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ABSTRACT

In this essay, research done on concept learning is discussed. The study analyzes concept learning as one form of learning, formulating guidelines for teaching concepts, and describes the abilities underlying the attainment of concepts. An analytical model is presented; various operations such as concrete concepts and identity concepts are described. Cognitive functions such as acquiring appropriate labels, remembering, and attending are discussed. Then, concept utilization and extension are discussed. The essay concludes with a consideration of the uses of the model just presented. (Author/JW)

COGNITIVE OPERATIONS IN CONCEPT LEARNING

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For the past decade, teams of graduate students and research scientists have been engaged in research on concept learning in laboratory and school settings. In 1961 we started studying strategies of concept attainment. Since 1966 we have been working on three interests simultaneously: to analyze concept learning as one of the forms of learning, to formulate guidelines for teaching concepts, and to describe the abilities underlying the attainment of concepts. Our primary methods in studying concept learning, the theme of this paper, are task analysis as described by Gagné (1968) and multivariate hypothesis-testing experiments. We carry out cross-sectional studies of the kind described by Olver and Hornsby (1966) in order to understand the developmental changes associated with concept learning. Factor analytic studies are run to identify and sort concept-attainment abilities.

To focus the research efforts on concept learning and also to bring closure to the cumulating results, in 1968 I formulated a descriptive model of the cognitive operations involved in attaining knowledge about concepts of varying levels of inclusiveness and abstractness. At about the same time, procedures for analyzing concepts and a paradigm for assessing the level of mastery of concepts (Frayer, Fredrick, & Klausmeier, 1969) were formulated. These procedures and the paradigm are used systematically in task analysis and in designing both the independent variables and the dependent measures in our controlled experiments on concept learning. With continuing assistance from research scientists, Dorothy Frayer and Elizabeth Schwenn Ghatala, the model has been refined to the point outlined in this paper.

A glance at Figure 1 provides an overview of the four parts of the model. Four levels in the attainment of the same concept at successively higher levels of inclusiveness and abstractness are outlined. The four successive levels are concrete, identity, rudimentary classificatory, and formal. The relationships among these four levels merit brief attention.

Attaining each higher level concept successively is postulated to be the normative pattern for large numbers of English-speaking individuals under two conditions. First, the concept is of the kind for which there are actual perceptible instances, and second, the individual has experiences with the instances starting in early childhood. For example, the individual will have successively formed a concrete, identity, and rudimentary concept of dog before he describes and treats "dog" formally in terms of its defining attributes.

Children have direct experiences during preschool years with many things and attain concepts of these things at the first two levels. They also attain many rudimentary classificatory concepts and the societally accepted names for the concepts and their attributes through formal and informal instruction.

It is clear, however, that not all concepts have perceptible instances; for example, the chemical elements and signed numbers. Also, when the attributes of a concept are well known and only a few instances are encountered, the individual may attain a formal concept without forming a rudimentary concept. It should also be noted that the mature person, although capable of attaining a formal concept, may attain only one of the lower level concepts and stop at that level because of the way in which the perceptible instances are encountered and other conditions of learning.

A second part of Figure 1 shows the ways that concepts may be used and extended. Both rudimentary classificatory concepts and formal concepts may be generalized to newly encountered instances. In addition, a formal concept may also be related to other concepts and may be used in problem-solving situations.

Third, Figure 1 indicates the operations involved in attaining each level of concept. Attending to and discriminating objects and then remembering what was discriminated are involved in attaining a concrete concept. The same operations are also involved at each subsequent level and are supplemented with the higher-level operations of generalizing, hypothesizing, and evaluating.

Although the same operations are postulated to occur at various levels, what is operated on changes with the attainment of the successively higher-level concepts. That is, the operations are carried out on more sharply differentiated and abstracted stimulus properties at the four successive levels.

It is to make clear the nature of the operations that the model includes the successive concept levels. It is easy to underestimate the importance of this. For, in the experimental psychological literature, the tendency is yet to describe concept learning only as the learning of concepts where the perceptible instances are present. Further, the dependent measure typically involves only the identification of positive instances. Consequently most experimental literature deals with the learning of a very narrow band of concepts and at a very minimum level of mastery.

A paper by Kagan (1966) stimulated me to give more attention to the levels while analyzing the operations. In his paper, Kagan stated that an individual's conceptual development passes through different stages which are characterized by qualitatively different structures, not by the mere accretion of more or richer concepts. The changes in the structures from infancy through adolescence were described in terms of cognitive units and cognitive processes. The processes were indicated as labeling, hypothesizing, evaluating, and transformation.

