The Information-Processing Model of Teaching

訊息運用的教學范例

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From the early centuries educators placed emphasis on the development of intellectual powers as the major aim of education. Cubberley (1923, p. 401) in his book *The Principal and His School* stated that the most improtant elements in good teaching are the development of good habits of study and the ability to do independent thinking. An NEA yearbook (1935, p. 191) proclaimed that "To think, not what to think, is the good curriculm's objective for the child." Whitehead (1929, p. 1) even regarded "the merely well-informed man as the most useless bore on God's earth". Symonds (1936, p. 3) explained that the specified facts and skills which children learn in school will soon be forgotten, but the power to attack problem situations and to reach a correct or reasonable solution is the enduring outcome to be achieved. Although there has been a general feeling among educators regarding the importance of developing powers of thinking, this aim of education is still not fulfilled in many of today's schools. In a nationwide study by the NEA Research Division (1963) on 1.5 million public school teachers, 40.6 per cent of the sample teachers believed that their undergraduate teacher preparation regarding teaching methods was inadequate in terms of their teaching needs, while only 27 per cent of the teachers sampled indicated that too little preparation was received in their subject-matter areas. It would be more interesting to know how many of the rest of the teachers consider their preparation dealing with teaching method for developing intellectual operations to be adequate. In an informal study by Raths, Jonas, Tothstein, and Wassermann (1967), hundreds of teachers indicated that "their college education prepared them most inadequately for appraising and encouraging the processes of thought." Taba (1966) also noticed that in typified classrooms there is really very little effort to stimulate or assist the higher levels of thought.

It is obvious that there is a gap between the major aim of education, emphasizing the development of thinking power and what is known about ways of realizing this aim. The gap even becomes wider when Guilford (1967) predicted 120 intellectual abilities in his Structure of Intellect (SI) model. Despite continuous emphasis on the education of the intellect among top psychologists and educators, the majority of teachers are still using traditional lecturing and testing methods requiring students to give back information through memory. There are some reasons that the teachers are not well prepared by their own education for developing intellectual operations: (1) the lack of a model and a set of strategies to develop intellectual abilities in the classroom situa-

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tion. (2) As Gage (1964) pointed out that learning theories fail to provide direct applicability in teaching situation. (3) To put it more explicitly, by using Guilford's (1967, p. 474) words, "psychology in the past has had too little to offer to the teacher who wants to know about the nature of mental functioning". (4) Even though there are some research and learning theories applicable to the classroom learning situation, they are too conceptual and technical to be communicable to the teachers. A cookbook approach needs to be adopted for writing "recipes" (instructional procedures) of teaching. In other words, there are theories and much talk about developing thinking power, not enough of "know-how". There is a great need for articulating research from theory into application in teaching situation. Besides, an NEA Committee (1963) was so insightful as to foresee the relationship between weak thinking operations and delinquency and recommended that the schools help to combat such serious national problems as youth unemployment and juvenile delinquency by evaluating the intelletual and creative potential of all children and youth in the schools.

The idea in this recommendation concerning juvenile delinquency was coincidentally supported by a study (Kuo, 1967) on creative thinking in delinquents. The delinquents in this study, in comparison with the nondelinquents, were found to be significantly inferior on measures of flexibility, originality, and elaboration. The impoverishment of these three intellectual processes of creative thinking in delinquents suggests that they might not be able to find a way out to solve their problems. This could be one of the reasons for trying a "delinquent way out". From this study on creative thinking in delinquents, it is obvious that the NEA committee was wise to recommend that the instructional program should provide "opportunity for developing the intellectual potentialities represented in the wide range of differences among people". This recommendation needs to bo followed and carried further to develop the intellectual and creative potential of all school children so that they can be better prepared to solve social and national problems, which they will encounter as adults.

The Relation of Past and Current Teaching Models to SI Abilities

Although many cognitive psychologists proposed models of instruction, none of these models dealt specifically with the developing of SI abilities. Bruner (1964, p. 307) considered that the teacher should teach at concept level rather then at fact level. He proposed an instructional model to include four kinds of experience: first, the experience with people, ideas, and things, which predispose the learner towards the new learning, should be specified. Second, the knowledge structure should be organized to adjust to the learner's cognitive structure. Third, the instructional materials should be presented in a logical sequence. Fourth, the nature and pacing of rewards and punishments should also be specified. This model should be considered as a general model of facilitating cognitive learning (using Bloom's taxonomy), but it is still not a model for developing SI abilities. Glaser (1966) has developed a model similar to Bruner's. In the first stage, the instructor should analyze

the "stimulus characteristics" which will elicit the specific kinds of responses from students. Second, the instructor should diagnose the student's current levels of functioning in order to organize his instructional materials accordingly. Third, the sequencing of material and scheduling of reinforcement should be specified. Finally, the student's preformance needs to be assessed according to the instructional objectives. This model does not establish a philosophy to specify what kind of responses need to be elicited.

