The Key to Higher Order Thinking Is Precise Processing

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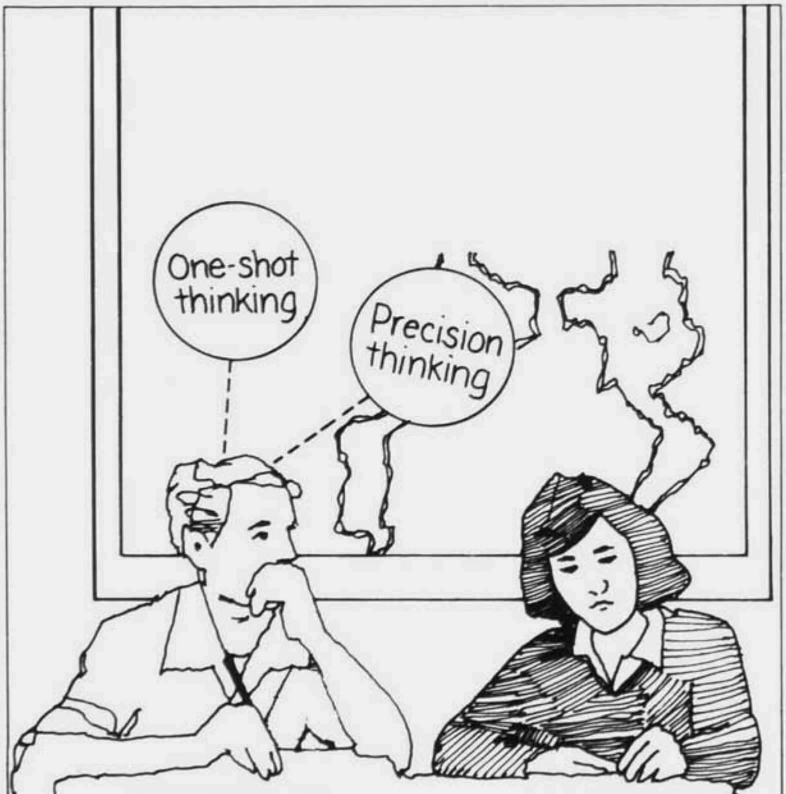

The split that is now developing in the science of teaching thinking skills recapitulates an earlier split in the science of measuring the skills: single vs. multiple factor theories.

The multiple factor approach to teaching thinking has been comprehensively reviewed by Beyer (1984a, 1984b), who noted the plethora of theories and consequent confusion about which skills to teach, and when. Should teaching follow the traditional inductive-deductive reasoning dichotomy, or perhaps the six skills in Bloom's (1956) taxonomy: recall, comprehension, application, analysis, synthesis, and evaluation? Are "problem identification" and "creating novel solutions" thinking skills that should be taught? Beyer suggested the need to pause until research clearly identifies the primary skills of thinking and then focus on three to five skills at each grade level.

But there may be an alternative. Are inductive and deductive reasoning

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Content area teachers can focus on thinking skills by having students describe their mental processes and giving them feedback on erroneous or incomplete reasoning.

really separate mental skills? None of the major test publishers (Educational Testing Service, American College Testing Program) have been able to develop reliable measures to separate these skills for use in differential prediction. How about the skills in Bloom's taxonomy? Not one major instrument for measuring them separately has been devised. The same is true of reading comprehension. Comprehension skills include the ability to understand the main idea, comprehend supporting details, derive literal meaning, make inferences from written material, comprehend serial order, and more. Yet none of the major reading tests (Nelson-Denny, Gates-MacGinitie) provides teachers with a separate score for any of these abilities. Instead, they offer a score for overall comprehension, another for vocabulary knowledge, and occasionally, but with decreasing frequency, a rate score.

The Nature of Human Ability

This failure in test refinement has not been due to a lack of interest or effort in psychometrics—the statistical study of human characteristics. As psychometrics developed in the first half of the century, two schools of thought emerged on the nature of human abilities. Spearman (1927) was spokesman for the single factor theory. After statistically examining correlation matrices from a variety of mental tests, Spearman concluded that one general (g) ability was responsible for performance on most such tests. Spearman regarded "g" as reasoning ability and described it as "educing relationships."

On the other side of the controversy and using somewhat different statistical techniques, Thurstone (1938) decided there were between seven and 12 Primary Mental Abilities, although a number of them were uncorrelated with academic performance.

