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CATEGORIES OF COGNITIVE SKILLS.

BY- FOSTER, HARRIET

CALIFORNIA UNIV., LOS ANGELES

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CERTAIN SYSTEMS FOR CLASSIFYING COGNITIVE FUNCTIONS ARE REVIEWED AND COMPARED IN A DISCUSSION OF GENERALIZING PROCESSES USED FOR EVALUATING INSTRUCTIONAL OUTCOMES. THE AUTHOR STATES THAT THERE ARE TWO IMPORTANT GENERALIZATIONS TO BE MADE IN THE EVALUATION OF INSTRUCTIONAL PROGRAMS--GENERALIZING THE PROGRAM RESULTS AND THE SKILLS OF THE PARTICIPATING STUDENT. BOTH GENERALIZATIONS REQUIRE A SYSTEMATIC DESCRIPTION OR TAXONOMY OF TASKS. THE DESCRIPTION MUST IDENTIFY GENERAL CATEGORIES OF SKILLS, AS WELL AS TASK DIMENSIONS WHICH MAY AFFECT THE QUALITY OF TASK PERFORMANCE. TO IDENTIFY TASK DIMENSIONS, THE EVALUATOR MUST CLASSIFY THE BASIC COGNITIVE SKILLS PERTINENT TO HIS RESEARCH. SOME EXISTING CLASSIFICATION SYSTEMS ARE BASED ON TASK ANALYSIS, EMPHASIZE TASK CHARACTERISTICS, AND ARE USED TO IDENTIFY PSYCHOLOGICAL AND/OR EDUCATIONAL PROCESSES. OTHERS, SUCH AS GUILFORD'S "STRUCTURE OF INTELLECT" (1959), ARE BASED ON FACTOR ANALYSIS, EMPHASIZE PERFORMANCE OF HUMAN SUBJECTS, AND INDICATE HOW VARIOUS TASKS (OR TESTS) CLUSTER. THE AUTHOR SUGGESTS THAT SUCH SYSTEMS SHOULD BE AS COMPREHENSIVE AS POSSIBLE SO ANY NUMBER OF COGNITIVE FUNCTIONS COULD BE FIT INTO THE SYSTEM FOR CONSIDERATION. COMPREHENSIVENESS WOULD ALLOW ALL TASKS TO BE CLASSIFIED UNAMBIGUOUSLY IN TERMS WHICH ARE PSYCHOLOGICALLY MEANINGFUL. THE AUTHOR ALSO SUGGESTS THAT GUILFORD'S MODEL IS PROBABLY THE MOST SYSTEMATIC AND INCLUSIVE OF CURRENT CLASSIFICATION SYSTEMS AND USES IT AS A FOCUS FOR COMPARING OTHER ANALYSES OF COGNITIVE PROCESSES. FOLLOWING THE ANALYSES OF POSSIBLE TYPES OF COGNITIVE PROCESSES, A DISCUSSION WAS PRESENTED OF THE STEPS NECESSARY TO CONSTRUCT A SCALE WHICH (1) WILL MEASURE PROCESS GENERALIZATION OVER DIFFERENT CONTENTS OR WITH DIFFERENT TASKS AND (2) WILL BE A SCALE ALONG WHICH EMPIRICAL RESULTS CAN BE GENERALIZED. (JH)

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CATEGORIES OF COGNITIVE SKILLS

Center FOR THE
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The CENTER FOR THE STUDY OF EVALUATION OF INSTRUCTIONAL PROGRAMS is engaged in research that will yield new ideas and new tools capable of analyzing and evaluating instruction. Staff members are creating new ways to evaluate content of curricula, methods of teaching and the multiple effects of both on students. The CENTER is unique because of its access to Southern California's elementary, secondary and higher schools of diverse socio-economic levels and cultural backgrounds. Three major aspects of the program are

> <u>Instructional Variables</u> - Research in this area will be concerned with identifying and evaluating the effects of instructional variables, and with the development of conceptual models, learning theory and theory of instruction. The research involves the experimental study of the effects of differences in instruction as they may interact with individual differences among students.
>
> <u>Contextual Variables</u> - Research in this area will be concerned with measuring and evaluating differences in community and school environments and the interactions of both with instructional programs. It will also involve evaluating variations in student and teacher characteristics and administrative organization.
>
> <u>Criterion Measures</u> - Research in this field is concerned with creating a new conceptualization of evaluation of instruction and in developing new instruments to evaluate knowledge acquired in school by measuring observable changes in cognitive, affective and physiological behavior. It will also involve evaluating the cost-effectiveness of instructional programs.

