DOCUMENT RESUME

ED 110 464	95	TM 004 724

AUTHOR	Klausmeier, Herbert J.; And Others
TITLE	First Cross-Sectional Study of Attainment of the Concepts "Equilateral Triangle", "Cutting Tool" and "Noun" by Children 5 to 16 of City A. Report from the Program on Children's Learning and Development. Technical Report No. 287.
INSTITUTION	Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
REPORT NO	WRDCCL-TR-287
PUB DATE	Feb 74
CONTRACT	NE-C-00-3-0065
NOTE	70p.; For related documents, see ED 103 481-485
EDRS PRICE	MF-$0.76 HC-$3.32 PLUS POSTAGE
DESCRIPTORS	Abstraction Levels; Child Development; *Cognitive Development; *Cognitive Measurement; *Concept Formation; Conceptual Schemes; *Cross Sectional Studies; Elementary Secondary Education; *Fundamental Concepts; Hypothesis Testing; Knowledge Level; Language Learning Levels; Models; Prediction; Tests
IDENTIFIERS	Cutting Tool; Equilateral Triangle; *Model of Conceptual Learning and Development; Noun

ABSTRACT

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. Assessment batteries were developed to assess each child's level of concept attainment and also the related use of the concepts equilateral triangle, cutting tool, and noun. Each of the three batteries was designed as a paper-and-pencil task and administered to from 60 to 100 children enrolled in each of four grades: kindergarten, third, sixth, and ninth. The three populations receiving the three batteries were not independent; more than 80 percent of the children received all three batteries. Predictions based on the model about children's conceptual development were strongly supported across all three concepts: (1) The three concepts were attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal. (2) As the concepts were attained to higher levels they were used increasingly (a) in cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept was an element of the hierarchy; (b) in understanding principles that stated a relationship between the attained concept and one or more other concepts; and (c) in solving problems that required the use of the particular concept. (3) Having the labels of the concept and of its defining attributes facilitated attainment of the concept, and mastery of the three uses of the concept. (Author)

ED110464

Technical Report No. 287

FIRST CROSS-SECTIONAL STUDY OF ATTAINMENT OF THE CONCEPTS EQUILATERAL TRIANGLE, CUTTING TOOL AND NOUN BY CHILDREN AGE 5 TO 16 OF CITY A

by

Herbert J. Klausmeier, Thomas S. Sipple, and Patricia S. Allen

Report from the Program on Children's Learning and Development

Herbert J. Klausmeier
Principal Investigator

TM 004 724

Wisconsin Research and Development Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

February 1974

2/3

Published by the Wisconsin Research and Development Center for Cognitive Learning, supported in part as a research and development center by funds from the National Institute of Education, Department of Health, Education, and Welfare. The opinions expressed herein do not necessarily reflect the position or policy of the National Institute of Education and no official endorsement by that agency should be inferred.

Center Contract No. NE-C-00-3-0065

Statement of Focus

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints—financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher student achievement and self-direction in learning and in conduct and also to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

Acknowledgments

The authors wish to acknowledge the cooperation and assistance provided by Donovan L. Richards, Assistant Superintendent for Instructional Services; Laurence Baker, junior high school principal; Charles Bruce, Joseph Checota, Martin Kerwin, and Wayne J. Simon, elementary school principals; and the staff and students of Riverside Junior High School, Douglas, Lincoln, Webster, and Schurz elementary schools of the Watertown, Wisconsin Public School System.

We thank Mary Montgomery, Assistant Scientist at the Wisconsin Research and Development Center for Cognitive Learning; Professor Roy A. Lindberg, Department of Mechanical Engineering, University of Wisconsin; and Sister Suzanne Lorentz, Edgewood High School, for their consultation with us regarding the content of the assessment batteries dealing with equilateral triangle, cutting tool, and noun, respectively. Assistance regarding statistics and measurement was provided by Professors Laurence Hubert, Joel Levin, and Michael Subkoviak, Department of Educational Psychology, University of Wisconsin; computer programming services by Geneva Diluzio and Ed Haertel, Wisconsin Research and Development Center; and art and design for the assessment batteries by Karen McLellan and Vera Meyer, Wisconsin Research and Development Center.

Table of Contents

List of Tables and Figures

List of Tables and Figures (con't.)

Abstract

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. The strategy and objectives of a longitudinal assessment of children's conceptual learning and development are presented. Perspective is provided regarding the role of the present cross-sectional study in the longitudinal assessment.

For the present study, assessment batteries were developed to assess each child's level of concept attainment and also the related use of the concepts equilateral triangle, cutting tool, and noun. Each of the three batteries was designed as a paper-and-pencil task and administered to from 60 to 100 children enrolled in each of four grades: kindergarten, third, sixth, and ninth. The three populations receiving the three batteries were not independent; more than 80% of the children received all three batteries.

Predictions based on the model about children's conceptual development were strongly supported across all three concepts:

1. The three concepts were attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal.
2. As the concepts were attained to higher levels they were used increasingly (a) in cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept was an element of the hierarchy; (b) in understanding principles that stated a relationship between the attained concept and one or more other concepts; and (c) in solving problems that required the use of the particular concept.
3. Having the labels of the concept and of its defining attributes facilitated (a) attainment of the concept, and (b) mastery of the three uses of the concept.

I
Introduction: Concepts and Concept Learning

Individuals at all levels of human development are constantly learning new concepts and extending and using old concepts in new situations. It is apparent, however, that an individual's level of mastery of a particular concept will differ depending upon his experiences with concept instances and his ability to perform the cognitive operations. For example, a four-year-old child and a biologist may both have a concept of tree; although both may perform equally well when asked to identify a few obvious examples and nonexamples of tree, their concepts differ markedly. Despite the large difference in level of understanding, concepts are the fundamental agents of thought for human beings from early childhood through adulthood.

A substantial amount of research on concept learning has been completed during the past two decades. Two types of research have been conducted, one dealing with the internal and external conditions of concept learning and another type involving the behavioral analysis of learning concepts related to various subject-matter fields. Sufficient knowledge has accrued so that Klausmeier, Ghatala, and Frayer (1974) were able to formulate a model that specifies and describes the cognitive operations involved in the attainment of concepts at specifiable levels of mastery by individuals whose abilities change in predictable ways with age. (We use "age" as a shorthand term to indicate the product of learning and maturation; age, per se, is not considered a determining factor of how well individuals can perform.)