The fourth part of the model shows that acquiring and remembering the names of the concepts may come at any of the four levels. The solid line indicates that having the name of the concept and the names of attributes is essential to attaining formal concepts. The broken lines indicate that an individual may acquire the name at about the same time he first attains the conce[illegible] but [illegible] is not requisite. For example, older children and adults may acquire the lowest level concrete or identity concepts and almost simultaneously the names. However, a young child might attain all three lower level concepts but not have the names. The younger the child is when attaining the concept, the less likely he is to have the name for it.

As will be inferred by noting the citations throughout the paper, most of the experiments conducted by the students and scientists working directly with me deal with the attainment of formal concepts. We have also carried out a few studies dealing with rudimentary classificatory concepts with elementary school children. The empirical information pertaining to concrete and identity concepts and also to the uses of concepts is drawn from other sources. Thus, information from many sources was used in formulating this analytical model.

OPERATIONS RELATED TO LEVELS OF CONCEPT ATTAINMENT

Having considered the overall features of the model, we may take up the operations in more detail, starting with those pertaining to concrete concepts.

Concrete Concepts

Attainment of a concrete concept is inferred when the individual cognizes an object that he has experienced on a prior occasion. The first step in attaining a concrete concept is attending to an object and representing it internally. Woodruff (1961) points out that:

> All learning begins with some form of personal contact with actual objects, events, or circumstances.... The individual gives attention to some object.... Through a light wave, or a sou wave, or some form of direct contact with a sensory organ in the body, an impression is picked up and lodged in the mind. (p. 66)

Gagne (1970) indicates that as the individual attends to an object he discriminates it from other objects. Woodruff (1961) calls the outcome of these attending and discriminating operations a concrete concept, a mental image of some real object experienced directly by the sense organs. The infant, for example, attends to a large red ball and a white plastic bottle, discriminates each one on a non-analytic perceptual basis, maintains an internal representation of each, and cognizes each of the objects when experienced later.

The discrimination of objects often involves attending to distinctive features that serve to distinguish them from one another. Thus, very early, the child learns to respond to gross differences in such features of objects as size, shape, color, and texture. As the child matures he becomes capable of making finer discriminations involving these and other features. The attainment of a concrete concept thus requires attending to perceptible features of an object and forming a memory image which represents the object as a unique, global bundle of features. The attainment of a concrete concept does not require having a name for the object.

The preceding analysis of the operations in attaining concrete concepts is sufficiently comprehensive to include motoric experiencing of objects. That is, an object may be manipulated physically and <u>represented enactively</u>, as well as to be seen and <u>represented ikonically</u>, to use the Bruner (1964) terminology. The model postulates that attending, discriminating, and remembering are involved in motor as well as in perceptual experiences with objects, or sensorimotor experiencing, to use the term of Inhelder and Piaget (1958).

The young infant is capable only of attaining concrete concepts. Although this is the case, the maturing individual continues to manipulate objects and to see, hear, smell, and the like. Thus, these forms of experiencing are applicable to the attainment of identity and rudimentary classificatory concepts and also to the attainment of formal concepts of the kind for which there are actual instances with intrinsic attributes.

Identity Concepts

An identity concept is inferred when the individual cognizes an object as the same one previously encountered when observed from a different perspective or sensed in a different modality, such as hearing or seeing. For example, the child's making the same response to the family poodle when seen from straight ahead, from the side, and from various angles is evidence of his having attained an identity concept of poodle. Whereas the attainment of a concrete concept involves only the discrimination of an object from other objects, the attainment of an identity concept involves both discriminating various forms of the same object from other objects and also generalizing the forms as equivalent.

The generalizing of various forms of the same object as being identical is central in Piaget's formulations. According to Elkind (1969) Piaget's conception of concept emphasizes the variability that goes on within things, that is, the changes in state, form, and appearance that can occur to any entity. Piaget postulated the principles of identity and conservation, identity being concerned with maintaining in thought the likeness or sameness of the same thing and conservation being concerned with maintaining the likeness or sameness of the same thing in experience. An individual's concept of dog, for example, presumes that an individual dog will retain its "dogness" both in the internal representation and in the direct experiences of the individual with the dog. Without this permance both in the mental construct and in the actual instance of the specific dog, the individual's criteria for recognizing a dog, or dogs, would shift from moment to moment.

Elkind pointed out further that American psychologists have tended to ignore this within-instance variability of concepts and have emphasized the discriminative response aspect of concept attainment by which positive instances are cognized and noninstances are discriminated. Elkind (1969, p. 187) summarized the two points of view thus: "From the discriminative response point of view, the major function of the concept is the recognition or classification of exemplars. The Piagetian conception, however, assumes that a major function of the concept is the discrimination between the apparent and the real. This discrimination, in turn, can be reduced to the differentiation of between- and within-things types of variability. Here again, a comprehensive conception of a concept must include both functions because, in fact, every concept does serve both purposes."