CATEGORIES OF COGNITIVE SKILLS

Harriet Foster

University of California, Los Angeles, Working Paper No. 1, Nov., 1966

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By Harriet Foster

Two quite different forms of generalization are important in evaluating instructional outcomes. On the one hand, any evaluation study, if it is to be of value, must be generalizable to new situations. Generalization of a seemingly very different sort is of interest as one of the objectives of instruction---the development of generalizable skills on the part of the student. Generalizable results on the one hand; generalizable skills on the other. Different as these two types of generalizations appear to be, both seem to require a systematic description or taxonomy of tasks. Such a description must eventually go beyond general categories of skills---the description must identify task dimensions which may affect the quality of task performance.

The identification of task variables or dimensions when related to generalizable skills would be used as the basis for measures of transfer or generalization. The objective would be to identify task dimensions which are relevant to the occurrence of transfer from one task to another and those which are not. Hopefully, not only the occurrence or non-occurrence of

transfer but the degree of transfer as well will show a systematic relationship with task dimensions. The emphasis here, as contrasted with much of the past experimental work on transfer, is on the process as a general skill rather than on similarity of content. This is similar to the emphasis on understanding as a basis for transfer, something which was of primary concern to Katona (1940).

The identification of task dimensions when related to the generalization of research findings would be used to specify what classes of performance would be expected to show the same results. For example, would it be valid to generalize an effect observed with a problem in formal logic to a similar (in some specified way) problem in mathematics or to problems of detecting logical fallacies in propoganda?

The eventual use of task dimensions in the construction of test or evaluation measures on the one hand, and as a basis for generalizing research findings, on the other hand, must be determined by experimental studies designed to determine the significance of particular task variables to the two problems. The experiments would differ, depending upon which form of generalization was under consideration. If both forms of generalization were to be investigated in relation to the same task variables, a commonality might be found which would con-

tribute to both functions and to an understanding of the cognitive skill under study.

As a first step in such an undertaking, one needs to select one or several apparently basic cognitive skills for study. The present paper is devoted primarily to a review of some of the classification systems already in existence which may suggest some of the basic processes worth considering. The various classification systems have been developed for different purposes. Some have been developed as the result of a kind of task analysis intended to identify psychological processes, either as preparation for experimental studies of these processes (e.g., Bruner, Goodnow, & Austin, 1956) or as a way of organizing research findings (e.g., Gagné, 1959). The taxonomy developed by Bloom, et. al. (1956) is another analysis of cognitive tasks but oriented more toward educational objectives than toward psychological research. Guilford's model (1959), on the other hand, is based on performance data indicating how various tasks (i.e., tests) cluster. Classifications based on task analyses and on performance data are both valuable. Task analyses emphasize identifiable task characteristics. Factor analyses emphasize performance characteristics of human subjects.

Descriptions of Cognitive Processes

There are probably as many systems for classifying the

different cognitive processes as there are authors writing about them. Part of the difference between systems may occur because the universe of behaviors with which the investigators are concerned differs. For example, the analysis may be concerned with "problem solving," "thinking," "decision-making," "concept formation," or may be limited by some context such as "education" or by available tests of skills, as in factor analysis. The differences in classification systems are probably also affected by bias or theoretical point of view of the writer and by the purpose for which the system is devised.

A classification system can be judged only in terms of its intended purpose. The present writer feels there is a need for cognitive processes to be classified in a way which is comprehensive (so that any particular task can be fitted into the system), in terms which describe identifiable task characteristics so the tasks can be classified unambiguously, but in terms which are also meaningful psychologically.

It is obvious that the comprehensiveness of the system depends upon the extensiveness with which tasks, behaviors, or processes are considered. Probably any such system will be incomplete, but one can continue to expand it as new cases are considered.

Description in terms of task characteristics may be determined to some extent by inspection. However, one may find that, when trying to fit specific tasks into the scheme, the task dimensions must be described differently. For example, a general description of problem solving as an information processing task involving a given amount of uncertainty may have no application to a concrete or realistic task.

For a system to be meaningful psychologically or, more specifically, behaviorally, it requires experimental testing to determine the relatedness of different performances.

Any initial categorization, then, must be tentative for several reasons, of which two are quite important. First, each new specific task which is considered will have some unique feature which may or may not require a revision of the classification system for unambiguous classification. Secondly, the relatedness of tasks can only be determined experimentally.

It would seem that a review of the systems already developed for one purpose or another would be the best starting point for a useful and significant task classification system. Perhaps the most systematic and most inclusive of these classification systems is the "structure of intellect" proposed by Guilford (1959). It will be used here as a focus for comparing other analyses of cognitive processes.