An analytical-descriptive model of conceptual learning and development (CLD model) was initially formulated by Klausmeier (1971) and described more fully by Klausmeier, Ghatala, and Frayer (1974). The model defines four levels of concept attainment and the possible uses and extensions of attained concepts, specifies the cognitive operations involved in learning concepts at each of the four levels, and postulates internal and external conditions of learning related to the specified levels. The levels of concept mastery, the operations, and the conditions of learning have been identified through behavioral analyses of concept learning tasks and through empirical research in laboratory and school settings carried out at the Wisconsin Research and Development Center for Cognitive Learning and other research laboratories.

The Nature of Concepts

The word concept is used by Klausmeier, Ghatala, and Frayer (1974) to designate mental constructs of individuals and also identifiable public entities that comprise part of the substance of the various disciplines. Thus, concept is used appropriately in two different contexts just as many other English words are. A concept is defined as ordered information about the properties of one or more things--objects, events, or processes--that enables any particular thing or class of things to be differentiated from, and also related to, other things or classes of things.

In connection with concepts as mental constructs it is noted that each maturing individual attains concepts according to his unique learning experiences and maturational pattern. In turn, the concepts he attains are used in his thinking about the physical and social world.

Concepts as public entities are defined as organized information corresponding to the meaning of words. Carroll (1964) related concepts, words, and word meanings in the following way. Words in a language can be thought of as a series of spoken or written entities. There are meanings for words that can be thought of as a standard of communicative behavior that is shared by those who speak a language. Finally, there are concepts--that is, the classes of experiences forme in individuals either independently of language processes or in close dependence on language processes. Putting the three together, Carroll stated: "A 'meaning' of a word is, therefore, a societally standardized concept, and when we say that a word stands for or names a concept it is understood that we are speaking of concepts that are shared among members of a speech community [1964, p. 187]."

At the inception of a large programmatic research effort dealing with concept learning and instruction, Klausmeier, Davis, Ramsay, Fredrick, and Davies (1965) formulated a conception of concept in terms of defining attributes common to many concepts from various disciplines. Klausmeier, Ghatala, and Frayer (1974) further refined the definition by specifying eight attributes of concepts: learnability, usability, validity, generality, power, structure, instance numerousness, and instance perceptibility. Other researchers and subject-matter specialists are also treating concepts in terms of defining attributes. For example, Flavell (1970) indicated that a formal definition of concept in terms of its defining attributes is useful in specifying what concepts are and are not and also in identifying the great variability among concepts. Markle and Tiemann (1969) and Tennyson and Boutwell (1971) have shown that the external conditions of concept learning can be delineated through research that starts with a systematic analysis of the attributes of the particular concepts used in the research. Scholars at the Wisconsin R & D Center demonstrated that analysis of concepts in terms of their relevant and irrelevant attributes is useful in clarifying the meanings of the concepts drawn from four disciplines: language arts--Golub, Fredrick, Nelson, and Frayer (1971); mathematics--Romberg, Steitz, and Frayer (1971); science--Voelker, Sorenson, and Frayer (1971); and social studies--Tabachnick, Weible, and Frayer (1970).

The CLD model deals primarily with concepts represented by words that can be defined in terms of attributes, although some concepts are defined on other bases, including through the use of synonyms and antonyms. Further, not all words potentially definable in terms of attributes are so defined, even in unabridged dictionaries. Therefore, the researcher and also the developer of curriculum materials must ascertain the defining attributes independently or cooperatively with scholars from the various desciplines.

An Overview of the Conceptual Learning and Development Model

Figure 1 shows the structure of the model. Four levels in the attainment of the same concept at successively higher levels are outlined. The four successive levels are concrete, identity, classificatory, and formal. As a concept is attained by an individual at the successive levels it becomes increasingly usable and valid, as defined earlier.

A sec[illegible] Figure 1 shows the ways in which [illegible] may be extended and used. Concepts [illegible] ared at only the concrete and identity levels can be used to solve simple problems that require only the relating of obvious sensory perceptions. For example, to save time, or for some other reason, a child may walk diagonally across a rectangular block rather than remaining on the sidewalk and walking around a corner of the block. He need not have attained the concepts of distance, angle, diagonal, or straight line at the classificatory level.

Concepts acquired at the classificatory and formal levels may be generalized to newly encountered instances, related to other concepts, and used in problem-solving situations. Here we are concerned both with transfer of learning and the use of concepts in thinking.

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

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

By focusing on the attainment of successively higher levels of the same concept, we are able to clarify the short-term learning conditions at each level and to describe conceptual development over long time intervals. Thus, the model provides a basis for organizing knowledge and carrying out research related to both the external and internal conditions of learning at each of the four levels.