The present model proposes that an identity concept of a specific object is typically formed before a class concept that includes two or more instances. Stated differently, various forms of the same object are generalized as equivalent before two different objects of the same class are. For example, the individual must be able to cognize various forms of a particular dog as equivalent before he is able to form a classificatory concept of dog, involving two or more different dogs.

Rudimentary Classificatory Concepts

The formation of a rudimentary classificatory concept is inferred when the individual responds to at least two different instances of the same class as equivalent even though he cannot name the attributes common to them. For example, when the child treats the family's toy poodle and the neighbor's miniature poodle as poodles but cannot name the attributes of poodles, he has formed a rudimentary classificatory concept. Deese (1967), like many other researchers, notes that individuals can group things together that are equivalent in some way without being able to describe the basis of the grouping. As shown in Figure 1, the attainment of a rudimentary classificatory concept, under the conditions noted earlier, involves all of the operations in the formation of identity concepts and in addition generalizing that two or more objects are equivalent in some way.

Formal Concepts

A high-level formal concept is inferred when the individual with normal language development can accurately designate certain objects or events as belonging to the same set and others as not belonging to the set, can give the name of the concept, and can name its intrinsic or societally accepted defining attributes. For example, the maturing child demonstrates a formal concept of dog if, when shown dogs, cats, and rabbits of various sizes and shapes and other animals of various sizes and shapes, he properly designates the dogs as such, calls them dogs, and names the attributes that differentiate dogs from the other animals. There is not a sharp demarcation between a rudimentary classificatory concept and a formal concept in terms of identifying precisely when the change occurs for the individual. The three distinctions made here are that in the case of formal concepts some or all of the defining attributes can be discriminated, the attributes can be named, and the concept can be named. The more attributes that can be discriminated and named, the more complete is the concept.

The operations involved in the learning of formal concepts are shown in Figure 2. These operations occur when the individual infers the defining attributes by examining instances of the concept; they do not hold when the individual is told the defining attributes, as will be discussed later. The operations are inferred primarily from experiments using college-age subjects and Bruner-type materials.

Several of the early Wisconsin studies, starting with Byers (1961), used Bruner-type materials.

<u>Discriminating and naming the intrinsic or societally accepted attributes</u>. The first operation in learning a formal concept is discriminating and labeling the attributes of the concept instances. Our experiments do not establish directly that the operation is essential to the attainment of formal concepts. However, four studies completed at the Wisconsin R & D Center and reported by Kalish (1966), Lynch (1966), Fredrick and Klausmeier (1968), and Klausmeier and Meinke (1968) have shown that instructions making explicit the attributes that define the concept population do facilitate subsequent concept attainment.

<u>Hypothesizing the concept</u>. Having discriminated and named the attributes, a concept may be inferred in either of the two ways shown in Figure 2. One way involves testing hypotheses and the other involves cognizing the common attributes in positive instances.

Levine (1963) defined an hypothesis as the subject's prediction of the correct basis for responding to the experimental task. In connection with learning formal concepts this is equivalent to the subject's prediction of the attributes that define the concept to be attained. Levine (1967) showed that the subject samples from a set of hypotheses and responds on the basis of the hypotheses sampled. If the experimenter tells the subject that his hypothesis is "wrong," the subject abandons the hypothesis and resamples from his remaining pool of hypotheses. Further, prior to the last error, the correct hypothesis is never sampled whereas following the last error the correct hypothesis is held.

Klausmeier, Harris, Davis, Schwenn, and Frayer (1968) summarized three experiments on hypothesizing conducted at the R & D Center.

Hypothesizing behaviors similar to those observed by Levine were noted. In these experiments, it was observed additionally that the relative salience of the attributes, the attribute that was relevant during the warm-up phase, and learning sets involving the relevant attributes affected the students' hypothesizing behaviors.

Remembering hypotheses. Remembering hypotheses is essential for the eventual inferring of a concept. A recent model of concept learning by Williams (1971), which treats the memory of hypotheses explicitly, assumes two memory stores: a decision store for information as to which attributes the subject has tested and rejected and a short-term buffer store for selected stimulus information. These stores are interrelated since information in the decision store determines which stimulus information the subject will select to enter into the buffer, and the stimulus information in the buffer is used to develop and evaluate a new hypothesis when the current hypothesis is shown to be incorrect.

In a review of the theory and research on the role of memory in concept learning, Ghatala (1971b) points out that focusing and scanning strategies can be viewed as control processes which determine, among other things, the size and contents of the focus sample of attributes which the subject selects to enter into his short-term stimulus information store.