Guilford's structure of intellect proposes three major dimensions of tasks: operations, products, and content. The "operations" dimension represents the major concern here. It is a classification system for cognitive processes. The content dimension is one across which one might expect to test generalization--that is, if there is psychological significance to the process or operations categories, one would expect some systematic effects across different contents, though possibly only within major content categories.

This writer finds the products dimension the most difficult to interpret. In general, the categories within the products dimension appear to differ in their level of complexity. Thus there are units, classes, relations, and systems as four products categories. However, this writer feels some confusion concerning the products categories of transformation and implication: although they may be products, it is sometimes difficult to distinguish them from operations.

The categories within the three major dimensions are really defined by the tests which load on each factor. They will be used in this discussion more as a convenient means of distinguishing or comparing processes than as precisely defined factors. It might be remembered, too, that had other tests been used in the factor analyses, the factors would

probably have looked somewhat different. There is nothing absolute or final about these particular factors.

Guilford identifies five operations: cognitive, memory, divergent thinking, convergent thinking, and evaluation. The cognitive factor or category within the operations dimension appears, for the most part, to concern the utilization of previous learning. However, the cognitive tests related to the different product categories seem to vary tremendously in complexity--from identifying familiar silhouettes with parts missing at the "units" product level to tests of general reasoning at the "systems" level. The cognitive process related to implications, Guilford suggests, might involve extrapolation or going beyond the information. The distinction between these higher order or more complex cognitive products and some of the complex convergent products is somewhat obscure to this writer.

Learning, as a process or operation, does not appear to be included, at least in simple form (e.g., paired associates learning or rote learning), in Guilford's structure of intellect. The facts or knowledge acquired and application of such knowledge are, however, included. The memory factor in Guilford's structure appears to be related primarily to a kind of short-term memory, being loaded on such tests as

memory span. Knowledge in a broader sense appears to be more related to the cognitive category. For example, tests of vocabulary are included in this category.

The cognitive operation appears to involve the understanding or utilization of information in unchanged form---that is, in the form in which it was originally presented or learned. The processes identified by other investigators which would appear to fall within Guilford's cognitive category are comprehension (Bloom, _et. al._, 1956), application (Bloom, _et. al._, 1956), reception of stimulus (Gagné, 1959), acquisition of information (Bruner, 1965), gaining information from the stimulus (Hunt, 1962), assimilation (Piaget, as reviewed by Berlyne, 1957), understanding (Duncan, 1959), becoming aware of a problem (Thorndike, 1950), a concrete attitude (Goldstein & Scheerer, 1941; Heidbreder, 1947, 1948; Johnson, 1962), perceptual search (Shipstone, 1960), recognition (Hunt, 1962), discrimination (Garner, 1962), and possibly interpretation (Watson & Glaser, 1952). Some of these processes, however, such as "comprehension," "understanding," "interpretation," and "application" could conceivably be tested under circumstances which might require something new to be added or some change to be made.

Divergent and convergent thinking both appear to involve

some change in the information being made by the responder, examinee, or learner. Divergent thinking appears to involve, in information terms, increased uncertainty. The subject sees possibilities or alternatives not immediately apparent, or not apparent to the average subject. The tests included in Guilford's analysis include tests which are believed to measure flexibility and originality (See Educational Testing Service Kit, 1963, for test illustrations). The formulation of hypotheses (Gagne, 1966; Bruner, Goodnow and Austin, 1956; Thorndike, 1950; Hunt, 1962, Shipstone, 1960), formulation of models, strategies, courses of action, programs, plans (Bruner, Goodnow and Austin, 1956; Goldstein and Scheerer, 1941, Hunt, 1962; Newell, Shaw and Simon, 1958; Shipstone, 1960), searching the memory for expressions which may be helpful (Newell, Shaw and Simon, 1958), insight into multiple possibilities of choice (Hanfmann and Kasanin, 1937), "conceptual span" (Shipstone, 1960), the invention part of inventive concept formation (Leeter, 1951), and flexibility of approach as contrasted to set, rigidity, or "centering" (Duncker, 1945; Goldstein and Scheerer, 1941; Duncan, 1959; Berlyne, 1957) are examples of divergent thinking as described by various other investigators. Probably analysis (Bloom, *et. al.*, 1956), breaking the whole into parts (Goldstein and

Scheerer, 1941), and recognition of assumptions (Watson and Glaser, 1952) should also be included as examples of divergent thinking.

