Thinking Processes: Being and Becoming Gifted

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Introduction

In this chapter we explore thinking processes as an important component of a contemporary conception of giftedness and its development. We address four issues related to thinking processes and giftedness: First, some of the principal ways in which the thinking processes of gifted persons differ from those of other people, with a focus on recent and ongoing research into cognitive processes; second, and very speculatively, evidence to link the intellectual performance of very young children to the higher level thinking observed in older children and in adults; third, and briefly, the nature and success of programs intended to train people to think in these ways and thereby to enhance their intellectual abilities; and fourth, some concluding thoughts about broader educational implications.

One of the first challenges facing a researcher interested in gifted children is to define giftedness in terms that can be operationalized in the investigations that follow. Studies have ranged widely in the definitions and their operationalization. We would like to suggest that rather than being a liability, this diversity may be an asset to the body of literature addressing the role of cognition in giftedness. This chapter will introduce the reader to findings of studies based on differing definitions and explore consistencies and inconsistencies that contribute to our evolving understanding of high ability.

In any attempt such as this, we are necessarily constrained by the persistent problem of defining giftedness. In adults, the cognitive literature has adopted the term "expert" (Ericsson & Smith, 1991), but there is no more agreement about the meaning of "expertise" than "giftedness". We have chosen to work with three operationally defined groups, and to live with the problems resulting from their inequivalence and the possibility that outstanding performance on one of the criteria at a particular stage in one's life is correlated with similar standing on either of the other criteria later at other times. These three groups are of children with high IQs, children who do very well in school, and adult experts.

To understand differences in thinking processes, we must examine children or adults who are exceptional in contrast to others in some recognized way. It is necessary to identify target processes that distinguish types of high performance, and to discover the correlates, predictors and consequences of these processes, with reference to the original variable on which the different groups were identified, and also with other variables. It is very important to take into account that this line of research is intended to produce alternative definitions of giftedness, not merely to embellish existing definitions.

With the very young, this research begins with children who might be described as developmentally advanced in their intellectual functioning. This includes advanced vocabulary, logical reasoning ability, ciphering, and verbal comprehension, among other qualities. It does not much concern us to attempt to define in advance whether we are talking about a "top" group of 1%, 5%, or 50%. Measures of IQ or similar tests directly address such issues, and are widely used in this type of research.

With school-age children and adolescents, some of the research on thinking processes continue to compare children who differ widely in IQ, and some consider scholastic performance. The continued emphasis on IQ reflects its ubiquity in identification procedures within formal "gifted programs" (Alvino, McDonnel, & Richert, 1981; Yarborough & Johnson, 1983)—we do not endorse this, but we merely observe it. The inclusion of children who do extremely well in school should, under ideal circumstances, take into account the nature of the school experience. High grades in a course of study exemplified by rote repetition of the texts or teachers' statements does not define the same kind of intellectual (including creative) performance as high success in an enquiry-based program in which students are investigators in the subject matter (cf. Bruner, 1960). Once again, the underlying thinking processes being equated with giftedness may be very different. On the other hand, if common thinking processes are found among gifted persons defined by a variety of definitions, then this would be especially interesting, and we are proposing in this chapter that such an understanding of high ability is beginning to evolve.

One of the ways the cognitive literature directly addresses high performance in adults is in the form of the discussion of expertise. While there is as much variation and imprecision in the definitions of expertise (Anderson, 1982; Ericsson & Smith, 1991) as there is about giftedness (cf. Maker, 1982; Renzulli, 1986; Sternberg & Davidson, 1986), essentially experts are people with advanced training, competence, and experience in a field. The cognitive literature compares experts in some context with nonexperts typically labeled as novices. The latter are usually adolescents or young adults about to enter a period of training to develop expertise (e.g., medical studies, tournament chess competition, computer programming, electronic or other diagnosis, etc.).

From this perspective we arrived at our three somewhat different working definitions of groups in whom thinking processes are to be studied: children with high IQ (or similar) scores, children who do very well in school, and adults recognized in their domains of activity as experts. As unsatisfactory as this situation may be to a doctrinaire theoretician or psychometrician, we propose that these definitions are educationally very useful. We do not purport that they cover all types of giftedness or any of their components. Education as a nearly universal activity of great social importance cannot wait for theoretically perfect circumstances to gain important understandings of how children and adults think, and how these might ultimately be connected. Working with key concepts based upon cognitive psychology, we and other researchers are discovering that there is much to be learned from the coordinated study of these three groups.

Thinking Processes and Giftedness

Theoretical Context

Three theoretical threads can be traced in current research on thinking processes in the gifted. The first is essentially developmental and is well represented by the works of Bloom (1985), Feldman (1986), Horowitz and O'Brien (1985), and the forthcoming volumes edited by Horowitz and Friedman (in press, a, b). There is a developmental controversy about high ability in school children: Is their superior performance merely precocity (Robinson, 1977; Rogers, 1986; Scruggs & Cohn, 1983), or does it reflect fundamental differences in thinking processes? Each view has direct implications: Accelerate gifted students through existing curriculum in response to precocity, or adapt curriculum (including teaching methods) to take account of differences in thinking processes. Both perspectives have been argued at one time or another, though the movement in this controversy has been increasingly toward understanding differences in thinking processes (Borkowski & Peck, 1986; Carr & Borkowski, 1987; Keating, 1975; Scruggs, Mastropieri, Monson, & Jorgensen, 1985; Shore, 1982; Sternberg, 1985; Webb, 1974). A quantitative alternative to the precocity argument is that gifted individuals are endowed with more of something that distinguishes them, such as denser dendritic structure of brain cells, myelinization, memory capacity, etc. The two are not incompatible, since one addresses function and the other structure. Of course giftedness may emerge as the result of both quantitative and qualitative differences rather than one or the other. Berliner (1986) has bridged these two positions with the interesting suggestion that sustained precocity eventually becomes differences in kind, not merely amount. This hypothesis remains to be tested in the context of cognitive research.