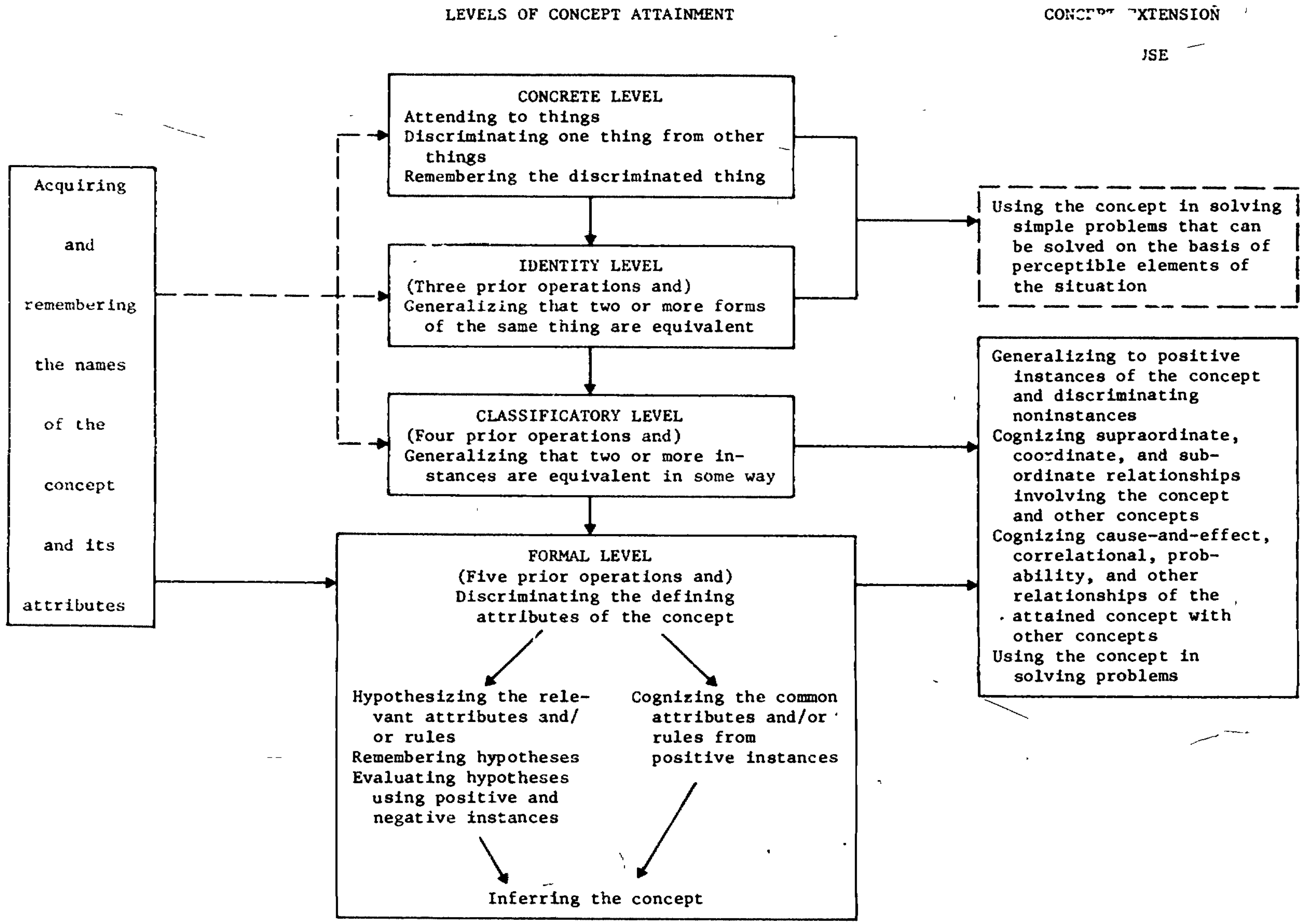

Figure 1. Cognitive operations in concept learning.

The fourth part of the model shows that acquiring and remembering the name of the concept may come at any of the four levels. The solid line indicates that being able to name the concept and its relevant attributes is essential to attaining concepts at the formal level. The broken lines indicate that an individual may acquire the name at about the same time he first attains the concept at lower levels but that this is not requisite. For example, a young child might attain a concept at all three lower levels but not the concept name. The younger the child is upon attaining the concept, the less likely he is to have the name for it.

At this time, we shall delimit the substantive domain that we are treating. The model in its totality describes the four levels of concept attainment and uses of the same concept rather than each of four kinds of concepts. The four levels apply to the many concepts that are or can be defined in terms of attributes and which have actual perceptible instances or readily constructed representations of instances. We have already cited a few examples of this kind, including all the concepts comprising the plant kingdom and the animal kingdom. However, the operations at each level are intended to be applicable also to different kinds of concepts, some of which, because of their nature, are not attainable at all four levels. We can specify these kinds of concepts and the levels at which they can be attained.

There are some concepts for which there is only one instance such as the earth's moon and Abraham Lincoln and some that have many identical instances, for example, inch and pound. Related to Figure 1, such single-instance or identical-instance concepts which have defining attributes can be attained at the concrete, identity, and formal levels, but not at the classificatory level. By our definition of classificatory level, there must be at least two nonidentical instances that can be placed in the same class. Therefore, some concepts cannot be attained at the classificatory level.

Other concepts are of such low validity that there may not be agreement as to the defining attributes, for example, beauty and morality. Concepts such as these might be learned at the three lower levels but not at the formal level.

Finally, there are concepts with no perceptible instances, such as infinity and atom. These cannot be learned at the three lower levels but might be learned at the formal level.

Returning to the four levels given in Figure 1, we postulate that attaining a concept at the four successively higher levels is the normative pattern for large numbers of individuals under two conditions. First, the concept is of the kind for which there are actual perceptible instances or readily constructed representations; and second, the individual has experiences with the instances or representations starting in early childhood. Furthermore, in order to proceed to the formal level, individuals must acquire labels for the concept and for its attributes. For example, the individual will have successively attained the concrete, identity, and classificatory levels of the concept plant before he describes and treats plant 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 concepts at the classificatory level and learn the societally accepted names for the concepts and their attributes through formal and informal instruction.

Earlier we indicated that some individuals, because of environmental conditions, may not encounter actual instances of a concept; rather, they experience instances only in verbal form. Thus, these individuals may attain a concept at either the classificatory or the formal level at the outset. It is also noted that the mature person, although capable of attaining a concept at the formal level, may stop at a lower level of attainment because of the way in which the perceptible instances are encountered or other conditions of learning.

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 the concrete level.

Concrete Level

Attainment of a concept at the concrete level is inferred when the individual cognizes an object that he has encountered on a prior occasion. We use the term "operations" as Guilford (1967) does. Guilford has defined the operations of cognition, memory, productive thinking, and evaluation in terms of test performances. He stated that cognition must be related to the products cognized and he formally defined cognition as follows:

Cognition is awareness, immediate

> discovery or rediscovery, or recognition of information in various forms; comprehension or understanding . . . The most general term, awareness, emphasizes having active information at the moment or in the present . . . the term, recognition, is applied to knowing the same particular on a second encounter . . . if cognition is practically instantaneous, call it recognition; if it comes with a slight delay, call it "immediate discovery;" [pp. 203-204]."

The first step in attaining this level is attending to an object and representing it internally. Woodruff (1961) pointed 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 sound 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].