Evaluating hypotheses. Evaluating whether an hypothesis is correct is essential to the eventual inferring of a concept. Bruner, Goodnow, and Austin (1956) indicate that an individual determines whether or not his hypothesized concept is valid by recourse to an ultimate criterion, test by consistency, test by consensus, or test by affective congruence. Inherent in all four procedures is establishing a criterion for judging the correctness of an hypothesis. In our experiments, instructions to the subjects which included a decision rule to evaluate hypotheses facilitated their attainment of concepts.

Cognizing common attributes in positive instances of the concept. The operations just discussed characterize individuals who cognize the information potentially available to them from both positive and negative instances. These individuals apparently reason like this: Instance 1 has land surrounded by water. It is a member of the class. Instance 2 has land but is not surrounded by water. It is not a member of the class. Therefore, lands surrounded by water belong to the class and lands not surrounded by water do not. Surrounded by water is a defining attribute of the concept. This individual has properly classified, based on experiences with only one positive and one negative instance of the concept.

According to Tagatz (1967), elementary school children up to about age 12 do not carry out this kind of logical thought well. Instead, they identify the attributes that are common to the positive instances of the concept. In arriving at this conclusion, Tagatz instructed fifth- and sixth-graders to use either a conservative focusing strategy or a commonality strategy in attaining concepts. Large differences in performance following instructions were found, favoring the commonality strategy. Also, in the course of attaining a series of concepts, one-half of the subjects instructed in the conservative focusing strategy shifted to the commonality strategy but none shifted from the commonality strategy to the conservative focusing strategy. Thus, two quite different sets of operations are involved in attaining formal concepts—one entailing the formulation of hypotheses and testing the hypotheses against information contained in positive and negative instances, the other cognizing the attributes common to the positive instances.

Acquiring Appropriate Labels

The importance of language in concept learning is widely acknowledged by American (Bruner, 1964) and Russian psychologists (Vygotsky, 1962). For having the labels of concepts enables the individual to think in symbols rather than in images and also to attain other concepts through language experiences in the absence of perceptible instances. Carroll (1964) outlined the close relationships among concepts, meanings, and words. Experiments by Carey and Goss (1957), Goss and Moylan (1958), Fredrick and Klausmeier (1968), and Rasmussen and Archer (196_) show that having the name of the concept or of the attribute facilitates concept attainment.

The purpose here is not to deal with the relationships between language learning and concept learning but to show at what points labels may be learned and associated with the various levels of concept.

Figure 1 indicates that a concept label may be associated with the concept at any of the four levels of concept formation--concrete, identity, rudimentary classificatory, or formal. American children who have somewhat similar sensory experiences and instruction regarding certain concepts might manifest a sequence like this. A young child first encounters a dog. The child's mother points to the dog and says "dog." The child then says "dog," and associates the name with his concrete concept of the dog. Next, the child develops an identity concept of the same dog through experiencing it in different locations and situations. His mother repeats the name at various times in the presence of the dog; the child says the word repeatedly. The word "dog" now comes to represent the child's identity concept of the dog. Subsequently, the child encounters other dogs and observes that they, too, are called "dogs." He generalizes the different dogs as equivalent and associates the name "dog" with whatever similarities he has noted. The word thus comes to represent the rudimentary class of things called "dogs." At the next level, the more mature child discriminates the intrinsic or societally accepted attributes of the class of things called dogs and also learns the names of the attributes. Now the child's concept of dog and the societally accepted definition of the word dog become alike. As Carroll (1964) points out, the concepts held by individuals and the meanings of the words representing the concepts held by the same individuals are much alike for individuals who share similar cultural experiences and the same language.

Attending and Remembering

Only a brief mention has been made of attending and remembering thus far. Ghatala (1971a) recently reviewed the literature dealing with attention in concept learning. That attending to environmental phenomena is requisite for subsequent discrimination of elements in the environment has long been accepted. However, only recently have experiments been conducted that explain why an individual attends to certain elements and not others and also how he organizes what he attends to. Related to the organization of perception, Kagan, Moss, and Sigel (1963) described global and analytic cognitive styles. Research reported by Fredrick (1968) and by Davis and Klausmeier (1970) shows that the cognitive styles of school age subjects, the salience of the attributes in a stimulus display, and orienting instructions do affect attentional responses of school-age subjects in concept attainment tasks.