A second important theoretical framework has been offered by Sternberg (1984, 1985). His Triarchic Theory of Intelligence has three main types of information-processing abilities: (a) metacomponents, for planning, monitoring and evaluating thinking, (b) performance components, used to execute tasks, and (c) knowledge-acquisition components, related to achievement. Davidson and Sternberg (1984) presented a subtheory of giftedness in which coping with novelty and automatization of complex tasks are important. Metacomponents were suggested in Flavell's (1976) earlier speculation about the nature of metacognition. With regard to performance components, we had been attracted to the importance of flexibility in problem-solving strategies as a complement to metacognition (Shore, 1982). Starting in the early 1980s, Sternberg and his co-workers began the development of extremely useful theory that permitted links to be made between cognitive processes and giftedness. Our major contribution has been to generate a large and still growing bank of evidence in support of some of the links perceived by both research groups. This theory and evidence link psychometric understanding of abilities and a cognitive approach based on a dynamic understanding of the processes.

The dynamic nature of the processes we are addressing raises the third important theoretical thread which has been emphasized in our work. It is an extension of Vygotsky's (1978, 1986) theory of the development of higher intellectual processes to the study of giftedness. Investigations of the IQ-related and individual differences in what and how children learn has provided evidence that the quantitative–qualitative controversy might better be conceptualized as a rich interaction (Kanevsky, 1990, in press). The combined contributions of the differences may result in spiralling developmental advantage for able learners over their peers. They acquire more knowledge more efficiently, and so on, throughout their lives.

Principal Contributions of Our Studies

In this overview of our contributions (and those of our students) to this topic, we focus on the evolution of our

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studies from replications or extensions of classic laboratory tasks through to studies of classroom learning. This development is partly but not entirely historical. While more of the earlier studies employed laboratory tasks that may be regarded as having less "ecological validity", understanding cognitive processes has required that we vary the designs of our studies across these settings at different times. We have also distinguished between studies that have been published and others which are in progress or recently completed. We have not yet determined if our data point entirely and directly support theories such as Sternberg's and Vygotsky's. There is certainly a great deal of congruence, and the opportunity to theorize about our findings will come soon; a few speculations will be offered later.

We began with studies employing familiar *laboratory tasks* on which individual differences warranted further study. Our results and those obtained by graduate students working with us showed that:

—on a variation of Piaget's conical mountain task in which we used a toy farm scene, gifted preschoolers were less likely to make egocentric errors in perspective taking and were better able to take another's perspective even when the two views partially overlapped (Tarshis & Shore, 1991);

—on a series of puzzles and construction tasks, mothers interacted with more able preschoolers in ways which favored the children's development of metacognitive techniques for monitoring their problem solving (Moss, 1986, 1990);

—on the portable rod-and-frame task in which a bar is to be aligned vertically while framed by a box without additional cues, verbally able teenagers used verbal abilities rather than spatial skills as the task appears to demand (Shore, Hymovitch, & Lajoie, 1982; Shore & Carey, 1984);

—on a highly spatial computer game in which successive operations in a machine shop are emulated in order to produce products from blocks, in addition to being more successful at the task, more able young teenagers also recommended improvements to the game that would have increased the challenge and complexity of the task (Bowen, Shore, & Cartwright, 1992);

—in research on impulsivity (fast, inaccurate performance) and reflectivity (slow, accurate), fast and accurate students are usually a minority and are not discussed; we found that children from an unselected group who were fast and accurate on the measures bore many similarities to students we might describe as gifted (based on IQ) and, further, that accuracy over speed was their distinguishing characteristic (Lajoie & Shore, 1986, 1987);

—high IQ children switched strategies on water–jar combination problems when alternative solutions were valid but not required; metacognition appeared to be higher with more able and accurate students when they were faster, corroborating Lajoie and Shore's advice that it was not necessary for able students to slow down to enhance certain kinds of performance; solution speed decreased on a key trial where an alternative solution was possible but not necessary, suggesting that it may have been considered (Shore & Dover, 1987; Dover & Shore, 1991).

—young high IQ children acquired and generalized a strategy for solving two versions of the Tower of Hanoi puzzle more efficiently than their average IQ peers; in addition, more of the high IQ children spontaneously expressed their recognition of the similarities in the tasks and their preference for achieving a solution without the tutors' aid when they were struggling (Kanevsky, 1990; Kanevsky & Rapagna, 1990).

Work yet to be reported (done with L. Lazar) has shown that:

—on a computerized pattern-recognition task which enabled separate timing of the planning and execution stages, more able subjects devoted a relatively greater proportion of their overall time to the planning stage, and executed the final solution much more rapidly.

The main problem with the above tasks was low "ecological validity". How much of real life is spent solving computer puzzles or doing laboratory style tasks? In addition, prior knowledge is of uncertain importance and it was difficult to examine creative processes.

We then introduced *confirmatory studies* in which the tasks were test materials from school curricula in mathematics and physics, wherein key research has been done on expertise. Our results to date have shown that:

—high performing secondary school physics students exhibited superior metacognitive knowledge and drew more extensively upon their prior knowledge in the subject than students doing less well in the same classes, and the patterns of responses for these better performing students more closely resembled those of experts than average-performing students also included in the study (Coleman & Shore, 1991).

Studies yet to be reported have shown that:

—more able secondary mathematics students will, when unsuccessful in mathematics problems, switch to a second legitimate solution strategy with apparent automaticity, whereas less able students revert, if they change at all, to trial-and-error (a study with C. Kaizer);

—the course of action for such flexibility may be determined very early in the solution process, for example, at the point of categorizing the problem; a study (with S. Pelletier) has shown that high performing secondary mathematics students and graduate students in mathematics spontaneously group and subgroup more problems together than average performing students, evidence that they perceive similarities across problems that are regarded as distinct by others;

—on a computer game based upon determining the pattern in number-series problems, able students more often test explicit hypotheses as part of their solution strategies (a study with M. Godrie).

