Education and Learning to THINK

NATIONAL RESEARCH COUNCIL

EDUCATION AND LEARNING TO THINK

LAUREN B. RESNICK

Committee on Mathematics, Science, and Technology Education

Commission on Behavioral and Social Sciences and Education

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Foreword

The Committee on Research in Mathematics, Science, and Education was established in the Commission on Behavioral and Social Sciences and Education of the National Research Council in 1984 in response to a request from the U.S. Department of Education. Its initial tasks, for that department and the National Science Foundation, were to develop a set of research priorities and to consider the role of multidisciplinary research for science, mathematics, and technology education. That work resulted in two reports, *Mathematics, Science, and Technology Education: A Research Agenda* (National Academy Press, 1985) and *Interdisciplinary Research in Science, Mathematics, and Technology Education* (National Academy Press, 1987).

While preparing the first report, the committee became interested in exploring in more depth two issues: how the school environment can be manipulated to maximize opportunities for children to succeed in learning science and mathematics, and how children learn reasoning and other complex thinking skills. Work on the first issue was carried out by Michael Cole, Peg Griffen, and their colleagues at the Laboratory of Comparative Human Cognition at the University of California at San Diego; their monograph *Contextual Factors in Education: Improving Science and Mathematics Education for Minorities and Women* was published by and is available from the Wisconsin Center for Education Research, Madison, Wisconsin. Work on the second issue was undertaken by Lauren Resnick at the Learning Research and Development Center of the University of Pittsburgh and resulted in this special monograph. Carnegie Corporation of New York is generously supporting the distribution of both volumes.

Preface

This paper addresses the question of what American schools can do to more effectively teach what have come to be called "higher order skills." Unlike most National Research Council documents, it is not so much a report as the result of extended reflection upon a set of questions raised by and about the nation's educational system. This reflection has received the guidance and critique of a splendid working group of psychologists, educators, computer scientists, and philosophers:

Carl Bereiter, Department of Applied Cognitive Science, Ontario Institute for Studies in Education
John Bransford, Department of Psychology and Director, Learning Technology Center, Vanderbilt University
Ann L. Brown, Center for the Study of Reading, University of Illinois
Jerome S. Bruner, Department of Psychology, New School for Social Research
Susan Carey, Department of Psychology, Massachusetts Institute of Technology
Allan Collins, Bolt Beranek and Newman, Inc., Cambridge, Mass.
Robert H. Ennis, College of Education, University of Illinois
David Perkins, Graduate School of Education, Harvard University and
Roger Schank, Department of Computer Science, Yale University.

The working group exchanged written statements and participated in a two-day meeting in Washington, D.C., in the fall of 1984, during which the issues raised in the written statements were discussed at length. Members of the group also provided guidance in

finding and interpreting information relevant to its concerns. Most important, members of the working group responded to drafts of this paper; these responses have been of great value in shaping the final version. However, what follows is not a group report, but a personal distillation of the working group's wisdom and advice. It should be read and used with that understanding.

Several individuals in addition to members of the working group have been generous with their time and ideas. I would like to mention two in particular, Carol Dweck of the University of Illinois and Mark Lepper of Stanford University. Thanks are also due to the many who sent materials about their own and others' work on the teaching of higher order skills and who were willing to talk with me and, in many cases, to comment on an early draft of this paper. A list of the individuals who responded to requests for information and ideas appears in the appendix.

Finally, special thanks are due to Senta Raizen, study director of the Committee on Research in Mathematics, Science, and Technology Education, for her organization of the initial working group and overall management of the project. Not least among her contributions was securing support for this effort from the Carnegie Corporation of New York, whose contribution is hereby thankfully acknowledged.