Gagné (1970) indicated that as the individual attends to an object, he discriminates it from other objects. Woodruff (1961) called 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 a large red ball and a white plastic bottle, discriminates each one, maintains a mental image of each, and cognizes each of the objects when experienced later

The discrimination of objects involves attending to distinctive features that serve to distinguish the objects 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 concept at the concrete level thus requires attending to the distinctive features of an object and forming a memory image which represents the object as a unique bundle of features. The concept at this level may or may not be associated with the concept label, depending on whether the label has been learned and remembered, and whether it has been associated with the concept.

The preceding analysis of the operations is attaining concepts at the concrete level is sufficiently comprehensive to include motoric experiencing of objects. That is, an object may be manipulated physically and represented enactively, as well as explored visually and represented iconically, to use Bruner's (1964) terminology. The model postulates that attending, discriminating, and remembering are involved in sensorimotor experiencing (to use the terms of Piaget, 1970) as well as in the visual perception of objects.

Identity Level

Attainment of a concept at the identity level 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. 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 the concept of poodle at the identity level. Whereas concept attainment at the concrete level involves only the discrimination of an object from other objects, attainment at the identy level involves both discriminating various forms of the same object from other objects and also generalizing the forms as equivalent. Generalizing is the new operation postulated to emerge as a result of learning and maturation that makes attainment at the identity level possible.

As noted earlier, there are some valid and powerful concepts, such as the English alphabet, for which there is only one instance but which can be represented in different ways, e.g., aurally and in printed form. These concepts are typically learned at the concrete and identity levels but not at the classificatory level. Therefore, individuals proceed directly from the identity to the formal level with this kind of concept.

Bruner, Goodnow, and Austin (1956) have pointed out that identity responses occur very early in life and that the capability to recognize identity may be innate and merely extended to new events through learning. Vernon (1970) indicates that infants have to learn by experience that objects and events in the environment are permanent even though they may change their appearance from time to time as their distance and orientation changes. Clearly, the capacity to recognize identity, indeed the expectation of the continuity of objects and events in the environment, is well developed in the perception of adults.

Recognition of object identity is central to Piaget's formulations. According to Elkind (1969), Piaget's conception of concept emphasizes the variability that occurs within things--changes in state, form, and appearance which can occur to any entity.

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 discriminated from noninstances. Elkind 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 examples. 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 [1969, p. 187].

The present model proposes that a concept is attained at the identity level temporally before it is attained at the classifactory level. Stated differently, the individual must be able to cognize various forms of the same objects as equivalent before he is able to generalize that two or more different objects belong to the same class.

Classificatory Level

The lowest level of mastery at the classificatory level is inferred when the individual responds to at least two different instances of the same class as equivalent, even though he may not be able to describe the basis for his response. For example, when the child treats the family's toy poodle and the neighbor's miniature poodle as poodles, although he may not name the attributes of poodles, he has attained a concept at the classificatory level.

While generalizing that at least two different instances are equivalent in some way is the lower limit of this level of concept learning, the individual is still at the classificatory level of concept learning when he can correctly classify a larger number of instances as examples and nonexamples, but cannot accurately describe the basis for his grouping in terms of the defining attributes. Henley (cited in Deese, 1967), like many other researchers, has observed this phenomenon. Many of her subjects were able to sort cards correctly into examples and nonexamples of the concepts being learned, yet gave totally erroneous definitions of the concepts.

Formal Level

A concept at the formal level is inferred when the individual can give the name of the concept, can discriminate and name its intrinsic or societally accepted defining attributes, can accurately designate instances as belonging or not belonging to the set, and can state the basis for their inclusion or exclusion in terms of the defining attributes. For example, the maturing child demonstrates a concept of dog at the formal level if, when shown dogs, foxes, and wolves of various sizes and colors, he properly designates the dogs as such, calls them "dogs," and names the attributes that differentiate the dogs from the foxes and wolves. The distinctive aspect of this level of concept mastery is the learner's ability to specify and name the defining attributes and to differentiate among newly encountered instances and noninstances on the basis of the presence or absence of the defining attributes.

As noted in Figure 1, the labels for the concept and the defining attributes may be learned at any of the three lower levels, but are not essential at those levels. Similarly, the discrimination of the defining attributes may occur prior to the formal level, but this is not essential. Thus, discrimination of things on their global and diffuse stimulus properties which is essential at the concrete level changes to discrimination of more specific and abstract properties at the identity and classificatory levels. However, at the formal level the individual must be able to discriminate and label all the defining attributes of the concept.

The operations involved in the learning of concepts at the formal level are also shown in Figure 1. The first operation given at the formal level is that of discriminating the attributes. As already noted, for some concepts with obvious attributes such as color and form, the discriminations may have occurred at earlier levels. However, making the discriminations and having the labels for the attributes are both essential at the formal level. This is true whether the individual infers the concept by hypothesizing and evaluating relevant attributes or cognizing the attributes common to positive instances, as shown in Figure 1.

Individuals differ in their ability to analyze stimulus configurations into abstract dimensions or attributes. There is evidence (Gibson, 1969) that this ability develops with age. Retarded children may have difficulty with simple concept learning tasks because of the difficulty in learning to select out and attend to specific dimensions (Zeaman & House, 1963). Even among children of adequate intelligence, there are those who characteristically analyze the stimulus field and apply labels to attributes while others tend to categorize on the basis of a relatively undifferentiated stimulus (Kagan, Moss & Sigel, 1963).

Orienting instructions may be given to make explicit the attributes of the stimuli (Klausmeier & Meinke, 1968). These instructions facilitate the learning of concepts at the formal level by assuring that the learner knows all of the attributes that may be relevant to the concept.

Having discriminated and named the attributes, an individual may infer the formal level of a concept in either of the two ways shown in Figure 1. One way involves formulating and evaluating hypotheses and the other involves cognizing the common attributes in positive instances. Which strategy a learner uses depends on the instructions he has been given, his age, and the kind of concept instances he experiences.

Levine (1963) defined a hypothesis as the subject's prediction of the correct basis for responding. In the hypothesis-testing approach, the learner guesses a possible defining attribute or combination of attributes. He then compares this guess with verified examples and nonexamples of the concept to see whether it is compatible with them. If they are not compatible, he makes another guess and evaluates it against further examples and nonexamples. Eventually, he combines the information he has obtained from testing his hypotheses so as to infer all the defining attributes and thereby the concept.