We are also trying to reach beyond "real" tasks in laboratory settings to the study of *learning over time* *in classrooms* or other settings. This work, recently completed or in progress, has found that:

—faced with the task of giving meaning to unfamiliar or erroneous terms embedded in a text, gifted learning-disabled students' performance and understanding of their own functioning resembled those of gifted children more than learning-disabled children—gifted learning-disabled students are metacognitively strong (see Hannah, 1989, for a preliminary report);

—more able senior high school physics students have more elaborate and inter-related knowledge structures into which new learning is integrated, and specific training in cognitive mapping (such as used by Donald, 1987; Kozma & Roekel, 1986) enhances this process across ability levels (a study with L. Austin).

Possible Theoretical Directions

Ascribing meaning in context, hypothesizing links among complex concepts, proposing enhancements to complex games, and the other processes we have examined involve a degree of creative or productive thinking. Getzels and Csikszentmihalyi (1976) pointed out that creative contributions depend on question asking and problem finding. This may be a useful theoretical perspective to take with these studies. Xenos-Whiston (1989) studied the teachers at our summer laboratory school for gifted students over eight years, and has shown that these exemplary teachers of the gifted are distinguished as a group by being contributors to knowledge (e.g., publishing, artistic production, program development, materials design) and in expecting similar efforts from their students. This supports attention to knowledge production as a curricular element. It is also consistent with Bruner's (1960) admonition not to teach the conclusions of a field, but, instead, the processes by which an expert learns. It also echos Kamii's (1985, 1989) observations of young children's mathematics learning, in which the discovery and invention of the subject is crucial, and peer teaching is the catalyst for learning.

In contrast, the acquisition of basic information is of relatively limited interest in this research, given the populations we are studying—gifted students and experts. It is important not to overemphasize parallels with classic studies in which the target learning is nonsense syllables, paired words, or simple factual knowledge. Nonetheless, Scruggs and Mastropieri (1984) have shown that differences in learning strategies occur between gifted and other secondary school students even with associative learning or the acquisition of factual information.

We have not yet decided what might be the best theoretical context to bring all these elements together. There is certainly great consistency with contemporary cognitive science, but this literature has paid insufficient attention to individual differences. There is also considerable support in our work for important elements of Sternberg's (1985) "triarchic" theory of intelligence and its componential subtheory (1981). Hé (1986) has also offered a conception of giftedness consistent with his theory. Some cognitive theories begin with the thinking processes of experts. They attend to these processes because the outstanding performance of experts is drawn to their attention in some manner. Correspondingly, intelligence theories need to describe and explain outstanding rather than merely commonplace accomplishments and functioning. Some cognitive theories have focused more on the development of cognitive abilities than on the products, for example those of Piaget and Vygotsky.

In addition, theories of intelligence have not been sufficiently integrated with theories of creativity to incorporate what appears to us to be an important element in any suitable theory, namely, knowledge production. Guilford (1967, 1972, 1975) had such an insight, but his work on the "Structure of Intellect" and that of his successors (most notably Meeker, 1969) does not deal adequately with the complexity and breadth of some of the tasks on which we have observed important differences, nor with the time frames on which this performance occurs.

Finally, Vygotsky's theory holds promise for gauging the similarities and differences in the thinking of high and average ability individuals; however, it is a relative newcomer to investigations involving gifted and creative individuals. At this time, its ability to contribute to this discussion is hindered primarily by the limited selection of tasks appropriate for implementation in the contemporary variations of his dynamic assessment methodology.

We expect that a theory which can account for the kinds of performance we are discussing will have to link all these elements: creativity or knowledge production, learning, individual differences, and the nature of expertise. Familiar examples are found in higher education: the occupational imperative for scholars to have original ideas, and the curricular goal for students to ask original questions and attempt to answer them. Research and development enterprises also place great value on knowledge production. Bruner (1960) pointed out the relevance of such efforts at all levels of education. Our goal is to examine learning processes and experiences—including educational experiences—that underlie becoming a knowledge producer.

This builds upon the work completed and that underway as follows:

—research on the thinking processes in relation to the education of gifted children, which suggests that knowledge-production goals are especially appropriate for gifted and creative children (Haensly & Roberts, 1983; Renzulli & Reis, 1985), perhaps for all children in different ways (Bruner, 1960);

—our examination of the relation between professors' research methods and teaching methods, which shows that few undergraduates engage in knowledge production (Shore, Pinker, & Bates, 1990);

—our research and others' demonstrating that in many ways the learning processes of gifted students resemble those of experts in a field different to those of other students—and one of the distinguishing characteristics of experts is their involvement in knowledge production.

How Gifted Children Think Differently

In this section we summarize seven of the principal ways in which the thinking processes of gifted children are different from those of others. We draw upon our own research described above but also upon the broader literature. Portions of this summary are also found in Shore (1991), and the complementary literature has also been summarized by Coleman and Shore (1991).

MEMORY AND THE KNOWLEDGE BASE

Capable students and experts know more, but that is not all. They better know what they know; their existing knowledge is highly interconnected and new knowledge is immediately linked in many ways to prior knowledge (Larkin, McDermott, Simon, & Simon, 1980). This was one of the most important of Krutetskii's observations: Capable students,

> without comparing the "similar", without special exercises or hints from the teacher, independently generalize mathematical objects, relations, and operations "on the spot" . . . (pp. 262–263).

Kanevsky (1990, in press) found this ability in her dynamic analysis of the learning potential of high IQ children as young as four years old. Three prominent cognitive theorists have made related assertions. Ausubel (1968) suggested that what a learner already knows and how it is organized directly affect further learning and memory. Resnick's (1989) cognitive theory of learning further asserts that learners elaborate what they learn and strive to understand it explicitly for the purpose of connecting new knowledge to old. Greeno (1989) and Resnick have suggested that effective memory absolutely requires such placement in content.