Concerning memory, Atkinson and Shiffrin (1968) postulate three memory systems--a long-term store, a short-term store, and a sensory information register. The structural properties of each system (e.g., capacity, rate of decay of information stored in the system) along with the control processes (e.g., c ding procedures, rehearsal operations) selected and regulated by the individual determine the flow of information between the memory systems. There is ample evidence that in adults the predominate mode of information storage in both the short- and long-term systems is the verbal-linguistic mode. However, other modes of storage must be possible since adults have the capability of recognizing smells, tastes, and visual stimuli which have not been verbally encoded. Also, a non-linguistic store is presumed essential for preverbal children to learn concrete, identity, and rudimentary class concepts. Bruner (1964) discusses this as the enactive and ikonic representation of sensory experience.

As mentioned earlier, in attaining formal concepts, the individual may store stimulus information as well as decisions regarding past hypotheses. The short-term storage of stimulus information has been shown to be particularly important under conditions where prior instances are no longer physically available as in experiments where the successive method of presentation is used. Miller and Davis (1968) who conducted a series of three experiments found that, upon completing a concept identification task, individuals could recall much specific information about each instance.

Thus there is widespread acceptance that memory for sensory information by young children is essential for the attainment of concrete, identity, and rudimentary class concepts and that the learning of formal concepts from verbal and nonverbal instances requires memory for both specific stimulus information and hypotheses.

CONCEPT UTILIZATION AND EXTENSION

The individual who has formed a concept may use and extend it as shown in Figure 1. Rudimentary concepts can be used and extended in generalizing to new instances while formal concepts can be used and extended in generalizing to new instances, cognizing superordinate-subordinate relations, cognizing various contingency relations among concepts, and generalizing to problem-solving situations.

No research was found that reported how a concept is extended simultaneously with use. Therefore only a few premises are offered regarding the extension of knowledge about an already formed concept. It is presumed that any use of a concept which may involve a change in the context in which the concept is used, in the attributes of the specific instance encountered, and in the operations performed may also extend one's knowledge of the concept. For example, when the native Canadian encounters for the first time various flowers and deciduous trees in January in a South American country, his concepts of flower and deciduous tree may be extended by observation of further variations of the attributes of these concept. Similarly, when the experimental psychologist first puts to use his conception of concept when preparing instructional materials for six-year-olds, his conception of concept may be extended by noting the ways in which the children's concepts and operations differ from his psychological model of concept learning. The operations to be discussed regarding use of the concept are presumed to be involved also in extending knowledge about the concept.

Generalizing to New Instances of the Same Concept

Concept learning reduces the need for constant learning and relearning, primarily because the individual is able to generalize to new instances of a concept. One test of concept learning in our experiments is the individual's ability to properly categorize instances not previously encountered as instances or non-instances of the particular concept. We find that both school children and college-age students generalize to new instances readily; however, errors are sometimes made.

Markle and Tiemann (1969) identify the three kinds of errors made by students as overgeneralization, undergeneralization, and misconception. They further indicate that the way to avoid the over- and under-generalization errors is through the proper use of positive and negative instances during instruction so that the student learns both the concept and its defining attributes.

Cognizing Superordinate-Coordinate Relationships

Besides generalizing to new instances, individuals can also use their concepts in cognizing relationships among classes of things as coordinate, superordinate, and subordinate. According to Kofsky (1966) cognizing a superordinate-subordinate relation among a small set of items increases as a function of age, with about 29 percent of children at age four and 90 percent at age nine cognizing that the number of the members in the superordinate class is equal to the number in the two subordinate classes that form the superordinate.

Cognizing Relationships Involving Cause and Effect, Correlation, and Other Contingencies

Cognizing inclusiveness relations involving superordinate and subordinate concepts is treated as different from cognizing relations involving cause and effect and other contingency relations. Though postulating that the two sets of relations are different, what all the contingency relations might be cannot be specified at this time. However, there is some agreement among psychologists that concepts are used, and possibly extended, in understanding relationships of the kind embodied in statements of principles.

Generalizing to Problem-Solving Situations

Gagne (1970) indicates that concepts are essential for rule learning and that rules are essential for problem-solving. Woodruff (1967) discusses in detail the role of concepts in higher-level mental activities, including problem solving. Again, there is some agreement that concepts generalize to problem-solving situations; however, we have not yet done research that specifies the role of concepts in problem solving.

A brief comparison of all the operations discussed thus far may be made with Gagne's ideas about learning hierarchies. In his presidential address to Division 15, Gagne (1968) postulated that it is the attainment of intellectual skills that permits vertical transfer to increasingly complex learning tasks, rather than entities of verbalizable knowledge as he had specified at an earlier time (Gagne, 1965). This paper supports his 1968 position regarding hierarchies. It is unions of operations and contents that produce positive transfer to the successive levels of concept attainment and then to the use of the concepts in forming principles and in problem solving. I prefer to call the union of an operation and a content an ability rather than a skill (Klausmeier & Ripple, 1971).