Essential to the hypothesis-testing approach are the operations of remembering and evaluating hypotheses. There is support (Levine, 1963; Williams, 1971) for the idea that the subject formulates and remembers a population of hypotheses, remembers the hypotheses that were rejected, and also remembers the last one accepted as correct. In connection with evaluating hypotheses, Bruner, Goodnow and Austin (1956) indicated 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 a hypothesis. In the present model, the validity of an individual's concept may be assessed in terms of how nearly it corresponds to expert agreement concerning the concept. Our experiments have shown that instructions to subjects which include a decision rule for evaluating hypotheses facilitate concept attainment.

The operations involved in the hypothesis-testing approach to inferring concepts appear to characterize individuals who cognize the information available to them in laboratory and classroom settings from both positive and negative instances. These individuals apparently reason like this: Instance 1 had 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 attained a partial and possibly complete definition of the concept based on experiences with only one positive and one negative instance.

A second way of inferring the concept is by noting the commonalities in examples of the concept. The commonality approach is used more often than the hypothesizing approach by children, either because they are incapable of carrying out the hypothesizing and evaluating operations or because they for other reasons pursue the commonality strategy (Tagatz, 1967). In this connection the commonality approach is entirely appropriate for use when only positive instances of the concept are available. Thus, it is probably employed in situations where the individual is given only positive instances or verbal descriptions of positive instances.

Our model is considered appropriate for learning concepts at the formal level by a didactic method of information presentation as well as an inductive one. We agree with Ausubel (1966) that many concepts are attained at the classificatory and formal levels by upper elementary, high school, and college students through being given the names of concepts, verbal definitions, and verbal examples, but no actual instances of the concepts. Ausubel has designated this kind of learning "concept assimilation," an example of meaningful reception learning, to contrast it with "concept formulation," an example of meaningful discovery learning.

We should consider briefly what takes place when the learner is given the concept name, its defining attributes, and a verbal description of an instance or two, as is frequently done in classroom settings. The individual may attain a concept at a low level of mastery through this brief instructional sequence. However, his main task thereafter is to generalize properly to newly encountered positive instances and to discriminate noninstances. The basic operations entailed in this identification of newly encountered instances are hypothesizing whether the instance does or does not belong to the concept and evaluating the hypothesis in terms of the defining attributes given in the definition. Prerequisite to these two operations are discriminating the attributes of the concept and knowing their labels.

Acquiring Appropriate Labels

The importance of language in concept learning is widely acknowledged by American (Bruner, 1964) and Russian (Vygotsky, 1962) psychologists. Having the labels of concepts enables the individual to think in symbols rather than in images and to attain other concepts through language experiences in the absence of perceptible instances. Carroll (1964), as noted earlier, has outlined the close relationships among concepts, meanings, and words. However, the purpose here is not to deal with the relationships between language and concept learning, which will be dealt with in a later chapter, but to show at what points labels may be learned and associated with the various levels of concepts.

Figure 1 indicates that a concept label may be associated with an instance of the concept at any of the four levels--concrete, identity, classificatory, or formal. For example, a child might manifest a sequence like this: The 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 the concept of the same dog at the identity level 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 concept of the dog at the identity level. Subsequently, the child encounters other dogs and observes that they, too, are called "dogs." He generalizes the different dogs as equivalent in some way and associates the name "dog" with whatever similarities he has noted. The word thus comes to represent his class of things called "dogs." At the formal level, the more mature child discriminates and learns the 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 approaches or becomes identical to the societally accepted definition of the word "dog." As Carroll (1964) pointed out, the concepts held by individuals and the meanings of the words representing the concepts are the same for mature individuals who share similar cultural experiences and the same language.

In connection with language and concept attainment, we recognize that deaf individuals and others who lack normal speech development may attain concepts at the formal level. By our definition, the individual must know the defining attributes of the concept and must be able to communicate this knowledge. Verbalizing is normally used in this kind of communication. Other types of symbolic communication, for example, sign language, may also be employed. Speech, per se, is not necessary for the attainment of concepts, but some means for symbolizing and communicating the concept in the absence of examples is necessary at the formal level.

Concept Extension and Utilization

The individual who has formed a concept may extend and use it as shown in Figure 1. As noted earlier, a concept attained only to the concrete or identity level may be used in solving simple perceptually based problems. Concepts learned at the classificatory and formal levels can be used in generalizing to new instances, cognizing supraordinate-subordinate relations, cognizing cause-and-effect and other relations among concepts, and in solving problems.

Ausubel (1963) and Gagné (1970) have theorized concerning the use and extension of attained concepts; however, very little empirical research has been done. In this regard Ausubel (1963) formulated the constructs of cognitive structure, advance organizer, correlative subsumption, and derivative subsumption to show how previously attained and newly encountered concepts are related, while Gagné has indicated that attained concepts are prerequisite to the learning of rules.

Generalizing to New Instances and Discriminating Noninstances

The attainment of concepts at the classificatory and formal levels reduces the need for additional learning and relearning, primarily because the individual is able to generalize to new instances of a concept and to discriminate noninstances. Having a concept also provides the individual with expectations which help him deal effectively with new instances of it. Once he identifies a plant as poison ivy, he may treat it gingerly. One test of concept attainment in our experiments is the individual's ability to properly categorize instances not previously encountered as instances or noninstances of the particular concept. We find that both school children and college-age students generalize to new instances readily. Furthermore, the use of instances and noninstances in instructional materials to teach concepts can be manipulated so that errors of overgeneralization and undergeneralization can be reduced (Feldman, 1972; Swanson, 1972).

Not only does having a concept enable the learner to identify new instances and act appropriately toward them, but direct and verbal experiences with the new instances possibly increase the validity and power of the concept for the individual. For example, the Canadian visiting Kenya during January, when it is summer there, may attain more valid and powerful concepts of flower and plant. Similarly, by being told that a whale is a mammal, an individual comes to realize that mammals can live in the water as well as on land. Hence, his concept of mammal has greater validity.