Gifted students and experts also know better how to use what they know. In a broad review of the literature, Alexander and Judy (1988) showed that the extent of specific and strategic knowledge interact to favor academic performance. Sternberg (1981) had theorized that gifted students might use their extensive knowledge bases differently from the non-gifted. Coleman and Shore (1991) found supporting evidence: High and average achievers in an advanced high school physics course, plus two physics graduate students and a physics teacher as experts, were asked to think aloud while solving five physics problems. The responses were tape-recorded, then transcribed and divided into clauses (noun–verb segments). These segments were coded in several categories. Experts and high performers made significantly more references to prior knowledge that was not given in the problem, and fewer to information given in the problem. Such use of prior knowledge implies more than its existence; one must also know how and when to use it selectively.

SELF-REGULATORY PROCESSES

Experts monitor and guide their own thinking while they work on a task (Bereiter & Scardamalia, 1987; Glaser, 1985; Paris, Lipson, & Wixon, 1983; Scardamalia & Bereiter, 1985). This process is called metacognition (Flavell, 1976). It has been raised in the gifted literature (Meichenbaum, 1980; Wong, 1982; Woodrum, 1979), and is evident in many of Krutetskii's (1976) reported protocols (see especially his Chapter 13). Sheppard (1992) found that high ability 10- to 12-year-olds were more aware of and able to describe the self-regulation of their thinking while they engaged in a challenging activity after drawing a machine intended to function in a manner similar to that of their mind.

In the previously mentioned study on physics problems, Coleman and Shore (1991) also found significantly more correct evaluations of their own thinking processes by experts and high performers (and fewer incorrect statements indicating metacognitive processes).

SPEED OF THINKING PROCESSES

It is commonly thought that bright students are intellectually faster. The more items one answers correctly on timed tests, such as most IQ tests, the higher one's score. The same is true for most school examinations. Overall solution times on problems are, indeed, shorter for experts, but the expert–novice literature points out that experts take longer pauses while retrieving relevant information to solve a problem (Larkin, 1979), and that they rapidly develop rapid, automatic skill (automaticity) in basic operations (Perfetti & Lesgold, 1979). Davidson and Sternberg (1984) proposed that more intelligent persons spend more time on higher-order planning in problem solving.

Several of our studies illuminate this point. Dover and Shore (1991) used Luchins's (1942, 1951) water–jar combination task with gifted and average 11-year-old pupils—we shall describe the study in more detail below. One of the results was that slower performance accompanied flexibility and metacognition in average subjects, but rapid performance accompanied greater metacognitive knowledge and flexibility in gifted subjects. Lajoie and Shore (1986) showed that accuracy was a more important predictor than speed of overall performance on an IQ test. A further study, as yet unreported (with Lazar), used a computer pattern-recognition task in which the planning and execution stages could be separately timed. Relatively more time was spent by more able students on planning, but much less on reporting the solution.

Problem Representation and Categorization

Experts represent and categorize problems differently from novices (Chi, Glaser, & Rees, 1982; Neigemann & Parr, 1986; Sternberg, 1981; Sternberg & Powell, 1983). Krutetskii (1976, see his chapter 12) clearly identified a period of "information gathering" as an important stage, and showed that able students more readily determine the nature of missing data, their representation of a problem extends beyond the information given, and they better exclude irrelevant information. Scruggs, Mastropieri, Monson, and Jorgensen (1985) reviewed similar processes in the gifted literature.

Kanevsky's (1990) average and high IQ four- to eight-year-olds differed in their spontaneous recognition of the similarity of features of the two versions of the Tower of Hanoi puzzle that they were given as acquisition and generalization tasks. As one would expect, the high ability children more often commented on the commonalities in the rules, apparatus, and strategy. It was suggested that this was due to differences in their understanding or internal representation of the problem that made these commonalities more apparent to them. As a result of this, the group differences in the generalization of the solution strategy is also believed to be partially attributable to differences in the children's problem representations. The high IQ children were also quicker to develop a clear understanding of the task. This was apparent in a distinct drop in their need for assistance two to three trials before their average ability peers. Most high ability children mastered the solution strategy in the two trials after achieving an understanding of the task while the average ability children required from three to eight.

Another study, nearing completion with graduate student S. Pelletier, used adaptations of several of Krutetskii's problems with high and average performing mathematics secondary students. Students were asked to group them into similar types (based on Chi, Glaser, & Rees, 1982). No mention was made of solving the problems. High performing students, like a sample of mathematics graduate students, used fewer levels of categorization, seeing greater common elements among more problems. Such differences during initial categorization of the tasks support the notion of differences in problem representation.

Procedural Knowledge

The cognitive literature distinguishes between declarative and procedural knowledge (Dillon, 1986). Declarative knowledge roughly consists of "what" one knows, and procedural knowledge with how to do things or to use one's knowledge. Experts employ highly elaborated procedures or strategies, sometimes rapidly developed (Glaser, 1985; Heller & Reif, 1984). Krutetskii (1976) described this vividly:

> The trials made by mathematically inept students always bore the character of blind, unmotivated manipulations, chaotic and unsystematic attempts to find a solution (more accurately, they were attempts at guessing, at coming across a solution at random).
>
> Capable pupils, however, were marked by an organized system of searching, subordinated to a definite program or plan. The trials of the capable pupils were always purposeful, systematized attempts, directed toward verifying the assumptions they had made. In making a trial, capable pupils usually realized why it was being made, what was expected, and what was to come next (p. 292).

In another study yet to be reported, with C. Kaizer, conducted with grade eight students, we observed students whose intellectual strengths were either more verbal or visual while they solved mathematical word problems from Krutetskii. When they had difficulty solving a problem, the more able switched to another appropriate strategy. The less able engaged in trial-and-error or guessing. Our study in progress (with M. Godrie) also appears to be confirming the testing of assumptions or hypotheses, as reported by Krutetskii.