There are some other models such as Stolurow's and Runkel's Stolurow's (1965) model emphasizes the matching of the instructional objectives and procedures with the student's level of functioning; while Runkel (Gage, 1963) emphasizes patterns of student-instructor interaction in the classroom. Neither of them gears his model to develop intellectual operations. Williams's (1966) model for teaching productive-divergent thinking through subject matter content comes closest to providing for the development of intellectual operations. This model is intended to portary how subject matter content can be arranged or manipulated through multiple classroom teaching strategies in order to produce those various behaviors affecting productive-divergent thinking. Williams's model was the first attempt to combine productive-divergent thinking and subject matter content through teaching strategies. Directly influenced by this approach, the present model broadens Williams's productive-divergent thinking dimension advocating the development of the known intellectual abilities specified in Guilford's (1967, p. 63) "Structure of Intellect."

Points of departure: In searching for some guides to develop a model for developing intellectual abilities in the classroom situation, some published materials on instructional models have been reviewed. Few of these models were specific or cencrete enough for developing SI abilities. Therefore, it is necessary to develop a model for developing intellectual abilities and to translate research findings as well as instructional methods into the functional strategies with operational meaning for teachers, so they can put into practice the step-by-step strategies. The teacher can follow Runkel's and Stolurow's models for planning the total teaching-learning process, but during her teaching process, when she begins to use the subject matter content and wants to develop various intellectual abilities, she needs to use the present model.

The Present Model

Rationale: The present model is an instructional application of Guilford's "Structure of Intellect" and his (Guilford, 1968) informational theory of learning. The philosophical basis of the information-processing model of teaching maintains that the teacher is not to feed information but to develop student's intellectual operations through the use of subject matter contents such as science, social science, etc. The subject matters are not just to be possessed, but to be processed by a variety of intellectual operations. The students are not in school just to learn information, but to use or learn to use what they have learned. The students may relate what they have learned to their own personal meanings, or self-understanding. They can use what

has been learned in solving problems or in creative endeavors. Therefore, this philosophy is in contrast to the concept of education which maintains that the students come to schools only to learn (knowledge). This philosophy is not a passive one advocating the acquisition of knowledge, it is an active and responsible one emphasizing the mastery of subject matter on the one hand, and encouraging the applications of many levels of intellectual operations on the other. Hopefully, as a result of developing intellectual operations on subject matter contents, the students will have a better chance to be creative. It is believed that creativity or creative thinking depends upon all kinds of intellectual operations, not just divergent thinking.

Intellectual operations can be developed. Recent research dealing with the relation between teaching behavior and student thinking indicates that intellectual operations can be developed through classroom teaching and strengthened by certain kinds of practice (Hutchinson, 1964; Schmitt, 1969; Parnes, 1966; Miller, 1963 Taba, Levine, and Elzey, 1964; Bahlke and Freffinger, 1970; Gallagher, 1965). Taba, *et al.*, (1964) especially showed the evidence of the influence of the teacher questioning method on the student's mental operations. Gallagher (1965) reported significant correlations between the type of questions asked by the teacher and the thought processes supplied by the students. Guilford (1967) also cited evidences strongly suggesting that exercise appropriate to each intellectual ability is likely to promote increase in that ability. Since influencing intellectual operations through classroom teaching is possible, we need to develop a set of teaching strategies in order to elicit student intellectual operations on subject matter contents. Teaching strategies, intellectual operations, and subject matter content comprise the triad of teaching. The attempt to put the triad into a single system is the "Information-Processing Model of Teaching.

The Model: The three kinds of classifications of the elements of instruction can be represented by means of a single triangular model, shown in Figure 1.