Where divergent thinking introduces more uncertainty, convergent thinking appears to be a process of reducing uncertainty. This is accomplished by combining information from various sources. The process of abstraction and the process of concept attainment or concept formation, as they represent a kind of summary of what is common to a number of diverse experiences, or the selection of a portion of characteristics out of many, seem to be examples of convergent thinking. Through this process, experiences are combined, redundancies are recognized, and uncertainty is reduced. Concept attainment or concept formation has been the object of much research and, probably in part because of this writer's bias, is a description used by many of the investigators surveyed (Bruner, Goodnow and Austin, 1956; Gagné, 1959; Hunt, 1962; Vinacke, 1951; Garner, 1962; Heidbreder, 1947, 1948; Johnson, 1962; Hovland, 1952; Leeper, 1951). Other related behaviors or descriptions include classification (Gagné, 1966; Hanfmann and Kasanin, 1937), integration and organization (Duncan, 1959), "resonance" and "precipitation of common elements" (Duncker, 1945), and inference (Gagné, 1966;

Watson and Glaser, 1952). Deduction (Watson and Glaser, 1952; Shipstone, 1960; Leeper, 1951) and various sub-processes (Newell, Shaw and Simon, 1958) and the solving part of problem solving also appear to be types of convergent thinking. Some forms of deduction which involve simple substitutions of one expression for another and not the combination of information should perhaps be categorized as cognitive rather than convergent thinking. Thorndike (1950) speaks of reasoning out implications. There might be times when this involves simple substitutions and thus belongs in the cognitive category but probably most of the time it will involve both convergent thinking and divergent thinking.

Memory is not always identified specifically as a factor, however, there is no doubt that the writers surveyed would recognize its importance. Those writers dealing with computer models of problem solving (Newell, Shaw and Simon, 1958; Hunt, 1962), certainly find memory to be a necessary function and make clear two aspects of memory: storage of information and search and retrieval of information in storage. Garner (1962) has suggested that there is not only a difference between discrimination (cognitive) and free recall (memory) processes but that they are quite differently affected by different forms of redundancy of information. References to

knowledge (e.g., Bloom, et. al., 1956), and experience (e.g., Thorndike, 1950) may fall in the category of memory, though they are also closely related to the cognitive process.

The last operations category in Guilford's structure is evaluation. It is a process mentioned, under one name or another, by almost all writers surveyed. Evaluation is identified as a process by Bruner (1965), Bloom, et. al. (1956), and Hunt (1962). The evaluation of arguments is one of the subtests on the Watson and Glaser Critical Thinking Appraisal (1952). Other writers mention the testing of hypotheses (Thorndike, 1950; Shipstone, 1960) and others make some mention of consistent or inconsistent classifications or concepts (Hanfmann and Kasanin, 1937; Vinacke, 1951), which could be thought of as a basis for evaluation. Decision-making (e.g., Gagné, 1959), as it has come to be defined in psychological studies, may be said to be concerned with evaluation; but, like a number of other kinds of behaviors (such as concept formation, probability learning, thinking, problem solving), probably involves nearly all of the operations categories in various mixtures.

It must be admitted that, although many of the different processes which have been proposed by writers seem to fit fairly well in one of Guilford's operations categories or another,

few if any are pure examples of one process. Factor analysis, of course, does not even suggest that the factors are completely independent. It is useful, in trying to deal with such complex processes, to try to identify the different processes. However, one should also perhaps consider a kind of "executive program" which integrates the different processes. The formation of plans or strategies ("executive programs") was mentioned earlier as probably being largely a divergent thinking example. The thinker then may evaluate and utilize these strategies he formulates and program his own sub-routines or operations.

On the products side, it was suggested earlier that at least four of the six products categories named by Guilford (1959) appear to form a scale of complexity--from units to classes to relations to systems. The suggestion of a hierarchical organization of behavior goes back at least to the studies of Bryan and Harter (1897, 1899) on telegraphy. The Bryan and Harter studies suggested that the learning of complex skills proceeds step-fashion, each step involving the organization of larger units---from letters to words to groups of words.

Miller's (1956) concept of chunking suggests hierarchical organization in the reception and processing of information.

The span of immediate memory apparently can be increased by recoding the input into another code with fewer chunks but more bits per chunk. The chunks can be thought of as a higher level of organization than the bits of information or units of which they are composed. If the observer is able to chunk, he may then operate on the chunks rather than the individual bits of information.

Bruner's (1965) use of the term structure emphasizes the importance of the organization of knowledge. The understanding of the structure or general principles is often a basis for transfer. The structure is also important in remembering details otherwise too numerous to store in memory. Structure, as the term is used by Bruner, appears to be most similar to Guilford's (1959) systems category of products. Structure seems to imply units and classes organized into a system or structure.