Flexibility

Flexibility has many meanings, of which the common feature appears to be the ability to see alternative representations or adopt alternative strategies, especially when it is necessary to make a change for success on a task. Flexibility has been a central concept in some conceptualizations of creativity (Cohen, 1989; Goswami, 1990), in Davidson and Sternberg's (1986) view of the role of insight and adaptation to novelty (also see Davidson, 1986), and in several influential views of special or remedial education (e.g., Feuerstein, Rand, & Rynders, 1988). Krutetskii (see pp. 282–283) also emphasized that flexibility is one of the most important qualities of outstanding performance in mathematics, and it is frequently referred to in general Russian views of abilities. Vygotsky's methodology for the dynamic assessment of learning potential challenges a learner to acquire and to transfer a strategy. Knowledge that can be flexibly applied is of greater interest than inert knowledge. We have to be careful not to say that the less able are incapable of being flexible, since their flexibility may be constrained by their more limited knowledge.

Shore and Carey (1983) selected two groups of teenagers, one high on a verbal subtest of an IQ test (vocabulary), and a second group that was higher on a spatial subtest (block design). All were presented with a spatial task, the rod-and-frame apparatus in which one is asked to recognize the verticality of a rotatable rod against a background which can also be turned so as to distract the viewer. The high-spatial students were "lost for words" to explain their own generally accurate performance. The high-verbal group talked much more while doing the task, using verbally expressed imagery to guide their equally accurate solutions. The high-verbal group appeared to reinterpret the task to suit their strengths. Getzels and Csikszentmihalyi (1976) found that one of the observable qualities of art students who a decade later became successful artists was that they carefully examined a still-life object from many perspectives and reinterpreted the problem; others leapt right into a direct representation.

Dover and Shore's (1991) water–jar study used nine tasks. The first two were practice. Numbers 3 to 6 required three jars. Numbers 7 and 8 could be solved with two or three jars. Number 9 could only be solved with two jars. We found that able students more often successfully broke the "set" at number 9 when they had to switch from using three jars to two, they made fewer errors on all trials (half made none at all), and they were faster on further test trials (numbers 3 to 6) where alternative solutions did not exist, but significant speed differences disappeared on trials 7 and 8 where either two or three jars could be used. Able children replied more often without prompting, and were more aware of how the "set" influenced their thinking strategies; however, they were not more likely to spontaneously offer the alternative solution strategy (using only two jars instead of three) when it was available but not necessary (numbers 7 and 8). This nicely illustrates the importance of examining the process of students' thinking across a task, not just their visible performance or a tally of right and wrong.

Preference for Complexity

Some time before the prominence of cognitive theory as we now know it, creativity researcher Barron (1958) documented how successful creative adults in such professions as architecture and art had greater preference for complexity in drawings and shapes than did an unselected sample. They were also much more tolerant of ambiguity and did not insist upon the tidy resolution of a problem. Today, we might well label his target group as "experts". Two recent studies have linked this preference for complexity to giftedness. Garofalo (in press) has shown that superior secondary mathematics students, whom he describes as meaning-oriented rather than solution-oriented, preferred more complex and demanding problems. Bowen, Shore, and Cartwright (1992) also found that gifted students suggested changes to a computer game that would increase its complexity and challenge.

Experts, gifted and creative people seem to thrive in environments which are rich and active, in which they do not know all the answers, indeed, where right answers to questions are not the principal intellectual commodity. This may well apply to all learners, though their achievements may vary even under such conditions.

When tasks were not found to be sufficiently complex, young, high IQ children attempting to master a Tower of Hanoi solution strategy would introduce some complexity of their own. They would elaborate the story context of the task or make suggestions of ways to make the task more difficult even before the strategy had been acquired.

Of course there is some overlap among these seven ways in which the thinking processes of gifted learners have been observed to differ from those of other people. Flexibility, for example, depends on procedural knowledge, the nature of the knowledge base and problem representation. These differences provide pedagogical clues which may benefit bright children and also help to improve the learning performance of other students. Some of these implications might also make for more interesting lessons and more interesting independent projects. These are hypotheses which could and should be tested in classrooms.

Development of Thinking Processes

Investigations of the lifespan development of thinking processes of gifted individuals do not exist. The research literature is interspersed with comparative studies of thinking, learning, and problem-solving skills, but none is longitudinal in nature. In this section we shall attempt to link our work with young children to other work that describes early evidence for the thinking processes addressed throughout this chapter. This will highlight areas that have potential to explain differences found in the thinking of gifted and non-gifted adults. It must be noted that these are highly speculative and desperately in need of further study.

Field observations made during the Harvard Project (White, 1983), a longitudinal study of two-and-a-half-year-olds, uncovered a number of similarities and differences between talented and average children. No "appreciable differences" were found in sensory skills, perceptual-motor abilities, general motor control, or popularity. The more talented children were, however, able to attract and hold the attention of adults more effectively. They used adults more effectively as resources, made more self-evaluative comments, had "an unusually well-developed capacity to sense discrepancies or differences" (p. 14), dealt well with abstractions, were less egocentric and thus better in perspective-taking activities. They were able to plan and complete more complex tasks and use resources more effectively in doing so. The picture of the differences that emerges appears to be consistent with the research reported earlier in this chapter regarding flexibility, monitoring, and a preference for complexity.

Other advances in our understanding of young children's learning have been facilitated by implementations of modified versions of Vygotsky's (1978) dynamic assessment methodology. One advantage of these procedures when working with young children is that they require the investigator to interact with the child throughout the acquisition and generalization of an intellectual skill, rather than observing passively. Thus we have gained insight into the progressive internalization of social interaction which Vygotsky believed played a critical role in development.