How have these theories withstood the test of time? Spearman's "g" has divided into two subabilities—verbal and quantitative aptitude—which statistically correspond closely to these Primary Mental Abilities in Thurstone's model that correlated with academic performance (Anastasi, 1968). Moreover, for the major test incorporating measures of both aptitudes— the Scholastic Aptitude Test—the correlation between verbal and quantitative sections is about .7 (CEEB, 1983). This indicates an underlying common ability, which might be called general academic aptitude or reasoning ability, represented by the SAT Total Score.

Thurstone's other Primary Mental Abilities have survived mainly in two areas:

1. *Spatial-perceptual* measures, such as those required by dentists to visualize teeth from different perspectives, which are included on the Dental Admission Test.

2. *Divergent thinking* (or fluency) measures, such as those used by Guilford (1959) and Torrance (1962) to test creativity rather than skills used in mastering and directly applying academic content.

Separate skills (other than verbal-quantitative) have not been isolated for analytical reasoning for, perhaps, two reasons:

1. Some studies point to a general *style* of processing complex information, which underlies most of the individual skills of reasoning postulated in the various theories.

2. Real academic tasks as well as test questions almost always involve a combination of most of the postulated skills of reasoning.

Problem-Solving Styles of High- and Low-Aptitude Students

Bloom and Broder (1950) asked college students with both low and high scores on academic aptitude exams to think aloud while solving reasoning problems so their thinking activities could be monitored. They concluded that each student showed a definite consistency in approaching and solving the various problems. This consistency was of such magnitude that Bloom and Broder regarded it as the student's habitual style of thinking. Furthermore, the habitual problem-solving style of low-aptitude students was characteristically different from the style of high-aptitude students. The cognitive profile of low-aptitude students has two prominent features that are, in a sense, mirror images of each other. First, there is one-shot thinking rather than extended, sequential construction of understanding; and second, there is a willingness to allow gaps of knowledge to exist—in effect, an attitude of indifference toward achieving an accurate and complete comprehension of situations and relationships.

Bloom and Broder observed that low-aptitude students were mentally careless and superficial in solving problems. They spent little time considering a question but chose an answer on the basis of a few clues. Frequently, the selection was founded on simply a feeling, an impression, or a guess. High-aptitude students, by contrast, made a decidedly active attack on problems. When a question was initially unclear, they often employed a lengthy sequential analysis in arriving at an answer. They began with what they understood of the problem, drew on the other information in their possession to further clarify the question, and carefully proceeded through a chain of steps that finally brought them to a solution.

A number of other researchers have reported similar differences between high- and low-aptitude students at various age levels and extending across academic areas (Bereiter and Englemann, 1966; Frankenstein, 1979; Sadler, 1979; Whimbey and Lochhead, 1983). Bloom and Broder described the processing style of low-aptitude students as *one-shot thinking*. A personal example may help in understanding the mind of a one-shot thinker. As a student of the whole-word method of learning reading, I found myself at age 28 still making errors in pronouncing unfamiliar words. The first time I saw "aerobics" I pronounced it "aerobatics." "Magenta" was "magneta." My pronunciations did not come from a systematic analysis of letter combinations and corresponding sounds. Instead, I jumped to a pronunciation that was often based roughly on a familiar similar word, and usually added, omitted, or reversed letter-sound combinations.

When a professional educator told me that the skill I lacked was learnable, I spent several days working through a programmed text in word-attack skills. Then I learned an important lesson about mental skills learning and relearning. For the next three weeks when I encountered an unfamiliar word, my attention would zip across it too quickly, getting the broad outline, and jumping in silent speech to a mispronunciation. I had to train myself to pause at unfamiliar words, to shift from looking at the meaning of the message, and to concentrate on accurate pronunciation. I now compare the way my remedial math and reading students process sentences, paragraphs, and math problems to the way I once processed words. Their attention flies by without picking up the pertinent elements, interpreting them, and combining them accurately.

Inductive/Deductive Reasoning

Turning now to the second reason for the failure to isolate different reasoning skills, does the following problem involve inductive or deductive reasoning? Observe your own thinking processes as you solve it.

A 80 C 79 E 77 G 74 _ _

As you probably observed, solving this problem involves both inductive and deductive reasoning. For example, as part of the solution you may have observed that the first, third, fifth, and seventh positions have letters, and inductively formulated the generalization: all odd-numbered positions have letters. Then you may have employed the following deductive argument:

All odd-numbered positions have letters.
The ninth position is an odd-numbered position.
Therefore, the ninth position must have a letter.

Additionally, you may have compared the first letter with the third to see what change occurred between them, or what operation allowed you to move from one to the other. You then compared the third with the fifth, and continued with inductive and deductive steps until you filled the blanks.