Cognizing Supraordinate-Subordinate Relationships

Besides generalizing to new instances, individuals can also use their concepts attained at the formal level, and possibly at the classificatory level, in cognizing coordinate, supraordinate, and subordinate relationships among classes of things. The lowest level of cognizing these relationships is inferred when the individual, according to verbal instructions, puts instances of hierarchically arranged concepts in their proper groups. For example, an individual upon request puts all instances of red and blue equilateral triangles and of right triangles in a grouping of triangles, and all instances of triangles and of rectangles in a grouping of polygons. Furthermore, he justifies each group formed on the basis of the defining attributes of the group. For example, he states that equilateral triangles include all the triangles that have three equal sides, triangles include all the polygons that have three sides, and polygons include all the closed, planar figures that have three or more sides. More precise terminology might be required such as "an equilateral triangle is a simple, plane, closed figure with three sides of equal length."

Possible higher levels of attaining the supraordinate-coordinate-subordinate relationships include what Kofsky (1966) designated as the "whole is the sum of the parts" and "some but not all." Again, merely being able to group a few instances properly according to verbal instructions is not a sufficient test of cognizing the sets of relationships; an adequate justification for the actions is required. According to Kofsky (1966), knowledge concerning supraordinate-subordinate relationships increases with age.

The understanding of supraordinate-subordinate relationships increases the validity and usability of the individual's concepts. For example, knowing the attributes of acid and also that vinegar is an acid leads to the inference that vinegar has the attributes of all acids, as well as the attributes peculiar to vinegar. Thus, all of the things known about acids--for example, how they react with bases--are true for vinegar also. In this way, learning that acid is a concept supraordinate to vinegar increases the validity and usability of the concept of vinegar for the individual.

Cognizing Other Relationships

In the model, statements of relations between or among concepts involving cause and effect, correlation, probability, and other lawful relations such as contained in axioms are treated as different from relations among supraordinate and subordinate concepts. These first three kinds of relationships are referred to by Marx (1970) as laws and by Gagné (1966, 1970) as principles or rules. Mathematicians particularly specify established lawful relations of "givens" in axiomatic statements.

Bruner, Goodnow and Austin (1956) have pointed out that understanding lawful relationships between or among concepts permits the relating of classes of things instead of individual things. In this connection, Gagné (1970) has cited the example of the rule "round things roll," and indicated that this rule enables the individual to predict what will happen to all round things under certain circumstances. Or, consider the more complex relationship: "When two substances at different temperatures come into contact, the temperatures of the substances tend to equalize." This relationship permits us to infer what will happen in such diverse situations as putting ice cubes in warm soda pop or being lost in a snowstorm.

In all cases, being able to understand and use a lawful relationship depends on knowing the concepts that are related. Only then can the principle or axiom be understood and possibly applied to the appropriate phenomena.

Using Concepts in Problem-Solving Situations

Woodruff (1967) discussed the role of concepts in higher-level mental activities, including problem-solving. Also, Gagné (1970) indicated that one way in which concepts are called into play in solving problems is by the application of principles to the problem-solving situations. For example, principles underlying the concepts of pressure, volume, gravity, and distance can be utilized to determine the height of a mountain using a barometer.

Additional Features of the CLD Model

The CLD model is more heavily oriented toward learning than toward development in that it implies that all the concepts held by any individual are learned; they do not emerge simply with maturation. In this context it is similar to four theories of concept learning generated by American experimental psychologists and reviewed by Bourne, Ekstrand, and Dominowski (1971): theory of associations (Bourne & Restle, 1959), theory of hypotheses (Levine, 1966; Trabasso & Bower, 1968), theory of mediation (Osgood, 1953), and theory of information processing (Hunt, 1962). Also, in agreement with these theories, the model specifies that the attainment of concepts is potentially explainable in terms of principles of learning. Despite some differences in terminology, the CLD model, like Hunt's, represents an information-processing approach to learning. The CLD model differs from the four theories just mentioned in that it describes different levels in the attainment of the same concept and specifies the operations essential to attaining concepts at the successively higher levels. While some of the operations are postulated to be common to more than one level, these operations at the successively higher levels are carried out on more highly differentiated and abstract properties of actual concept instances or on verbal descriptions of instances and attributes.

The CLD model is similar to Gagné's (1970) cumulative learning model in that both provide a framework for studying the internal and external conditions of learning. It also differs in two regards. Whereas Gagné describes seven forms of learning, ranging from the simplest learning through rule learning and problem solving, in the CLD model only one form of learning, concept learning, is analyzed according to its several constituent cognitive behaviors at each of four levels. Gagné also postulated a linear vertical learning hierarchy extending from signal learning through problem solving. The CLD model, as shown in Figure 1, indicates that a concept when learned at the classificatory or the formal level may be used in cognizing supraordinate-subordinate relations among the concept and other attained concepts, in understanding relations among concepts such as incorporated in principles and laws, and in problem solving. Thus, the CLD model departs from the straight linear learning hierarchy postulated by Gagné.

Possibly different from the preceding learning theories and more in agreement with Piaget (1970), the CLD model presumes that the new operations at each successive level involve qualitative changes in operating on instances and attributes of concepts, not merely additions to or modification of prior operations. Further, the operations that continue from one level to the next are carried out on more highly differentiated and abstracted concept attributes. While the model does not postulate a stage concept associated with age levels as does Piaget, qualitative differences in thinking of the kinds pointed to by Kagan (1966) and Bruner, Olver, Greenfield, et al. (1966) are recognized. Also, Bruner's (1964) conceptualization of enactive, iconic, and symbolic representation is accepted as a satisfactory global explanation of how experiences are represented and stored.

The roles of language and directed learning experiences are recognized as of central importance in attaining concepts at the classificatory and formal levels. The cross-cultural studies of Bruner, Olver, Greenfield, et al. (1966) support the directed-experiences point of view (cf. Goodnow, 1969). Also, Bruner's (1964) intermediate position that specifies how language facilitates thinking, rather than being essential to thinking (Luria, 1961) or being dependent on thought (Inhelder & Piaget, 1964), appears valid for the present model. Accepting directed experience as critical in concept attainment deemphasizes a maturational readiness viewpoint, such as that expressed by Gesell (1928, 1945). While it is accepted that certain cognitive operations emerge with educational experience, this conception does not espouse a behaviorist-environmentalist point of view regarding learning to the extent that either Gagné (1970) or Staats (1971) does.