Patterns of early social interaction between high ability preschoolers and their mothers appear to be one of the influences that promote the development of superior thinking abilities (Moss, 1990). In her investigation of dyadic problem solving of non-gifted and gifted preschoolers with their mothers, Moss found a greater proportion of gifted children's and their mothers' comments were metacognitive in nature than that of their average ability peers. These included comments related to checking results, predicting consequences, monitoring and reality testing in nature. The children were perceived to be internalizing the patterns of questioning and problem solving modeled by their mothers. Based on her findings, Moss suggests that direct modeling of metacognitive activities in parent–child play activities offer "scaffolding" experiences that will facilitate the acquisition of a repertoire of higher level thinking skills that can play a key role in classroom competence when a child reaches school age.

Age-related differences in children's learning were also found in Kanevsky's (Kanevsky, 1990; Kanevsky & Rapagna, 1991) study of generalization using the Tower of Hanoi. In addition to applying their learning more flexibly and learning more independently, the seven- and eight-year-old high IQ children seldom repeated a mistake and were more likely to comment spontaneously on the similarity in the strategy used on the various versions of the puzzle than the four- and five-year-old high IQ children. The increased level of their problem-solving skill was also reflected in the decline in the number of planning comments made with increasing age. The latter can be explained within Vygotsky's theory as evidence of the internalization of what was once experienced in social interaction. Planning for this activity had become "inner speech". There was also evidence of an increasing level of intrinsic motivation for learning (Kanevsky, in press). The high ability children, more than their average peers, enjoyed increasing control over the solution. As age increases, so does their collection of learning-to-control-learning skills. Thus, their learning becomes more efficient and their knowledge increases.

To speculate that this trend might continue throughout life has an intuitive appeal when one considers the superior scores able learners earn on achievement tests, intelligence tests, problem-solving assignm nts, and so on. Expert learners are expert thinkers when faced with a novel task. This potential to learn is a life-long advantage which offers accumulating benefits. However, this is only speculation. Current research on learning requires the consideration of influences beyond the cognitive when attempting to explain differences in what and how children learn. These include interest, volition (Corno, 1989), self-efficacy (Schunk, 1989), achievement motivation (Ames, 1992; Elliott & Dweck, 1988), the nature of the interaction (if any) with the investigator or teacher (Zimmerman, 1989), and so on. Therefore, future investigations of the thinking processes of gifted individuals should also acknowledge the roles played by these variables.

Training Thinking Processes

All education is ultimately concerned with thinking skills of one type or another, but we shall limit our discussion of this topic to three issues, and in each of them we shall focus on the kinds of cognitive processes we have discussed: for example, metacognition, flexibility, and planning of responses. We shall not address such approaches as the Meekers' development of Structure of Intellect (SOI) materials (Meeker & Meeker, 1986), or de Bono's (1982) Cognitive Research Trust (CoRT) program. Though these and others have some following in gifted education, neither has been related to the kinds of thinking processes we have described in this chapter.

The three topics we shall address are thinking skills training in general, in special education, and with regard to exceptionally competent performance. We caution that this chapter presents our reflection on a topic for which there is not enough hard evidence to be certain, and it is therefore again highly speculative. Our goal is to provoke reflection on these issues, not to settle them.

Thinking Skills Training in General

The literature on this is small but growing. There is also great divergence of models and types of thinking skills that are presented. Specific training approaches particularly address metacognition (Carns & Carns, 1991; Pesut, 1990), including the use of self-questioning techniques to enhance metacognition (Haller, Child, & Walberg, 1988), and control of transfer (Jelsma, VanMerrinboer, & Bijlstra, 1990), and generally take the form of direct training practice in the skills involved. We earlier mentioned our ongoing research (with L. Austin) that is demonstrating that cognitive mapping (Kozma & Van Roekel, 1986) can be used to enhance the webbing of concepts and high level learning in the classroom. The literature is characterized by optimism that these strategies can be taught and learned, accompanied by suggestions about how to do it (Anderson, 1982; Lochhead & Clement, 1979; Nickerson, Perkins, & Smith, 1985; Peat, Mulcahy, & Darko-Yeboah, 1989; Pressley & Associates, 1990; Segal, Chipman, & Glaser, 1985), but very few studies have addressed the transfer of these skills from the training programs to arms-length classroom learning (Feldman, 1990) or to performance outside the classroom (several unanswered research questions are offered by Chipman, Segal, & Glaser, 1985). There is not universal agreement that these programs work, including observations of the limitations of the evidence available (Sweller, 1990).

It is our impression that the processes and their applications are too general and still too vaguely defined for broad applications to lead to useful specific results. If we accept Piaget's thesis that children must construct their own realities to learn well, expressed in educational terms by Bruner (1960) and Kamii (1985, 1989), then we cannot expect children to learn general thinking strategies out of context and to then apply them to specific learning. There cannot be a process without context or content, a lesson still not learned even by many gifted programs. Every mathematics student learns that operations are performed on something, and what the something is can considerably affect the process.

Teaching metacognition, strategy flexibility, knowledge webbing, or other cognitive skills, needs to be what the cognitive literature calls situated, in context. Perhaps this is not necessarily the case with adults whose knowledge base is already large and more abstract. One of the problems in the cognitive literature from which these ideas have come is that it is a literature of adult (expert) performance, yet the majority of applications have been with children. This is a risky extrapolation, but definitely worthy of study.

Thinking Skills, Special Education and Reading

The greatest amount of research on metacognitive and other thinking training has been in special education and in remedial reading instruction. As we have just suggested, this is an example of extremely broad generalization, from concepts recognized in expert adult performance to underperforming children. This daring application has met with considerable but not universal success.

Metacognitive skills, especially monitoring (Chan & Cole, 1986; Palincsar & Brown, 1984), can considerably improve children's performance. Thinking-skills programs have been extensively used among learning-handicapped students (Larson & Gerber, 1987; Orlando & Bartel, 1989) and in the improvement of reading (Duffy & Roehler, 1987; Duffy et al., 1987; Palincsar, Brown, & Martin, 1987; Paris, Jacobs, & Cross, 1987; Stevens, Madden, Slavin, & Farnisch, 1987). The weight of evidence to date is that cognitively based thinking strategies, especially self-questioning and metacognition, do enhance substandard performance, especially in young adolescents (Haller, Child, & Walberg, 1988), and sometimes dramatically (Feuerstein, Rand, & Rynders, 1988).