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INTRODUCTION

The question of whether schools can do a better job of teaching American children "higher order skills" is very much in the air. It arises in Congressional hearings, where calls are heard for school graduates better able to take on work that requires responsibility and judgment. It is reflected in public concern that changing employment demands are not being met, students' preparation for college is less than satisfactory, and general problem-solving abilities remain low. Yet beyond the agreement that our schools ought to be doing better than they are at building the intellectual capabilities of American young people, it is extremely difficult to discern what really should and can be done.

The first difficulties arise with the very question of what is meant by the term "higher order skills." Many candidate definitions are available. Philosophers promote critical thinking and logical reasoning skills, developmental psychologists point to metacognition, and cognitive scientists study cognitive strategies and heuristics. Educators advocate training in study skills and problem solving. How should we make sense of these many labels? Do critical thinking, metacognition, cognitive strategies, and study skills refer to the same kinds of capabilities? And how are they related to the problem-solving abilities that mathematicians, scientists, and engineers try to teach their students? Are intelligence tests and scholastic aptitude tests good indicators of higher order skills, and if so, should we be

teaching students the kinds of things that appear on these tests? What about artistic creativity and interpretive skill, and the ability to find and refine problems as well as to solve those others have set? And, perhaps most troubling of all, do any of these "intellectuals' concerns" really have much to do with what the vast majority of students will do in their work and personal lives after school? Do the higher order skills needed on the job or in the exercise of one's rights and duties as a citizen really depend on the kinds of abilities educators and the academic community are discussing?

Mingled with the difficulty of defining higher order skills is the troubling sense that there may, in fact, be little new to say about the topic. Inevitably, we hear the question: Is there really anything new about schools' trying to teach higher order skills? Haven't schools always hoped to teach students to think critically, to reason, to solve problems, to interpret, to refine ideas and to apply them in creative ways? Most of us can remember a teacher who inspired us personally in these directions, and schools everywhere include such aspirations in their statements of goals. Nevertheless, we seem to agree that students do not adequately learn these higher order abilities. Perhaps the fact that our schools have been less than successful at meeting these goals means that we have simply given up the old truths in education. Perhaps if we went back to old-fashioned courses and old-fashioned methods, the problem of teaching higher order skills would be solved without further special attention. Or, more pessimistically, perhaps we should conclude that decades of trying unsuccessfully to teach higher order skills in school show that such goals are not reachable; perhaps higher order abilities develop elsewhere than in school, and it would be wisest for schools to concentrate on the "basics," letting higher order abilities emerge later or under other auspices. To consider these fundamental questions, we need a working definition of higher order skills and an understanding of their historical role in American schools.

HIGHER ORDER SKILLS: A WORKING DEFINITION AND A HISTORICAL PERSPECTIVE

Thinking skills resist the precise forms of definition we have come to associate with the setting of specified objectives for schooling. Nevertheless, it is relatively easy to list some key features of higher order thinking. When we do this, we become aware that, although

we cannot define it exactly, we can recognize higher order thinking when it occurs. Consider the following:

- Higher order thinking is *nonalgorithmic.* That is, the path of action is not fully specified in advance.
- Higher order thinking tends to be *complex.* The total path is not "visible" (mentally speaking) from any single vantage point.
- Higher order thinking often yields *multiple solutions,* each with costs and benefits, rather than unique solutions.
- Higher order thinking involves *nuanced judgment* and interpretation.
- Higher order thinking involves the application of *multiple criteria,* which sometimes conflict with one another.
- Higher order thinking often involves *uncertainty.* Not everything that bears on the task at hand is known.
- Higher order thinking involves *self-regulation* of the thinking process. We do not recognize higher order thinking in an individual when someone else "calls the plays" at every step.
- Higher order thinking involves *imposing meaning,* finding structure in apparent disorder.
- Higher order thinking is *effortful.* There is considerable mental work involved in the kinds of elaborations and judgments required.