Viewing the problem through Bloom's taxonomy, again a number of skills come into play.

- The series is *analyzed* into numbers and letters.
- The alphabet is *recalled*.
- Pairs of numbers or letters are compared and their relationships *analyzed* to find systematic differences and changes.
- The differences are *synthesized* into general rules for moving from one letter or number to the next.
- The rules (such as, each time increase by one the number subtracted) are *applied* in filling the blanks.
- And the answer is *evaluated* to be sure it is reasonable and without error.

Number/letter series problems are interesting because the particular combination of mental activities used in solving them are similar to those used in much math and science learning. Instead of providing just verbal descriptions, math and science textbook writers often include worked examples of problems. Even with these examples, weaker students do not correctly solve new problems. Notice what is involved when you learn from a worked example. You compare the first step in the example with the second step in order to clearly identify the difference or change between them and the operation required in moving from one to the other. You continue to do this for each pair of steps until you inductively formulate general rules that will work for all problems of this type. Then you deductively apply the rules to any new problems. Students who have trouble inducing and applying the rule underlying the series 80 79 77 74 tend to also have trouble learning from worked examples and, more broadly, analyzing mathematical relationships. This is why number/letter series tests, once regularly employed to measure Thurstone's "inductive reasoning" factor (SRA, 1962), have fallen into disuse. Psychometrically, they are superfluous because their variance is largely predictable from math aptitude tests like the SAT and ACT quantitative sections (Anastasi, 1968).

Since isolating analytical skills is so difficult, let's turn to the question of whether students really need to be taught specific reasoning skills or relationships such as inductive-deductive and cause-effect. T. H. Huxley (1904) explained that the processes of inductive reasoning, deductive reasoning, and cause-effect analysis used by scientists are basically the same as those used by any normal adult.

> There is no more difference, but there is just the same kind of difference, between the mental operations of a man of science and those of an ordinary person, as there is between the operations and methods of a baker or of a butcher weighing out his goods in common scales, and the operations of a chemist in performing a difficult and complex analysis by means of his balance and finely graduated weights. It is not that the action of the scales in the one case, and the balance in the other, differ in the principles of their construction or manner of working; but the beam of one is set on an infinitely finer axis than the other, and of course turns by the addition of a much smaller weight.
>
> There is a well-known incident in one of Molière's plays, where the author makes the hero express unbounded delight on being told that he had been talking prose during the whole of his life. In the same way, I trust, you will take comfort, and be delighted with yourself, on the discovery that you have been acting on the principles of inductive and deductive philosophy during the same period.

Huxley illustrates how an average person would go through a series of discriminations, classifications, inductions, deductions, and hypothesis formulations in determining the culprit in a burglary. He concludes:

> . . . precisely the same mode of reasoning was employed by Newton and Laplace in their endeavors to discover and define the causes of the movements of the heavenly bodies, as you, with your own common sense, would employ to detect a burglar. The only difference is that, the nature of the inquiry being more abstruse, every step has to be most carefully watched, so that there may not be a single crack or flaw in your hypothesis. A flaw or crack in many of the hypotheses of daily life may be of little or no moment as affecting the general correctness of the conclusions at which we may arrive; but, in a scientific inquiry, a fallacy, great or small, is always of importance, and is sure to be in the long run constantly productive of mischievous, if not fatal, results.

Precision of Thought

Huxley, like Bloom and Broder, saw *precise processing* as the key attribute of higher-order thinking. The implication for teaching analytical reasoning in school is that we can often use course material in its natural form, rather than rearrange or restructure academic topics to exercise specific reasoning skills. All we need to modify is our pedagogy, shifting the emphasis to mental processing, with provisions made to observe and provide feedback on the processing. For example, if a student has difficulty following worked examples to solve new problems, a teacher might ask the student to explain the changes or operations occurring between the first and second step of the example, probe with helpful questions when the explanation is incomplete or erroneous, and continue this until the student is able to precisely spell out the series of operations and apply them in solving new problems.

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Because a teacher normally cannot spend this much time with any one student, we have been using Thinking Aloud Pair Problem Solving (TAPS) for helping students learn remedial arithmetic (Whimbey and Lochhead, 1982) as well as advanced topics like probability and computer programming (Whimbey and Lochhead, 1984). Students take turns as problem solver and listener, with the problem solver reading and thinking aloud while analyzing worked examples and new problems.