Nonetheless there remain cautions in the design and implementation of such programs (Abikoff, 1991; Bettencourt, 1987; DeStefano & Gordon, 1986). The most difficult problem is to be able to generalize from successful applications. How individualized are the interventions, and to what extent is their success related to the general skills being taught or to the nature of the program? There is the risk of an implicit contradiction in a domain of educational activity characterized by individual educational plans (IEPs) and the successful application of highly generalizable teaching strategies. We need to know what the critical ingredients are in each successful case. We especially need to know the limits of such interventions. Case studies have indicated that amazing progress is possible in individual cases, but what can be reasonably expected in large numbers? Do cognitive training programs overcome intellectual deficiencies, do they provide a path around them, or to some extent a combination of the two? Are the newly acquired skills used in the same ways as they are by initially more competent learners and by adult experts? Are they as effectively transferred? Are there individual differences in their applicability?

Thinking Skills and Giftedness

A number of recommended programs for gifted children, especially in North America, include explicit thinking-skills training. Among the most common approaches in gifted programs are SOI (Meeker, 1969; and subsequent materials), Future Problem Solving (Crabbe, 1982), Odyssey of the Mind (Micklus, 1985), numerous applications of Creative Problem Solving (Parnes, 1962), and CoRT (de Bono, 1982; Maier, 1982). We found only one reference to cognitive processes such as we have addressed, in a program for disadvantaged gifted children (Shlomo & Reichenberg, 1990), and others to art education for gifted students (Kay, in press). Kay's work in particular suggests that cognitive skills can be acquired in context with excellent outcomes. Replication in a number of other areas is, however, much needed. An excellent model for assessing the impact of such training in both gifted and general education is provided by Starko's (1988) evaluation of the outcomes of students' involvement in programs designed according to principles recommended by Renzulli (cf. Renzulli & Reis, 1985). She demonstrated positive effects not merely in the training activities, but also in attitudes toward school, insight into personal strengths and weaknesses, career goals, and research skills.

Slightly contrary results were obtained in a study in which the intervention was more constrained than in Starko's observation of the implementation of Renzulli's Type III activities. Average and high ability 10- to 12-year-olds were found to be differentially sensitive to a five-day metacognitive awareness program. On the first day, Sheppard (1992) found the high ability students were more able to create a metaphorical machine that worked as their minds did while they were also engaged in a challenging activity (in this case a hard mathematics problem). Their descriptions of the machine's operation included more steps than those of their average ability peers. By the fourth day, the high

ability students had tired of the machine metaphor and began to invent fictional machines or ignore the machine constraint on their product completely (it seemed as though they changed the task from Type II to Type III). The average ability students were still growing in their ability to find machines and explain the similarities between the machine's operation and their mind's on the fifth day. A more thorough investigation of the effect of awareness training on the outcomes of metacognitive strategy instruction is planned. At this point, it can be said that high ability students are more metacognitively aware before training and, as in other skill domains, they become bored with routine practice.

One of the speculative issues that has attracted our attention is the place of gifted students in the development of adults who later become experts. We have suggested elsewhere (Shore, in press) that experts may be selected for training from the ranks of highly motivated young people who already have acquired a large part of the knowledge and skills that enables them to be recognized by recognized experts as likely to be able to be trained to be like themselves. These people are called novices in the cognitive literature, and the research we have cited suggests that gifted students greatly resemble these novices (not to be confused with total beginners). Shulman (1986), in his discussion of teaching, wrote: "Our central question concerns the transition from expert student to novice teacher" (p. 8). This relativistic use of the term "expert" may be appropriate, since being a student is an occupation that some people definitely master. However, at the point of choice of occupation or application of the rudiments of expertise already acquired, the learner is definitely a novice. We suggest that this developmental issue may be one of the most interesting to pursue in terms of cognitive skills and gifted students, and that it might provide a very useful link between the gifted and cognitive literatures.

Overall Assessment of Training Programs

Some very interesting models have been developed, but they have so far little direct application to programs for highly able students. A lot of work remains to be done in validating the training of cognitive skills among less able students, but the work shows great promise. It is not possible to state clearly at this time that anybody can learn to think like a gifted child or like an adult expert, and that may never come to pass, but an entirely reasonable goal is to enhance the thinking skills of a large number of people to any reasonable degree as a result of studying successful thinking in children and adults. This is clearly an attainable goal. The next task is to present the successes with sufficient precision to be able to better understand the limitations and opportunities of this approach, and thereby to more effectively plan future applications. This has been done is some areas of special education and remedial reading, but not yet in general education.

Part of the problem is that the applications have so far been from successful adult or expert thinking to developing solutions for children with difficulties. One of the great opportunities for links between gifted and general education is to redefine some of these processes in developmental terms, and specifically in terms of the childhood antecedents of expertise. The specification of developmental trajectories for cognitive and metacognitive skills must be pursued before this can be achieved. Are there qualitative differences in the nature of the skills that develop? Do they simply differ in the rate of development? Are other factors at work as expertise develops? These are goals that we shall pursue and look forward to exploring with others, and we begin with the following (and concluding) discussion.

Educational Implications

An important component of educational success is teachers' awareness of how children learn and think. Carpenter, Fennema, Peterson, Chiang, and Loef (1989) showed that a simple week-long workshop intervention which helped teachers understand how children learned mathematics led to noticeable changes in their classroom performance and in their students' learning. If we are going to be able to define appropriate differentiated pedagogy for bright students, then educational researchers and practitioners need to understand if and how these pupils think differently from others. If they merely think more quickly, then we need only teach more quickly. If they merely make fewer errors, then we can shorten the practice and skip some of the review. Precocity and accuracy do not necessarily imply any qualitative difference fundamental to an understanding of intellectual giftedness any more or less than differences in the nature of children's problem representation and the flexibility of their thinking.