In this model, each angle represents one of the parameters of problem solving activity. Along the left angles are found various kinds of intellectual operations, along the right ones are the various kinds of subject matter contents, and the top angle is the teaching strategy. This model is intended to portray how one or more than one kind of intellectual operation can be elicited through the use of subject matter content by single or multiple teaching strategies. The triangle itself represents an intellectual ability—the product of intellectual operations on subject matter content. Further examination of each of these angles is necessary for a thorough understanding of this model.

Angle I: *Intellectual Operations.* In this model, Guilford's (1967) five categories of intellectual operations are used. The order of the categories along the upper side of the angle and the length of the base line of each angle have some logical reasons behind them. Let's first use Guilford's reasoning:

"As for operations, cognition is basic to all kinds; hence it appears

first. If no cognition, no memory; if no memory, no production, for the thing produced come largely from memory storage. If neither cognition nor production, then no evaluation."

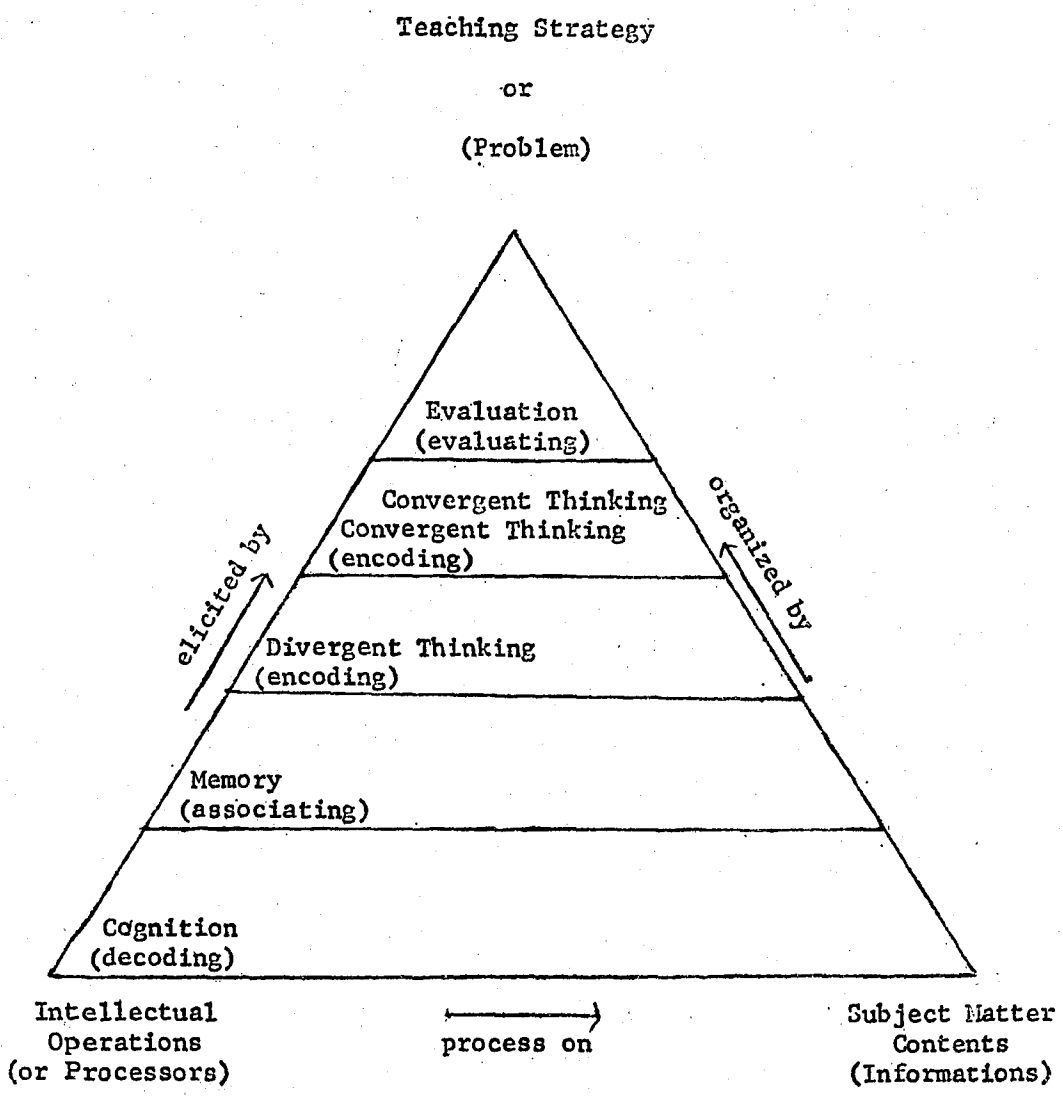

Figure 1

The Information-Processing Model of Teaching

Guilford also considers that there is increasing dependency of one kind of operation upon others. So far as the scope of each operation (represented by the base line of the angle) is concerned, cognition is the broadest and should be used all the time,