A NOTE ON THE LEARNING OF CONCEPTS FROM BEING TOLD

It is well to note that the model does not exclude the learning of concepts from being told. There is agreement with Ausubel and Robinson (1969) that many formal concepts are learned by upper elementary, high school, and college students through being given the names of concepts, descriptions and names of examples, and the concept definitions without direct experience with actual instances of the concepts. Experiments at Wisconsin (Frayer, 1969; Scott, 1970) have been completed using printed text materials in which variables are manipulated, such as the number of examples and nonexamples, the use of verbal definitions of the words representing the concepts, and uses and extensions of the concept in forming principles and in solving problems. The model shown in Figure 1 is considered appropriate to this didactic method of presentation. For, although told the concept name and attributes, the individual still must discriminate the attributes and evaluate instances against the defining attributes he has been given to determine whether the instances encountered are or are not members of the concept.

USES OF THE MODEL

It may be instructive to consider areas for the further study of concept learning posed by the model and also other purposes for which R & D Center personnel are using the model.

Four successively higher levels in concept attainment are indicated and the cognitive operations involved in attaining each level are described. Related to each level three questions will illustrate possible directions for further experimentation.

1. How are the individual's experiences with instances and noninstances represented internally and what conditions present at the time of experiencing the instances and noninstances facilitate subsequent recall? The internal representation of experience is central to the various levels of concept attainment. The propositions formulated by Bruner (1964) and Piaget (1971) regarding internal representation are considered the best available; however, they have not been related to the present model through experimentation. Another theory of memorial representation, outlined by Underwood (1969), specifies various attributes of memory which are the different types of information the learner may encode given a stimulus event. Experimentation is needed to relate Underwood's analysis of memory to the memory of instances, attributes, and hypotheses discussed in this paper.

2. What conditions facilitate the learning of the various levels of concepts? Research concerning many variables related to concept attainment has been carried out (for literature review see Bourne, 1966; Frayer & Klausmeier, 1971). These variables include the availability of actual concept instances, the form in which the instances are represented if actual instances are not available, the number, proportion, and sequence of positive and negative instances, the number of relevant and irrelevant attributes, the salience of the attributes, the amount of time available to the learner to attend to the instances, the availability of positive and negative instances for simultaneous

comparison, the method of presentation of instances, and the amount and kind of instructions given to the learner prior to attempting to attain the concept. This kind of experimentation conducted at the Center and elsewhere has not been reported in this paper, nor has the experimentation been related directly to the model.

3. What is the nature and extent of individual differences related to the operations at the various levels? For example, generalizing that two or more forms of the same object are equivalent and generalizing that two or more instances are equivalent in some way are key operations in the attainment of identity and rudimentary classificatory concepts. It is presumed that individuals of the same age vary widely with respect to these generalizing operations but the extent of the variability and the reasons for it have not been studied.

R & D Center personnel are using the model and related information in research and development pertaining to instruction. As noted earlier, we have developed a paradigm for assessing the level of concept mastery, based on the present model. This paradigm includes testing for the attainment of classificatory concepts, discrimination of attributes, attainment of formal concepts, knowledge of superordinate-subordinate and contingency relationships, and the ability to use the concepts in problem solving. Inhelder and Piaget (1958) hypothesized a fixed order of eleven steps in which children group objects. Kofsky (1966) developed eleven tasks involving geometric shapes that required children of various ages to demonstrate their understanding of the eleven classificatory operations postulated by Inhelder and Piaget. Kofsky administered these tasks to children of various ages; however, the invariant sequence postulated by Inhelder and Piaget was not identified even though some stages without great overlap among age groups were found. We are presently preparing to administer both the tasks developed by Kofsky and tasks based on the paradigm to determine relationships between the levels and operations specified in this paper and the stages postulated by Inhelder and Piaget.

Second, while the model and the related assessment paradigm have been under development and refinement during the last three years, they were also used in school experiments in three ways: to develop statements of instructional objectives for short instructional sequences, to specify the independent variable in two or more versions of the same curriculum content, and to develop the dependent measures in school experiments (Frayer, 1969; Nelson, 1971; Scott, 1971; and Wiviott, 1970). It is anticipated that the results of these and other experiments will have implications for curriculum materials under development in the Center in environmental education and mathematics. Also, if our analysis of levels of concept attainment is reasonably accurate, it should have implications for tests of word comprehension, also under development at the Center.