An introductory chemistry course that focuses on precise processing illustrates another format (Carmichael and Ryan, 1979). To impress upon students the goal of accurate processing, the pass criterion for the weekly mastery quizzes has been set at 90 percent correct, rather than the 70–75 percent frequently used in modularized courses. A student who does not reach this criterion receives cognitive-therapy tutoring by someone trained to elicit vocalized thinking from students as they analyze and solve problems. They learn to carry out logical operations more thoroughly and accurately. As students develop this detail and precision of thought, they change from Huxley's ordinary person to his scientist. Scores on a standardized test of introductory chemistry administered at the end of the semester have jumped a whole standard deviation since the focus on processing was introduced. Other measures suggest long-term effects on reasoning ability.

The fact that course material can be used for teaching analytical reasoning does not preclude the use of special classes to support its development. Since the time that content course instructors can devote to improving precise processing is restricted, enrichment as well as remedial classes for teaching this important skill might be offered to students who need or desire practice beyond that furnished in content courses.

Furthermore, viewing the core of analytical reasoning as precise processing does not mean that materials designed to teach a particular set of thinking skills are any less valuable. Worsham and Austin (1983) have reported that a program based on Albert Upton's model of thinking produced significant gains in SAT scores. The categories of thinking identified in the model—classification, structural analysis, operational analysis, and analogizing—have been useful in generating exercises and in providing guidelines to help weak students analyze the exercises. The same holds for categories of skills in reading comprehension: main idea, supporting detail, chronological order, and so on. Textbook writers and instructors have used these in developing exercises and in providing students with a framework to analyze information (Whimbey, 1983). Moreover, a unit on cause-effect in history—looking just at causes or effects of different events during a particular period—might be very powerful not only in guiding analytical discriminations but also in stimulating "active learning" of history.

Students already know many simple cause-effect relationships and, in fact, use some of them daily. Our primary goal is to help them progress from one-shot thinking toward precise processing, so they can make *refined* analyses of any relationships or situations that may be important to them, now and in the future.☐

References

Anastasi, A. *Psychological Testing*. 3rd ed. New York: Macmillan, 1968.

Bereiter, C., and Englemann, S. *Teaching Disadvantaged Children in the Preschool*. Englewood Cliffs: Prentice-Hall, 1966.

Beyer, B. "Improving Thinking Skills—Defining the Problem." *Phi Delta Kappan* (March 1984): 486–490.

Beyer, B. "Improving Thinking Skills—Practial Approaches." *Phi Delta Kappan* (April 1984): 556–560.

Bloom, B., and Broder, L. *Problem-Solving Processes of College Students*. Chicago: University of Chicago Press, 1950.

Bloom, B., and others. *Taxonomy of Educational Objectives—Handbook I: Cognitive Domain*. New York: David McKay, 1956.

Carmichael, J. W., and Ryan, M. "Cognitive Skills-Oriented PSI in General College Chemistry." Department of Chemistry, Xavier University of New Orleans, 1979.

College Entrance Examination Board. *ATP Guide for High Schools and Colleges*. New York: CEEB, 1983.

Frankenstein, C. *They Think Again*. New York: Van Nostrand, 1979.

Guilford, J. *Personality*. New York: McGraw-Hill, 1959.

Huxley, T. H. "The Method of Scientific Investigation." In *Darwiniana*. New York: Appleton, 1904.

Sadler, W. "Tapping the Potentials of Interdisciplinary Studies in a Freshman Core Program." *Journal of Interdisciplinary Perspectives*. (Fall 1979): 12–19.

Spearman, C. *The Abilities of Man*. New York: Macmillan, 1927.

SRA Primary Mental Abilities. Science Research Associates. Chicago, 1962.

Thurstone, L. "Primary Mental Abilities." *Psychometric Monographs*, no. 1, 1938.

Torrance, E. *Guiding Creative Talent*. Englewood Cliffs: Prentice-Hall, 1962.

Whimbey, A. *Analytical Reading and Reasoning*. Stamford, Conn.: Innovation Sciences, 1983.

Whimbey, A., and Lochhead, J. *Developing Math Skills: Computation and Problem Solving*. New York: McGraw-Hill, 1982.

Whimbey, A., and Lochhead, J. *Problem Solving and Comprehension: A Short Course in Analytical Reasoning*. Philadelphia: Franklin Institute Press, 1983.

Whimbey, A., and Lochhead, J. *Beyond Problem Solving and Comprehension*. Philadelphia: Franklin Institute Press, 1984.

Worsham, A., and Austin, G. "Effects of Teaching Thinking Skills on SAT Scores." *Educational Leadership* 41 (November 1983): 50–51.