therefore, the cognition line is longest; not all the contents which are cognized should be memorized, therefore the memory line should be shorter; not everything which is memorized will be used in divergent thinking, therefore, the line of divergent thinking is shorter than memory. Since the ideas produced from divergent thinking need to be further processed by convergent thinking in order to reach certain conclusions, the line of convergent thinking should be shorter than that for divergent thinking. If several conclusions are reached, evaluative thinking would be used to compare the different conclusions and made a final choice among those conclusions. Therefore, the line of evaluation is the shortest one.

It has been said early that the student are not in school just to learn information, but to use or learn to use what they have learned. To learn information requires the operations of cognition, evaluation, and memory. The use of information requires convergent and divergent thinking. The operations of cognition, memory, divergent thinking, convergent thinking, and evaluation may differ, but the basic function is the same—they all process information. Therefore, they are all information processors. Cognition plays the role of decoding* the input information; memory associating* the material; convergent and divergent thinking encoding* all the necessary data into output; and evaluation may play the role of critical thinking all the way in the information processing process. Since intellectual operations cannot be separated from information, a model for developing intellectual ability can be considered as "an information processing model** of teaching."

Angle II: Subject Matter Contents. The subject matter content represents the input data of a school curriculum. It should not be misequated with *contents* in SI model which only include figural, symbolic, semantic, and behavioral data. The subject matter content to be learned by the student "is in the form of products of information" (Guilford, 1967, p. 271). But the products themselves may be any of the four aspects of *contents* like figural, symbolic, etc. For instance, the encoding and evaluating of figural units differ from those of semantic units; and the processing of figural class is quite different from that of figural implication. Therefore, in using teaching strategies, the subject matter content should first be classified in terms of *content-product* configuration such as figural unit, semantic class, etc. The teacher can follow Meeker's (1969, pp. 115-116) "Decision Flow Charts" for analyzing contents and products.

Although "what is learned is in the form of products of information," the outputs as the result of intellectual operation may not necessarily be the same form as input. The input may be stored in memory (in the same form), or may be reoriented in different forms as a result of a divergent operation. It may be reproduced as a unit,

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* These terms are all adapted after Meeker's book, *The Structure of Intellect, Its Interpretation and Uses.* Columbus, Ohio: Charles E merrill Publishing Co. 1969.

**This term is adapted after Meeker's book, *The Structure of Intellect* (1969),

or classified into a class. Which output the student may produce depends upon the teaching strategy the teacher uses.

In some teaching situations, the teacher can divide the subject matter content into several knowledge units. Each unit may be treated by a special kind of intellectual operation. In some cases, the units can be arranged along the right angle of the model in an ascending hierarchial order as shown in Figure 2, starting with the most simple cognitive operation (e.g., identify some figural units, describe their attributes, etc.) to more complex operations (e.g., select one of the conclusions or recommendations in terms of established standards).

Such a way of relating a specific intellectual operation to a specific input unit results in the planning of teaching strategies to achieve instructional objectives concerning the use of students' intellectual operations. To complete the hierarchies of developing intellectual operations through subject matter content, many instructional objectives and teaching strategies are needed. Each hierarchy is an instructional objective to be achieved. For example, the first one may be cognition of a figural