Third, a factor analytic study is in its second year to ascertain the possible general, group, and specific abilities that underlie concept attainment in English, mathematics, science, and social studies. Data have been gathered for this study on 200 boys and 200 girls of about age 11. Many persons contributed to the development of 360-item tests in each of the subject fields and also to the development of ability tests of the kind outlined by the Thurstones and by Guilford. The concept analysis and related tests have been reported in working papers of the Center. The results of the factor analyses are projected for publication in 1972 by Margaret Harris, Chester Harris, and Mary Quilling.

To conclude, four levels of concept attainment have been defined operationally. The operations at each level have been identified. Extensions and uses of concepts have been treated briefly. Acquiring the names of concepts and attributes has been mentioned. The major emphasis throughout the paper is relating the operations to the levels that in turn permitted this detailed analysis of concept learning. It is hoped that the operations have been described in terms more readily understood than those of Piaget and that the detailed analysis will permit more precise instructional applications than the global strategies described by Bruner et al (1956).

This model, combined with the theoretically and functionally related paradigm for assessing the level of concept mastery, is proving useful not only in the analysis of concept learning but also in clarifying developmental phenomena and in generating principles and procedures that may be used in designing effective printed and audiovisual instructional materials. These tasks will properly be perceived as enormous by anyone who studies the great variety of concepts that comprise a substantial portion of organized knowledge of mankind or who identifies the vast differences among individuals of about the same age in the level of mastery of the same concepts. Perhaps the scope of these tasks and their importance in psychology and education will encourage individuals to think about and investigate them experimentally.

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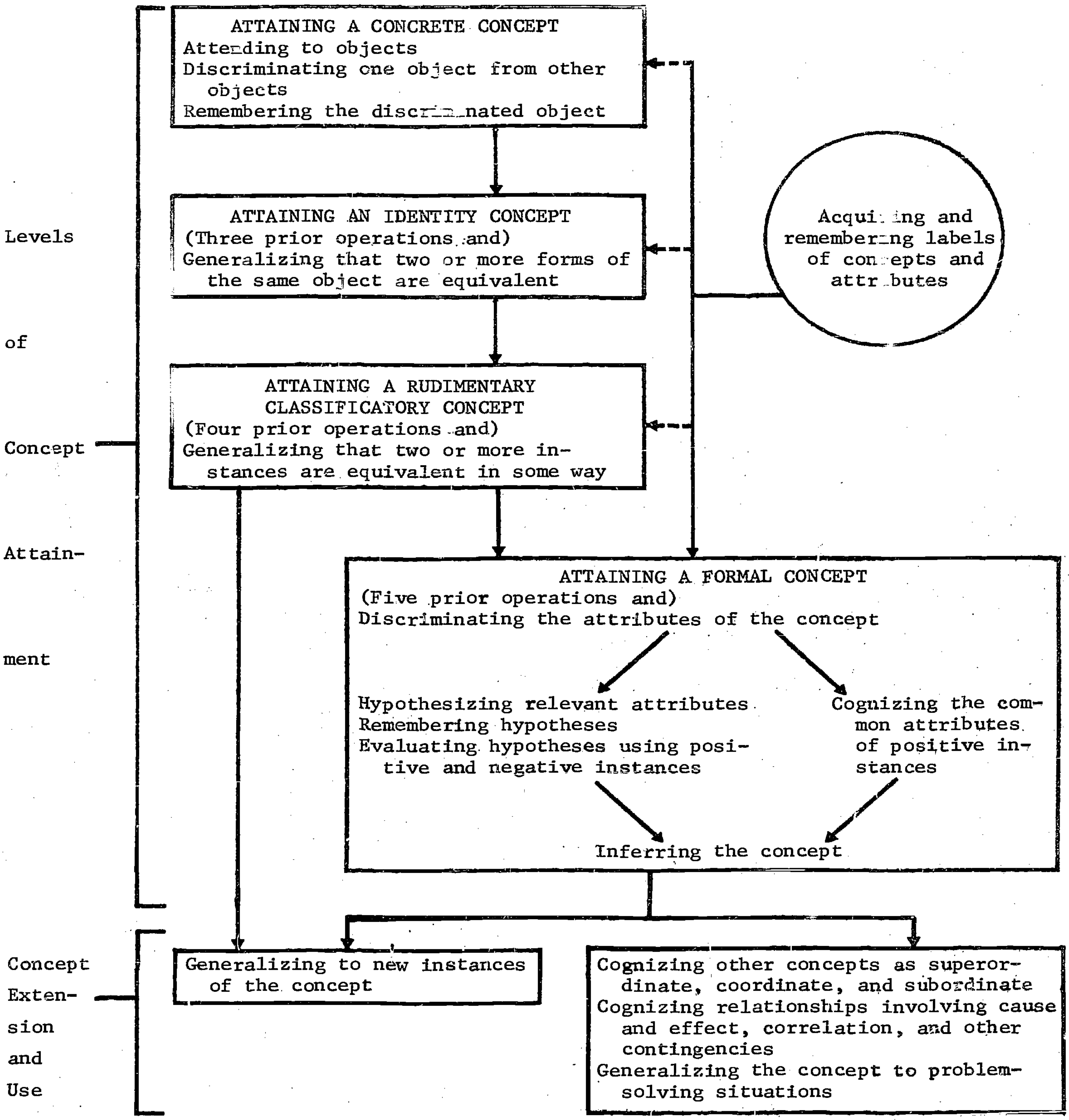