This broad characterization of higher order thinking points to a historical fact that is often overlooked when considering the school curriculum, a fact that helps to resolve the question of what is new about our current concerns. American schools, like public schools in other industrialized countries, have inherited two quite distinct educational traditions—one concerned with elite education, the other concerned with mass education. These traditions conceived of schooling differently, had different clienteles, and held different goals for their students. Only in the last sixty years or so have the two traditions merged, at least to the extent that most students now attend comprehensive schools in which several educational programs and student groups coexist. Yet a case can be made that the continuing and as yet unresolved tension between the goals and methods of elite and mass education produces our current concern regarding the teaching of higher order skills.

If we examine the educational institutions aimed at the elite in the population, today's higher order goals are nothing new. They represent what might be called the "high literacy" strand in the history of education (Resnick and Resnick, 1977). Since there have

been books and writing, there also have been schools and related institutions established to train an intellectual elite, drawn largely from privileged social strata, in capabilities of reasoning, rhetoric, mathematical and scientific thought, and other skills that today carry the higher order label. These were state, private, and religious institutions with, over the centuries, extremely varied ideas of how to go about the educational task. All were highly selective institutions. A minority of the population attended them, and this minority was selected at least in part on the basis of a taste for academic learning and the ability to perform well in a very special kind of institution.

In America, various "academies," some private and some public, carried on this tradition through the nineteenth century and into the twentieth. Until they began to be transformed early in this century, even public high schools were in the academy mold. Only a minority of young people attended or even thought of attending them. There were entrance examinations. The curriculum was quite strictly academic. Extensive writing, textual criticism, and the like were expected. Although today we might not recognize nineteenth-century academy curricula as promoting creative thinking or independent problem solving, the elite academies expected to produce, and to a considerable extent succeeded in producing, intellectual performance beyond the ordinary.

Historically, it must be stressed, the academies did not treat education of the full population of young people as within their purview. Schools for the masses arose from different roots and are a much more recent phenomenon in the history of education. Mass education derives from a "low literacy" tradition (Resnick and Resnick, 1977) aimed at producing minimal levels of competence in the general population. It originated in Europe in Reformation and counter-Reformation efforts to produce a literate, catechism- and bible-reading population. During the nineteenth century, mass schooling was adopted as part of a new national agenda in countries that were just beginning to form citizen armies and to impose common language and culture on their populations. In the United States, village and township schools were established early, probably reflecting radical Protestant traditions as well as new definitions of citizenship appropriate to the new nation. Throughout the nineteenth century, this nation knew levels of school attendance and literacy ahead of most other countries, despite the continuing flow of poor and poorly educated immigrants. As cities began to grow,

massive urban school systems grew as well. Only racial minorities were systematically excluded or separated within the schools.

The mass education system that evolved under these circumstances focused largely on elementary schooling, and rather sharp divisions between elementary and secondary education persisted. This distinction was apparent both in who went to school and in what was taught. Almost everyone went to elementary school, although a limited number finished the entire eight-year course. Only a few went to high school or its equivalent. The elementary schools served the masses and concerned themselves with basic skills of reading and computation, with health and citizenship training, and the like. Routinized performance rather than creative and independent thought was stressed. Mass education was, from its inception, concerned with inculcating routine abilities: simple computation, reading predictable texts, reciting religious or civic codes. It did not take as goals for its students the ability to interpret unfamiliar texts, create material others would want and need to read, construct convincing arguments, develop original solutions to technical or social problems. The political conditions under which mass education developed encouraged instead the routinization of basic skills as well as the standardization of teaching and education institutions. Standardization was a means of ensuring that at least minimal curriculum standards would be met, that teachers would be hired on the basis of competency for the job rather than political or familial affiliation, and that those responsible for the expenditure of public funds could exercise orderly oversight over the educational process. Standardized testing was one of the methods developed to exercise oversight and centralized control of the schools (Resnick, 1980).