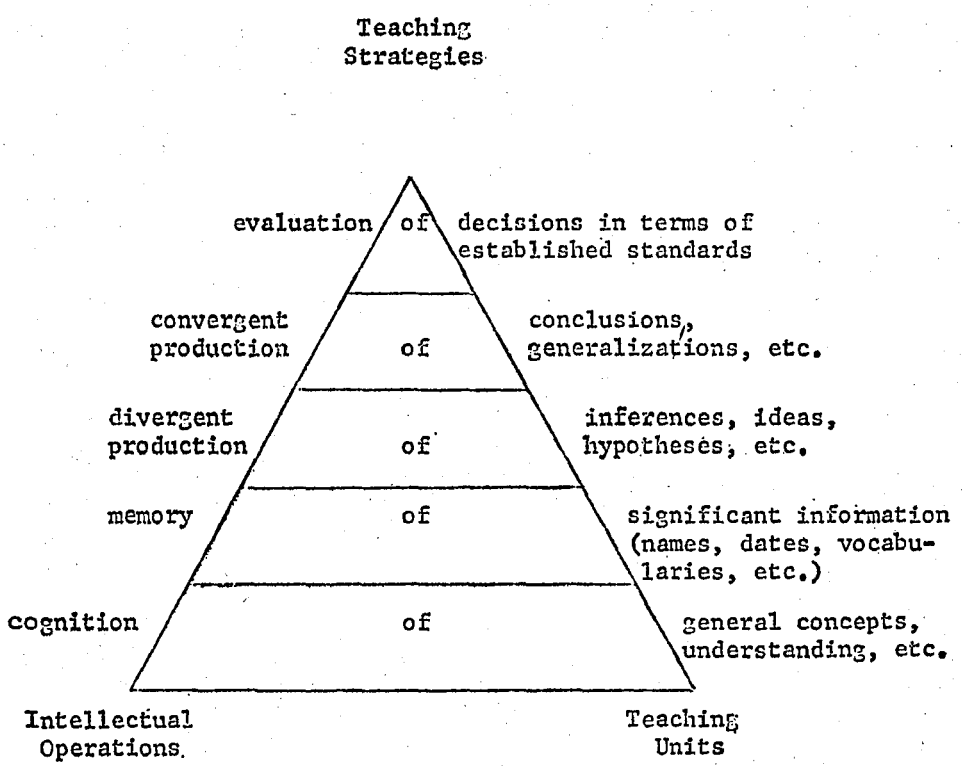


Figure 2

Hierarchical Order of Teaching Units in Relation to Intellectual Operations

unit (or semantic unit) stated as "identify the names of objects presented in pictures". Each instructional objective can use a sub-triangular model to express the triad relations among strategy, intellectual operations, and knowledge unit.

Angle III: *Teaching Strategy*. Teaching strategy is defined as the setting of instructional sequences by the teachers to elicit students' intellectual operations through subject matter contents. Such an approach seems to be too dominating on the teacher's part, but many psychologists and educators express the same view in one way or the other. Bruner (1964, p. 307) considers that the instructional materials should be presented in a logical sequence. Glaser (1966) advocates that the instructor should analyze the "stimulus characteristics" which will elicit the specific kinds of responses from students. His view is more aggressive than Bruner's in its attempt to elicit students' specific responses. But in order to elicit specific responses, a carefully planned teaching strategy with logical instructional sequence is needed. Gagné (1970) has done this in a general way by outlining some conditions for learning each type of learning. Those conditions are actually the sequential procedures to teach each type of learning. In one type of learning, he actually outlined five steps of instructional sequence for teaching rules (Gagné, 1970, p. 203). Both Bruner and Gagné also adovcate discovery learning and creative teaching. The organized and step-by-step approach of teaching does not hinder creativity. Even Rogers (1970) *Freedom to Learn* philiosophy is supposed to foster feeling and facilitate creativity, but his *contract system* can be considered as a well-structured teaching strategy.

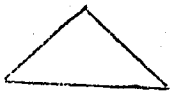
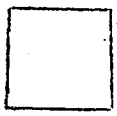
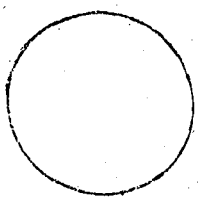
Ausubel (1968) believes that the primary purpose of teaching is to present in some systematic way an organized body of knowledge. The organization should be explicit and given in explicit form to the student. The teaching strategy should not only be able to fulfill Ausubel's idea, but also go beyond it to develop specific intellectual abilities. Central in the strategy is the confrontation of the students with problem situations in the forms of questioning, assignments, discussions, etc., that create a feeling of bafflement resulting in the use of intellectual operation(s) together with "an organized body of knowledge" in order to solve the problem. Outside the class, teaching strategy can be replaced by a problem solving technique. Hence, the present model can also be considered as a model of problem-solving structure with the Angle I remaining the same, Angle II changed to contents, and Angle III changed to problem-solving technique.

A teaching strategy can be designed to elicit one kind of intellectual operation or a combination of several intellectual operations. For example, brainstorming can be used as a teaching strategy to elicit divergent thinking; the classification technique can be used to develop cognition and/or convergent thinking.