Figure 1. Cognitive operations in concept learning

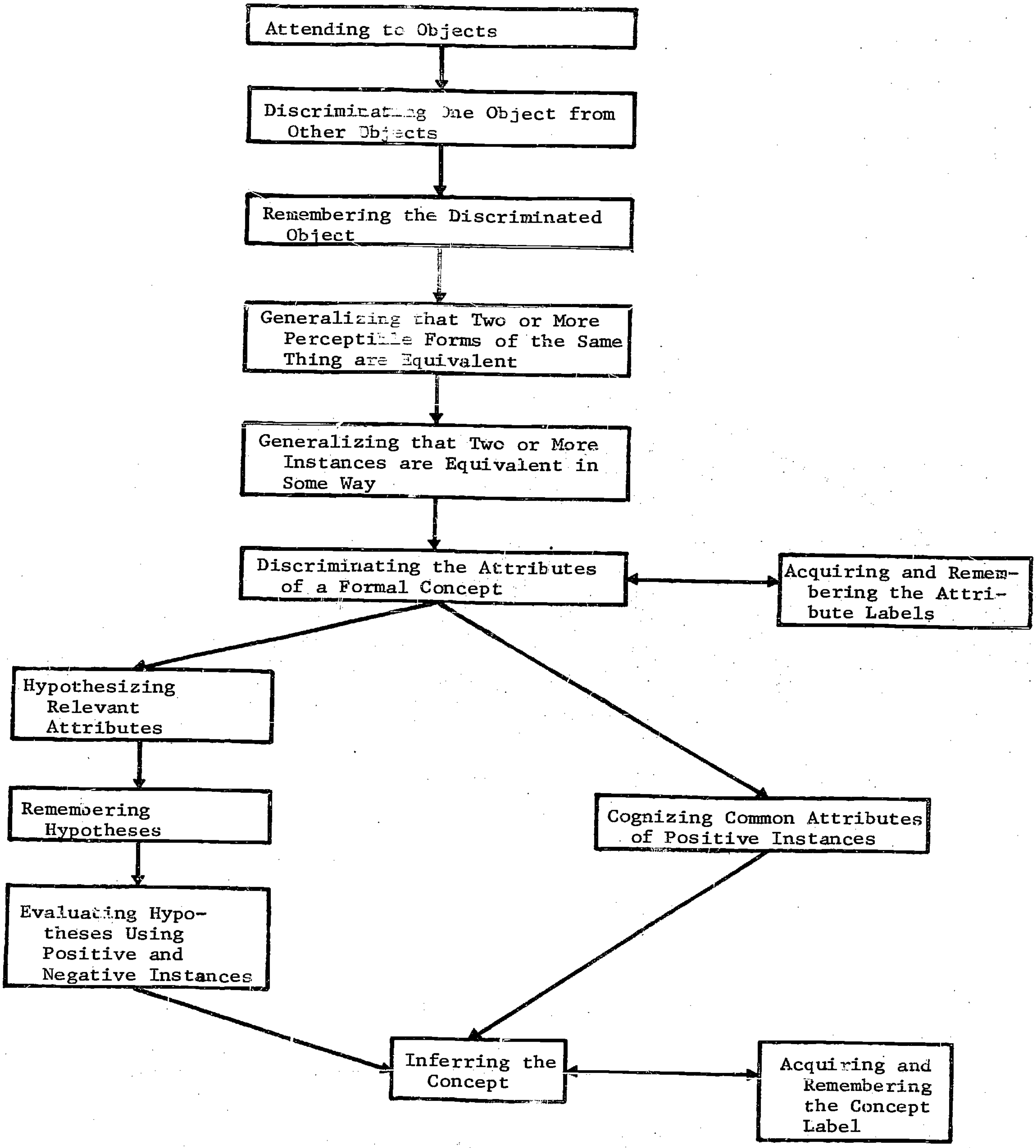

Figure 2. Cognitive operations in the attainment of a formal concept