Early in the twentieth century, the institutional division between routine-oriented elementary schools and secondary academies in the high literacy tradition began to dissolve. Responding to changing economic and social conditions, more and more young people began to seek high school education, and educators gradually began to treat secondary education of a much larger and more varied population as being their proper concern. The secondary schools were over the next decades to become the mass institutions the elementary schools had been. The growth of this new secondary school population marked the beginning of a debate that continues even today. This debate concerns what the appropriate curriculum ought to be for secondary schools designed to serve everyone. The terms of the debate were set,

in great part, by a National Education Association (NEA) commission report entitled *The Cardinal Principles of Secondary Education* (Bureau of Education, 1918). The report provided a theory and ideology for the place of a vocationally oriented curriculum in the high school as part of a diversified secondary program adapted to different types of students. This represented a clear challenge to the older ideology that organized the high school curriculum around a common core of the traditional liberal disciplines.

The tension between vocationalism and traditional disciplines as the center of the high school program has never been resolved. Responding to post-World War II manpower needs, the 1950s and early 1960s saw a greater emphasis on traditional disciplines, especially mathematics and science. Yet political and social pressures from many quarters sustained the demand for vocational training and other programs designed to keep students in school as long as possible. Other developments in the later 1960s and 1970s led to a near-complete abandonment of the traditional core curriculum, even for students who had been its traditional consumers. Schools continued to require academic courses, but the requirements were often minimal and course content focused increasingly on application and practical topics—often replacing more traditional, demanding material. Written composition and other activities that engaged higher order skills all but disappeared from the curriculum.

The effect of all of this has been to reduce, and sometimes to drive out of existence, the high literacy goals that had been the focus of the academies and their preparatory institutions. Yet the taste for such goals has survived and can be seen in recent efforts to revive interest in higher order skills teaching. This revival, however, takes place in an educational and social context that dictates an extension of high literacy goals to a much broader segment of the population than has ever before been considered capable of such learning. Today, we are committed to educating all Americans in the secondary schools and a large proportion (higher than in any other country in the world) in some form of postsecondary institution. These students' educational needs cannot be met by traditional vocational programs that no longer prepare students for productive participation in an increasingly diversified economic environment. Employers today complain that they cannot count on schools and colleges to produce young people who can move easily into more complex kinds of work. They seem to be seeking general skills such as the ability to write and speak effectively, the ability to learn easily on the job, the ability to use

quantitative skills needed to apply various tools of production and management, the ability to read complex material, and the ability to build and evaluate arguments. These abilities go well beyond the routinized skills of the old mass curriculum. In fact, they are much like the abilities demanded for college-bound students in the College Board's book, *Academic Preparation for College* (College Entrance Examination Board, 1983). Yet teaching such competencies to the mass of students remains a considerable challenge.

This, then, is part of what is new about the current drive for teaching higher order skills. The goals of increasing thinking and reasoning ability are old ones for educators. Such abilities have been the goals of some schools at least since the time of Plato. But these goals were part of the high literacy tradition; they did not, by and large, apply to the more recent schools for the masses. Although it is not new to include thinking, problem solving, and reasoning in *someone's* school curriculum, it is new to include it in *everyone's* curriculum. It is new to take seriously the aspiration of making thinking and problem solving a regular part of a school program for all of the population, even minorities, even non-English speakers, even the poor. It is a new challenge to develop educational programs that assume that all individuals, not just an elite, can become competent thinkers.

THE NATURE OF THINKING AND LEARNING: GOING BEYOND THE ROUTINE

This challenge comes at a time when we also have new knowledge about the nature of thinking and strong hints about how thinking abilities are learned. In the last decade or two, cognitive science research has allowed us to look into the thinking mind, figuratively at least, and to specify more precisely the reasoning processes of both successful and less successful thinkers (Newell and Estes, 1983). More recently, researchers have begun to investigate how the ability and the propensity to think well are acquired and maintained. These two bodies of research—on the nature of human thinking and on the acquisition of thinking and learning skills—are beginning to make explicit what we mean by higher order skills and what means of cultivating such skills are most likely to be successful. This process of making explicit the abilities formerly left to the intuitions of gifted learners and teachers is precisely what we need to establish a scientific

foundation for the new agenda of extending thinking and reasoning abilities to all segments of the population.