In order to show the claimed influence of a teaching strategy, Table 1 is constructed to illustrate the role of strategy in the process of input data. The Table also shows how the same input can be prodessed in different ways through the media of different strategies.

Table 1

Information Processing via Teaching Strategy

Input	Task	Processor	Output
	name, define, explain, etc. (teacher's task) show spelling	cognition in terms of identifying, recognizing, decoding, etc.	cognition of figural units
	ask students to reproduce the figures named by the teacher	memory association recall	memory of figural units
	ask students to judge the figures as being similar or different	evaluation judging	evaluation of figural units
	ask students to classify the figures according to shapes	convergent thinking classifying	convergent production of figural units
	ask students to classify the figures into as many categories as possible	divergent thinking classifying and imagining	divergent production of figural units
			

For simplicity's sake, only a part of the total teaching strategy is used here under the heading of "task". The task is the teacher's if she only wants the student to understand the material. In this case the teacher is active, the student passive. If she wants the student to *use* convergent or divergent thinking, the task is mainly the student's activity.

Teaching Strategies: Past, Present, and Future

About 2,400 years ago, Socrates maintained that the absolute truths were inherent in the soul and the nature of instruction was to guide the student in "recalling"

truths and in associating and relating specific concepts to arrive at the universal truth. Based on this philosophy, he developed a dialectical method of finding out things by question and answer. By using the dialectical strategy, the learner could grasp the logical or consistent relations inherent in the knowledge. "Socrates was not given much to scientific speculation. His foremost interest was with the Good" (Russell, 1951, p. 54). Since he was mainly interested in clarifying some ethical problems by discussion on a face to face basis, his method should be considered as a specific strategy to develop evaluative thinking. His discussion method is time-consuming and reduces the scope of learning if used exclusively.

Despite the celebrity of Socrates' method, teachers have been mainly using the Jesuit method for four centuries. This method emphasizes the acquisition of factual knowledge through recitation and debate, drill and repetition. The strategy of teaching and motivating students is to lecture and discipline. This kind of method can develop cognition, memory, and convergent thinking, but it is not an efficient one to develop divergent and evaluative thinking.

Ausubel (1963, 1967) has developed a cognitive-structure theory of school learning. His (Ausubel, 1968) advance organizer strategies facilitate the understanding and retention of meaningful verbal materials; they are mainly to develop cognition of a semantic system with a side effect on retention. The teaching strategies developed by Taba (1966) only include three cognitive tasks: concept formation, inferring and generalizing, and application of principles. From the information processing model's point of view, Taba's concept formation strategy which includes listing, grouping, and categorizing activities, can train for convergent production of semantic class and/or system. Her inferring and generalizing strategy deals with convergent production of semantic implication. Her "application of principle" strategy deals with divergent production of semantic implication. None of her strategies deal with evaluation and with some encoding of other information such as unit, relation, and transformation. Bruner, Goodnow, and Austin (1956) do have some good strategies for the attainment of concepts, but their strategies of "simultaneous-scanning," "successive-scanning," "conservative-focusing," and "focus-gambling" are regarded by Guilford (1967, p. 276) as a behavioral system. This behavioral system is not yet a formal subject matter content in the elementary and secondary schools.

It should now be clear that some existing teaching strategies only get along with some of the decoding and encoding abilities in SI model where there are many more abilities for which specific teaching strategies are to be developed. Meeker (1969) in her book, *The Structure of Intellect*, has made some curriculum suggestions for developing each kind of known SI ability. The present model suggests that each kind of SI ability needs special kind of subject matter content and strategy to develop it. Future research is needed to design a set of teaching strategies for developing intellectual abilities. If a set of teaching strategies are available to the teachers and are used early in the elementary school, the following implications can be expected:

Developing abilities: Guilford (1959) maintained that within the possible limit of heredity, "The best position for educators to take is that possibly every intellectual factor can be developed in individuals at least to some extent by learning." Guilford's notion has been supported by a number of studies among which Upton's (Samson, 1965, p. 15) experiments are especially interesting. He has demonstrated that training in the meaningful use of words through exercises (they can be considered as strategies in this model) of qualification abstracting, classification, structure analysis, operation analysis, and analogy has increased his students' IQ scores by more than ten points. Hopefully, the application of more strategies will eventually increase children's thinking power.