A hierarchical arrangement of skills in the learning process has been emphasized by Gagné and Paradise (1961). These authors analyzed the skill of solving algebraic equations. The analysis resulted in a hierarchy of eight levels of skills, where each level depended on the integration of skills at lower levels. Learning data supported the analysis.

Hierarchies, organizations, or systems of processes or of concepts have also been discussed by many other writers (e.g.,

Bloom, et. al., 1956; Newell, Shaw and Simon, 1958; Berlyne, 1957; Hanfmann and Kasanin, 1937; Goldstein and Scheerer, 1941; Vinacke, 1951; Johnson, 1962). Strategies (Bruner, Goodnow and Austin, 1956), programs (Newell, Shaw and Simon, 1958; Hunt, 1962), and plans (Goldstein and Scheerer, 1941), can also be thought of as higher order or complex hypotheses.

A hierarchical scale or a scale of complexity, then, appears to be a necessary or, at least, a very useful dimension for describing cognitive tasks. This writer finds some difficulty in including transformation and implication in such a scale. For the time being, no attempt will be made to fit these "products" into any dimension.

In studies of problem solving or concept formation, very little attention appears to have been given to Guilford's third dimension, content. Generally, in research on processes or operations, the basic assumption seems to be that the particular content with which a process deals is irrelevant to the operation, so long as the degree of learning, or the subjects' familiarity or understanding of the material, is controlled. The major exception to such an assumption appears to be across content categories.

Guilford distinguishes four content categories: figural, symbolic, semantic, and behavioral. He says little about the

behavioral category, and it will not be considered here.

Bruner, Goodnow and Austin (1956) compared concept attainment with "abstract" as contrasted with "thematic" materials. The abstract materials consisted of abstract visual figures, varying in color, shape, number of figures, etc. The "thematic" materials consisted of drawings of human figures, varying in age, sex, dress, etc. Concept attainment was less systematic and generally more difficult with the thematic materials.

A study by Wilkins (as reported in Woodworth, 1938) found that the correct solution of syllogisms occurred more often with concrete content (words used as terms) than with abstract content (letters used as terms). In Guilford's content categories, words would probably fall in the semantic category and letters in the symbolic category. The Bruner, Goodnow and Austin (1956) distinction between abstract and thematic content does not correspond as clearly to any of Guilford's distinctions.

The implication of these studies seems to be that generalizing research findings across content categories is of questionable validity.

Studies of transfer or of the generalization of learning appear to have concentrated on generalization with content

categories (transfer based on similarity of content) (e.g., Osgood, 1949; Gagné, Baker, and Foster, 1950) or transfer across complexity levels (transfer of components or transfer resulting from the integration of components) (e.g., Gagné and Foster, 1949; Gagné and Paradise, 1961). However, there is also evidence that transfer of processes or strategies can occur where content is quite dissimilar. Harlow's (1949) study of "learning sets" in monkeys shows that monkeys can learn a kind of problem-solving strategy which can operate in spite of content changes. The elementary science program described by Gagné (1966) is another example of an emphasis on the transfer of processes with dissimilar contents.

It must be kept in mind, however, that transfer or generalization does not occur automatically with the occurrence of certain kinds of similarity in content or process. It is easy sometimes in research findings to overlook the extent of individual differences in transfer. Teachers are probably much more frequently aware of individual variations in transfer. One of the most clear-cut contrasts in the ability to abstract (an aspect of transfer) is the contrast between "normal" and brain-injured subjects (Goldstein and Scheerer, 1941). The difference in performance between these two groups suggests that generalization or transfer itself may be a general

process or skill.

This discussion has been concerned with an analysis of possible types of cognitive processes. The question remains whether a scale can be constructed which will measure process generalizatior over different contents or with different tasks and a scale along which empirical results can be generalized. The preceding descriptions of processes are felt to be the first step in the development of such generalization scales. A second step is to consider a variety of concrete tasks (or tests) and to categorize them in terms of the processes which they appear to require. The selection or construction of cognitive tasks should be a continuing process. Although one cannot ever consider all possible tasks, he can continue to add to those already considered.

When specific tasks are considered in relation to Guilford's structure, it becomes apparent that most tasks involve more than one process. However, they appear to differ in their mixtures of processes and in the predominance of various processes, so that clusters of tasks appear as a result of the armchair analysis.

What remains to be done (in addition to the continual elaboration and revision of the task description) is to evaluate the task description procedure experimentally. The

experimental questions are: (1) to what extent does an experimental finding, using one specific task, apply to another task which differs in specified ways from the first task--- or, put another way, what are the critical task characteristics for valid generalization of findings? And (2) what are the task characteristics which distinguish and order tasks in the degree of generalization of process which learners show from one task to another?

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