The most important single message of modern research on the nature of thinking is that the kinds of activities traditionally associated with thinking are not limited to advanced levels of development. Instead, these activities are an intimate part of even elementary levels of reading, mathematics, and other branches of learning—when learning is proceeding well. In fact, the term "higher order" skills is probably itself fundamentally misleading, for it suggests that another set of skills, presumably called "lower order," needs to come first. This assumption—that there is a sequence from lower level activities that do not require much independent thinking or judgment to higher level ones that do—colors much educational theory and practice. Implicitly at least, it justifies long years of drill on the "basics" before thinking and problem solving are demanded. Cognitive research on the nature of basic skills such as reading and mathematics provides a fundamental challenge to this assumption. Indeed, research suggests that failure to cultivate aspects of thinking such as those listed in our working definition of higher order skills may be the source of major learning difficulties even in elementary school.

Reading as a Higher Order Skill

The process of understanding a written text, as it emerges in current psychological and artificial intelligence accounts, is one in which a reader uses a combination of what is written, what he or she already knows, and various general processes (e.g., making inferences, noting connections, checking and organizing) to construct a plausible representation of what the author presumably had in mind (e.g., Just and Carpenter, 1980; Perfetti, 1985; vanDijk and Kintsch, 1983). The mental representation constructed by the reader does not match the text itself, nor does the reader even try to match it, except under special circumstances. Instead, the reader tries to represent the situation the author had in mind or the argument the author hoped to build. The reader's representation omits details that do not seem central to the message. It also *adds* information needed to make the message coherent and sensible. The written text, then, is a vehicle that permits a partially common representation of some situation or argument to be constructed by two separate minds—the writer's and the reader's.

By their nature, normal, well-written texts are incomplete expressions of the author's mental representation. They leave out some things essential to the representation on the assumption that readers will fill them in. If this assumption is not met, comprehension fails—even if every word and every sentence has been individually understood. Usually, this process of filling in is so automatic that skilled readers are quite unaware they are doing it. Only when the flow of comprehension breaks down do competent readers become aware of their inferential and interpretive processes. Yet our models of skilled comprehension suggest that inferences are being drawn and interpretations are being made throughout. And studies of eye movements during silent reading, of pause patterns as texts are read aloud, and of disruptions in comprehension caused by minor modifications at key points in the text provide convincing evidence of the reader's inferential work even for quite simple texts.

Four kinds of knowledge are called upon as readers construct meanings for texts. The first is linguistic knowledge: knowledge about how sentences are formed, rules of forward and backward reference, and the like. This knowledge is often only implicit, but readers depend on it to find common referents, to link agent to action to object, and to otherwise construct a representation of a coherent set of events and relationships. The second kind of knowledge is topical knowledge, that is, knowledge about the text's subject matter. Like linguistic knowledge, topical knowledge is often used so automatically that readers are unaware of its contribution. Third, readers invoke knowledge about rules of inference. This knowledge, too, is likely to be implicit for the skilled reader. Finally, knowledge of conventional rhetorical structures often aids the process of text interpretation.

An example drawn from the work of Walter Kintsch (1979) demonstrates the role of the first three kinds of knowledge in reading comprehension and shows how interactive they are:

> The Swazi tribe was at war with a neighboring tribe because of a dispute over some cattle. Among the warriors were two unmarried men named Kakra and his younger brother Gum. Kakra was killed in battle. According to tribal custom, Kakra was married subsequently to the woman Ami.

The first three sentences of this short passage are understood so effortlessly that the reader does not notice the special linguistic work required to build a coherent representation. Yet some inference is required. Note that the term "warriors" in the second sentence has not