II
Purposes and Methods of the Study

This chapter is intended to provide some perspective regarding the role of the present study in a longitudinal assessment program and to delimit the specific purposes of the present study. The plan of the longitudinal research is briefly outlined. Then, the purposes of the present study, the specific predictions that are evaluated, and the research design are described in detail.

Overview of the Longitudinal Study of Children's Conceptual Development

The primary objective of the longitudinal research is to chart the conceptual development of children from about age 4 to 18. This goal will be accomplished primarily from analyses of longitudinal data that are collected once each year over a period of several years. The rationale and strategy for this programmatic research on children's conceptual learning and development from preschool to the high school years have been outlined in an earlier paper by Hooper and Klausmeier (1973). The theoretical framework for the study reported in this paper is the CLD model which has been described in Chapter I.

The data collected annually as part of the longitudinal study may be treated as a cross-sectional assessment of children's conceptual learning. The present report, based on the first year assessment of the longitudinal study, is the first such reporting of cross-sectional findings from the larger program. Performances of children on three CLD assessment batteries are compared over four age groups in order to obtain information about the course of children's conceptual development. This information is evaluated in terms of various predictions that are derived from the CLD model.

The Strategy for the Longitudinal Assessment

The plan of the longitudinal investigation is to study a sample of children from four age groups at four consecutive times during slightly more than three calendar years. The grade groups at the time of first-year assessment in 1973 were kindergarten, third, sixth, and ninth. Each group will be tested in the spring of 1974, 1975, and 1976. Thus, over three calendar years data will be gathered that include the entire age range of 5 to 18 years with 100% overlap of the first and final assessments for the four age groups.

Essential control groups are incorporated in the longitudinal design to permit an evaluation of possible confounding effects commonly associated with long-term repeated-measurement designs. Among these methodological concerns is the possible role of repeated testing effects. In the present instance a variation of the Campbell and Stanley (1963) posttest-only control group design will be employed to evaluate the role of repeated test administrations. Since the design to be used does not provide for the disentanglement of the effects of repeated testing and selective drop-out, special attention will be directed toward the possible changing characteristics of the surviving core longitudinal samples.

Sampling Design of the Longitudinal Study

Selective sampling problems and the associated constraints upon external validity are difficult to avoid in any investigation of the present type. While generalization of the resultant developmental norms will obviously be confined to similar age-grade levels and demographic classifications, attempts will be made to ensure representative sampling among classes within two different school populations. Cohort biases are not expected to be a major concern but will be controlled for in one school district.

The target field locations for the longitudinal study are Watertown, Wisconsin, and Beloit, Wisconsin. The public schools of Watertown provide the locale for the initial tryout and validation of the CLD model assessment batteries related to the concepts of equilateral triangle, cutting tool, noun, and tree. At the same time, the four age groups that participate in these studies will also be followed for each of the successive years.

The Watertown and Beloit studies comprise a simultaneous replication of the longitudinal study. Beloit has been designated as the major source of longitudinal data, however, because its population better reflects the distribution of socioeconomic levels in the U.S. The overall sampling design for the research in Beloit is shown in Table 1. The Watertown sample includes a smaller number of children at each grade and no control groups.

Objectives of the Longitudinal Study

The major data analyses will utilize the longitudinal and cross-sectional assessments under the following general guidelines. The cross-sectional data collections will permit the specification of relative task difficulties (e.g., group means comparison, intercorrelations, and pass/fail contingency analyses) and the suggestion of the probable order of acquisition of these concept domains. The longitudinal data collections will enable us to (1) specify the order of attainment of the various levels and uses of concepts by children in the various grade groups of the two school districts; (2) describe the form of the developmental curve for each level of attainment, concept use, and vocabulary acquisition, from first partial attainment through final full mastery; and (3) relate the mastery of each level to the mastery of each use, and to vocabulary development.

Thus, the primary objectives of the longitudinal study are (a) to chart the course of children's attainment of selected concepts in various subject fields during their school years; (b) to chart the course of children's uses of the same concepts during their school years; (c) to chart the course of children's development of crucial terminology related to the selected concepts; and (d) to relate the three preceding areas of development. The general propositions and more specific predictions pertaining to these matters that can be tested in a cross-sectional study are treated later in this chapter.

Other goals of the longitudinal study, cross-sectional studies, and various controlled experiments are as follows: (1) to determine more explicitly the internal conditions of learning associated with children's mastery of the various levels of concept attainment and their uses; (2) to determine more explicitly the external conditions of learning that facilitate children's attainment and use of concepts in school settings; (3) to relate children's performances on the four CLD batteries dealing with equilateral triangle, cutting tool, noun, and tree; (4) to relate children's levels of conceptual development as assessed by CLD model batteries to their school achievement in various subject matters; and (5) to validate the CLD model in terms of its robustness in providing a framework for research in concept learning, concept development, and related instruction.

Design of the Present First-Year Cross-Sectional Study

The data collected each year as part of the longitudinal study may provide useful information about patterns of conceptual learning and development. Therefore the present study serves both as the initial data collection in the longitudinal program and also as a cross-sectional study of conceptual development.

Purposes of the Study

The CLD model embodies three major propositions. Related to each proposition there are several specific predictions. These major propositions and the related predictions concern hypothesized patterns of children's conceptual learning and development. The purpose of the present study is to test these predictions, thereby clarifying presumed sequencing in conceptual development.

