theorists and program developers
use to talk about those processes. Cognitive skills training cannot be the same
for all students and must adapt to the characteristics of the learner. Because of
the practical importance of these issues for educators, a section of Volume 2 is
devoted to them, and chapters on developmental studies appear in the major
skill sections of Volume 2 as well.

A CLOSING AND OPENING WORD

These open questions beckon to researchers exploring the powers of the human
mind. theirs is an adventure we invite you to share in these volumes. It is an
adventure shared and renewed in the life of each developing individual who
experiences the unfolding of the intellect to encompass more and more of expe­
rience. The powers of the human mind are amplified, we hope, as the creative
intellectual insights of one generation become the common self-knowledge of
the next. Educators make that hope a reality by shaping the insights of exceptional
thinkers or the hard won conclusions of analytic research into effective instruc­
tional experiences. In doing so, the teacher is privileged to share students’ delight
in their developing competence and to increase the number who experience it.
Minds become capable of dealing with the future by mastering the insights and
inventions of the past. The challenge to all who have contributed to these volumes, and to all who read them, is to bring about that translation from research into the thinking minds of our students.

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APPENDIX: Sample CMLR/LS Materials

Word Analogies Unit 6: SA-2-1 ANALOGIES Student Activity
#2 Review You should remember, from the exercises about word pairs, that words can be related to each other in many ways. Three of these ways are: Word-Pair Examples u4vw
A R E. x »i/p v ;o 0 t ^ tt 2 IN G G O T AAV ^ tAOCH ? AMALnr.s/ EXERCISE A INSTRUCTIONS Identifying Word Pairs 2
/ Simi.

S made 1. MAKE A MENTAL PICTURE as you read each word pair.
in columns 1 and 3. — 2. DECIDE which type of pair it is.
(How are they related?) 3. WRITE lar, Opposite, or
Part-to-Whole in columns 2 and 4. The first comparison is
for you. EXERCISE A CHART Column 1 - Word Pair Column 2
Column 3 - Word Pair Column 4 A-1. frown - grin Opposite A-
house A-5. thin - skinny A-10. shirt -blouse

B. What Is an Analogy? A word analogy means that the
relationship between one pair of words is similar to the
relationship between a second pair of words.

________Analogy Example________________________
Grandfather is to Grandmother as uncle is to aunt. (Word
1) (Word 2) (Word 3) (Word 4) Explanation: The example
above is really a short code for saying the following:
Word 1 is related to Word 2 in the same way as Word 3 is
related to Word 4. REMEMBER THIS CODE! When you apply this
code to the example above, it looks like this: (Fill in the
blanks.) Grandfather is related to _______ in the same
way as uncle is related to (Word 1) (Word 2) (Word 3) (Word
4)

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292 Similar-Meaning Pair smile - grin Opposite-Meaning Pair
happy - sad Part-to-Whole Pair toe - foot

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AN AL ANALOGIES Student Activity #2

Word Analogies Unit 6: SA-2-2

C. The Word Analogy Strategy Doing word analogies is like
breaking a code. It is a thinking process with specific
steps and decisions. Once you understand the steps, and
decisions, solving word analogies becomes much easier and
fun to do. To break this code, you must follow six
thinking steps. Example C-1________________________
Player is to team as student is to ____________ (Word 1) (Word 2) (Word 3) Word 4) Step 1. Make a mental picture of Word 1 (PLAYER). Step 2. Make a mental picture of Word 2 (TEAM). Step 3. Compare the two mental pictures (PLAYER and TEAM). Step 4. Decide how Word 1 (PLAYER) is related to Word 2 (TEAM). This is Decision 1. Ask yourself if Word 1 and 2 form: a. a Similar-Meaning Pair? ________ b. an Opposite-Meaning Pair?________ c. a Part-to-Whole-Pair?_______ PUT A CHECK _____ next to the type of pair you think Example B is. Step 5. Make a mental picture of Word 3 (STUDENT). Step 6. Think up a word that relates to Word 3 (STUDENT) in the same way that Words 1 and 2 (PLAYER - TEAM) are related. This is Decision 2. WRITE your answer here:____________________________ Your answer have been the word CLASS because Word 3 (STUDENT) is related to Word 4 (CLASS) in the same way that Word 1 (PLAYER) is related to Word 2 (TEAM). They are both part-to-whole word pairs. Now we have completed the analogy. Player is to team as student is to class. ____________ Example C-2____________________________ Toe is to foot as finger is to ____________. (Word 1) (Word 2)(Word 3) (Word 4) It's your turn to fill in the correct word for each step. The first word is filled in for you. Step 1. Make a mental picture of Word 1 (TOE). Draw it in Box 1. Step 2. Make a mental picture of Word 2 (______ ). Draw it in Box 2. Box 1 Box 2 Step 3. Compare the two pictures (______ ) and(______ ). Think: Word 1 is physically attached to Word 2.

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Major Ideas Unit 4: SA-2-3 UNDERLINING AND OUTLINING
Student Activity #2 Outline Notes List / Breathing difficulties / Symptoms Avoid open fields Swelling in the throat Stay indoors Treatment Hay fever Watering eyes / Take antihistamine tablets Outline #2 Think: Headings I and II must be equally general. Look at II. Find another major idea on the list. 1. Think: Details 1, 2, and 3 must be equal. What is another detail that is a symptom? Think: Details 1, 2, and 3 must be equal. What is another detail that is a symptom? Think: Subheadings A and B must be equally general. Look at A. Find another minor idea that is related to the heading. 1. ____________________________ Think: Details 1, 2, and 3 must be equal. What is another detail related to subheading B? 3.__________________________________
Think: Details 1, 2, and 3 must be equal. What is another
detail related to subheading B? Middle ear Nausea
Symptoms / Ear infection Hearing loss Dizziness Inner
ear / Locations Fever / Outer ear II. Ear infection 1.
________ 2 . 3. Outer ear

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294 A. I. _ A. 3. B. AN AL AN AL AN AL AN AL AN AL
AN AL

Inferred Main Ideas Unit 2: SA-7-2 ANALYZING PARAGRAPHS
Student Activity #7 Example B: Identifying the Inferred
Main Idea_________________________________________ j As the
race began, Marti took an outstanding lead in the bike
race. His greatest ambition in life was to win this bike
rally. He had to prove to himself and his family that all
that time he had spent tuning his bike and improving his
racing skills was worthwhile. Proving that he was the best
biker in town was his last goal to reach, mountain to
climb, before going to college. Down the stretch he raced,
sure he was going to win, when, out of the clear blue sky,
Phil pulled ahead and won by an eyelash. It was the
biggest disappointment of Marti’s life. He was crushed. He
knew he would never race again. But when he saw the gleam
in Phil’s eye as he held the first-place trophy, Marti
knew he had to try again next

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