In accord with the theoretical directions which we speculated might be taken by this line of research, we are drawn back to an educational implication which we propose may be of over-riding importance, and which may, in somewhat different but equally important ways, apply across ability levels. This is that bright children need, especially need, to be introduced to learning from the point of view of an enquirer, an explorer, a question asker. Bright learners should experience the kind of thinking that leads to new discovery, at every opportunity. There is also little doubt that all children can benefit from such a mindset. They might not benefit to the same degree or in all the same ways, but discovering these differences is one of the challenges of this research.

Discovering the nature of outstanding ability and factors influencing its development should, in general, have benefits for all children.

From this perspective, the challenge in the selection and training of teachers is to ensure that they are independent learners, have experienced and experience making a contribution to knowledge in any valued field of human endeavor, be it artistic or cultural, social, academic, or professional. Shulman (1986, p. 14) explored the nature of teachers' professional knowledge and turned Shaw's rather insulting phrase "He who can, does. He who cannot, teaches" into "Those who can, do. Those who understand, teach". The offending phrase appears only in an appendix to *Man and Superman* (Shaw, 1946/1903, p. 253) in a somewhat tongue-in-cheek handbook for a revolutionary or anarchist. Education is not the only enterprise to suffer his fifteen pages of biting wit.

Studies of highly gifted or high performing individuals (Bloom, 1985; Feldman, 1986) have repeatedly shown "that extraordinary achievement requires recognition, encouragement, and years of hard work" (Gruber & Richard, 1990, p. 148). Parents, teachers, mentors, coaches—they go by many names—are central to this process.

Teachers need to respond to children's interests as primary curriculum guides. There are also some very specific things, derived from the research we have described, that should be validated as important practices, for example:

(1) Help students to make broad connections in memory.

(2) Use knowledge widely in new situations.

(3) Use different learning modes, not always verbal.

(4) Invent new solutions to problems.

(5) Value elegant solutions, not just right answers.

(6) Emphasize planning of response strategies.

(7) Relate new learning to old.

(8) Assessing patterns, relations, missing and redundant information.

(9) Downplay (but do not ignore) low-level functions.

(10) Reinforce and model metacognitive strategies.

(11) Provide diverse tasks that require the application of new learning in different contexts and media in order to promote generalization.

(12) Nurture an awareness of self-regulatory activity.

When learning new material it is possible to summarize the main points and to consider how this new learning is related to previous learning in the same and different subjects, and to general experience. The links, direct or fuzzy, become as important as the points. When students are working on a project or task, they can be asked and ask themselves to assess how their work is proceeding, whether it appears to be leading them to their desired outcome, and whether they wish to reconsider part of the plan they are pursuing (if they have not such a plan, this exercise might help). Students can try to divide their work on tasks into information-gathering and execution stages. They can concentrate on evaluating the quality of their harvest in the first stage before launching into the latter. They can judge if they reached out adequately into the extremes of linked knowledge in order to make the best of their current activity. Are there other suitable strategies, or how would someone with other expertise approach this? When they encounter a difficulty, what adjustments to plans may be useful? Do they sense themselves guessing inappropriately? Can they anticipate what might be the difficult points in a task before beginning it, and be prepared with alternative approaches? Can they benefit from working collaboratively?

Our view has been expressed elsewhere in the literature on general education, and it is interesting how closely it parallels advice available in the gifted literature (cf. Rogers, 1983):

> Indeed, the urgent need to teach thinking skills at all levels of education continues, but we should not rely upon special courses and texts to do the job. Instead, every teacher should create an atmosphere where students are encouraged to read deeply, to question, to engage in divergent thinking, to look for relationships among ideas, and to grapple with real-life issues (Carr, 1988, p. 73).

With these recommendations in mind, the need for a better understanding of the developmental trajectory of cognitive and metacognitive skills becomes critical. Learners will need developmentally appropriate assessments of their performance and feedback in order to optimize their progress.

Might these approaches be well matched to processes that are spontaneously demonstrated by very capable learners? How much would their learning and attitudes toward school improve if this were done? Could other students benefit as well from such elaboration of their curriculum?

These questions have not been answered by research on practices in gifted education (cf. Shore, Cornell, Robinson, & Ward, 1991), and laboratory-style research is not likely to provide full answers. Such research can be done in classrooms with the active collaboration and even leadership of teachers who are interested in the education of capable students. In classrooms, the interactive contributions of cognitive, metacognitive, motivational, emotional, and environmental variables to learning can be considered in concert rather than in isolation. Thus, an integrated understanding of the influences they play in overall development can be constructed. To study them individually is no longer satisfactory.

The research summarized in this chapter has offered evidence of both precocious development and qualitative differences in the content and processes of the thinking of gifted or expert individuals and their less able or experienced peers. It may also be appropriate to resume studies of aptitude–treatment interactions to investigate the differences in the outcomes of gifted and other students who have been provided the same curriculum and instruction.

We have been concerned for a long time that gifted education has been progressively cutting itself off from the mainstream of education by expressing the learners' uniqueness in terms of qualities that appeared to be in conflict with the goals and methods of general education (Shore, Rejskind, & Kanevsky, in press). Attention has been focused on the need for rapid pacing and other acceleration, extended and advanced subject matter. Little attention has been paid to the adjustments that need to be made in methods of learning and teaching to take account of thinking differences, nor to what we can learn from the successes of able students to improve the learning of other students as well. Research on thinking processes may offer the possibility of a benefit to general education through meeting the needs of able students. This may be politically as well as pedagogically important.

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The section of this chapter enumerating examples of thinking processes in gifted children is based in part upon a presentation in Moscow, in June 1991, to the Institute of General and Educational Psychology of the Academy of Pedagogical Sciences. Portions of an abridged version of that talk (Shore, 1991) are included in this chapter with the permission of the journal.

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