Adding a new dimension to teacher education: Teaching has been widely considered as a non-technical occupation. The advancement of educational psychology and teaching methods have still not changed the geneal conception that anyone who knows the subject can teach. If teaching processes and considered as explaining and feeding information, an intelligent person specialized in acertain area probably can "teach" some subject matter. But if teaching processes include using selected strategies to develop certain intellectual abilities, future teachers should be well versed in the intellectual development of the children, logic, subject matter content, and teaching strategies. It is anticipated that wide recognition of the importance of using teaching strategies will bring about a new orientation in teacher training. Because of the possible new requirements for the teachers advocated in this study, teaching will become a highly technical occupation, and the teacher will be considered not only as a specialist, but also as a "mental engineer".

Influencing remedial teaching: The strategies designed to develop SI abilities can be used to reduce intellectual deficiencies due to educational deprivation. Knowing which teaching strategies can be used to process a certain kind of subject matter content, the teachers can locate the particular phase of information processing abilities that should be improved and then concentrate on this aspect by using some strategies developing these abilities. For instance, a girl of seven years was diagnosed by this writer by means of the Stanford-Binet Intelligence Scale to have a deficiency in memory of semantic contents, subsequently a remedial reading program was recommended for coaching her verbal comprehension with emphasis on repetition of simple materials beginning at kindergarten level. Various teaching strategies based on different association learning theories were recommended in the drill. Indeed, remedial teaching of this type, especially using Schwartz's (1967, a, b) approach, is already evident in a random fashion in some schools. The availability of a number of logically derived teaching strategies will provide methodological prescriptions to the children who need help.

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訊息運用的教學範例

郭 有 遹

教學的目的在啓發智能（ intellectual abilities ）。這一教育目標已經談之已久，迄今還是停留在紙上談兵的階段。至於如何去實現這一目標，則很少有人認眞地去研究。更少人將實際研究的結果應用在教學上。從基爾福特（ Guilford ）的智慧構造原理可知智慧是應用訊息（ information ）的能力。訊息的本身是一種內容（ content ）也是一種智能的產品（ Product ）。所謂教材（ 如歷史，化學等，術科除外 ）就是內容與產品兼涵的訊息。所以欲啓發智能，必須先透過教材。教師可以應用種種教略（ teaching strategy)以及教材以使學生運用某種智能。這種發展智能的教學範型可以稱爲訊息運用的教學範型。

無論從經驗上或實驗上我們都知道學生在教室中所用的智能深受教師的教略所影響。若是教師要求學生背誦，學生必須運用記憶。若是教師要求學生將一些物品或單字分成三類或數類，每一物品或單字不能同時屬於二類，學生必須運用會通思考 （ convergent thinking ） 。若是要求學生盡量分門別類，門類越多越好，則學生必須用分殊性的思考（ divergent thinking ）。所以爲了發展智能，教師必須設計一些教學步驟，藉教材以啓發學生智能。這種步驟本文稱之爲教略。基爾福特在理論上推測有120 種智能（ 實際上已發現有96種 ）。每一種智能至少須用一種教略。因此我們至少必須設計120 種教略方可啓發全面的智能。除此之外，我們還可設計一些教略以啓發一個以上的智能。

教略的設計必須根據現有的學習理論與實驗。否則由個人所設計的教略必須經過實證之後方可確定是否可以啓發所預定的智能。舉例言之，何修貝爾（ Ausubel ）著名的「概念組織法」（ advance organizer ）可用以發展認知力與記憶力。腦轟法（ brainstorming ）可用以發展分殊思考。教師只須應用實驗上認爲有效的思考法或教學法，然後根據基爾福特對各智能的定義予以分類，即可確定某種思考法或教學法對某種智能的關係。本文只在提出設計啓發智能教略所應根據的教學範型。至於整套教略的設計與實驗，尙有待教育界的共同努力方可有成。

若是教師有一整套教略可以運用，則會產生以下數種影響：(一)可以全面發展智能。何普吞（ Upton ）曾經訓練大學新生應用分類法（ classification ）。結果這些新生的智力平均增加十分之多。分類法只是許多所可設計的教略中之一種。若是教師從低年級開始有系統地應用教略。兒童的智力必可大幅地增加。(二)教育心理學家可以根據智力診斷的結果將有問題的智能予以隔離，然後選擇適當的教略予以訓練。(三)師範教育必須訓練教師應用教略以啓發思考。教師從此成爲啓智工程師，教學遂成爲一種技術性的職業，非一般學者或退休人員所可勝任。由此，教師的地位就可提高。