A. Many concepts are attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal. Each level is presumed to be increasingly difficult to attain because of the new operations which are essential to attaining the particular level. It is further presumed that to attain a concept at any particular level an individual must be capable of all of the

TABLE 1

SAMPLING DESIGN FOR THE CLD TESTS

Cohort	1973	1974	1975	1976	
		Time of Measurement			
1967	6* (N=100) →	7 →	8 →	9	
1968	[Kindergarten]	6 → 40	7** →	8**	(Cohort effect group)
1967		7			
1969			6** →	7**	
1967			8**		
1970				6**	
1967				9	(Test effect group)
1964	9 (N=100) →	10 →	11 →	12	
1965	[Third Grade]	9 →	10* →	11**	
1964		10			
1966			9** →	10**	
1964			11 **		
1967				9**	
1964				12	
1961	12 (N=100) →	13 →	14 →	15	
1962	[Sixth Grade]	12 →	13** →	14**	
1961		13			
1963			12** →	13**	
1961			14**		
1964				12**	
1961				15	
1958	15 (N=100) →	16 →	17 →	18	
1959	[Ninth Grade]	15 →	16** →	17**	
1958		16			
1960			15** →	16**	
1958			17**		
1961				15**	
1958				18**	

* Table entries are approximate mean ages

**These groups will not be continued if cohort and practice effects are not found after the first year. If effects are found, decisions about continuing will be made after data are analyzed.

operations at that level and at the prior level and must also have attained the particular concept at the preceding level. These, then, are the prerequisite internal conditions for attaining each consecutive level.

The major proposition also indicates that many, but not necessarily all, concepts are attained in an invariant sequence. Three conditions are essential for concepts to be attained according to the invariant sequence. First, many actual instances or readily constructed instances are present in the immediate environment that children experience. Second, the child must have experiences with the actual instances or the representations thereof starting early in childhood. Finally, the child must be developing normally, free of severe handicaps of speech, language development, brain injury, etc.

The preceding proposition concerning the invariant sequence can be evaluated definitively only through longitudinal study. However, there are a number of predictions which follow from the proposition that can be tested in a cross-sectional study in which children of various age levels or grade groups participate. The three specific predictions tested in the present cross-sectional study are as follows:

1. All children of all grade groups will conform to five acceptable patterns of mastery of the four concept levels. These acceptable patterns are to (a) fail all four levels (FFFF), (b) pass the concrete and fail the next three levels (PFFF), (c) pass the concrete and identity levels but fail the next two levels (PPFF), (d) pass the first three levels but fail the formal level (PPPF), and finally, (e) pass all four levels (PPPP).
2. The number and proportion of children within a single grade group who pass each successive level of concept attainment will decrease. For example, fewer third-grade children will pass the classificatory level than pass the identity level.
3. The number and proportion of children of successively higher grade groups mastering each concept level will increase. For example, more sixth-grade children than third-grade children will pass each of the four levels.

B. Concepts attained to various levels may be used in (1) cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept is an element of the hierarchy, (2) in understanding principles that state a relationship between the attained concept and one or more other concepts, and (3) in solving problems that require use of the particular concept.

The specific predictions which follow from the preceding proposition and which were tested in the present study are as follows:

4. A higher proportion of children who attain a concept at the formal level, in comparison with those who attain it the classificatory level, will also master each of the three concept uses.
5. Children who attain a concept to only the concrete and/or identity level will be able to use that concept only in understanding simple perceptual relationships with other object concepts and in solving simple perceptual problems.
6. The number and proportion of children of successively higher grade groups who master each concept use will increase.

C. Having the labels of the concept and its attributes (1) facilitates attainment of the concept at the classificatory level and possibly the other levels, (2) is requisite for attaining the concept at the formal level, and (3) facilitates mastery of the three uses of the concept. This proposition emphasizes the importance of language in attaining concepts at the classificatory and the formal levels and also in being able to use the concept in various ways.

The two specific predictions related to this proposition which were tested in the present study may be stated as follows:

7. Vocabulary scores and scores based on attainment of the four levels and the three uses will correlate positively within grade groups. The correlations must be positive to support the prediction; however, within some grade groups they may be low due to very little variability in either mastery of the vocabulary or in attainment of the various levels and uses.
8. Vocabulary scores and scores based on the levels and uses will correlate positively for the combined grade groups; correlations should be higher than those obtained within grade groups. These correlations should be of greater magnitude since large variations among the children both in vocabulary attainment and in attainment of the levels and uses in expected when all the children of the combined grade groups are included.

Assessment Batteries Used

In addition to the usual criteria of reliability, objectivity, and usability, several other criteria guided development of the batteries. First, the materials and instructions had to permit assessment of subjects of preschool through high-school age. It was presumed that not all subjects of preschool age would attain a given concept at the concrete level and that not all high-school subjects would attain it at the formal level. Second, to test for attainment at the concrete, identity, and classificatory levels the particular concept selected had to have perceptible instances or representations thereof. Third, the concept had to be definable by publicly accepted attributes in order to test attainment at the formal level. (It should be noted that many concepts are definable in terms of attributes even though this method of definition is often not used, even in unabridged dictionaries.) Fourth, the concept selected for a battery should be relatable to the subject matter which pupils encounter in school. This is in keeping with the supposition that directed experience, including instruction in school, is a powerful determinant of the particular concepts attained by individuals and also of their level of attainment and use. Further, since much instruction in school deals with concepts, the CLD model should be applicable to the design of instruction, and the subtests, when fully validated, should be usable in assessing the level of conceptual development in school-age children. Fifth, the particular concept had to be part of a taxonomy in order to test its use in cognizing supraordinate-subordinate relationships. Finally, the concept had to be usable in cognizing principles and in problem solving. (A concept may be usable in solving simple problems that can be solved on a perceptible basis without being used first in understanding a principle, or it may be used first in understanding a principle and then in solving more complex problems.)

In the present study, assessment batteries were developed for each of the following three concepts: equilateral triangle (Klausmeier, Ingison, Sipple, and Katzenmeyer, 1973a) from the field of mathematics; cutting tool, (Klausmeier, Bernard, Katzenmeyer, and Sipple, 1973) which is a general concept probably related more to science than to other curriculum areas; and noun (Klausmeier, Ingison, Sipple, and Katzenmeyer, 1973b) from the field of English language arts.

To develop the tests of concept attainment and utilization, the behaviors involved in attaining the concept were analyzed and then test items and administrative procedures to assess the behaviors were developed. For each of the three batteries, a subtest was developed to assess each of the four levels of concept attainment. Each subtest was constructed specifically to assess the particular operations involved in attaining a concept at each of the four levels. A subtest was also developed to ascertain the extent to which a child could apply the concept in each of the three uses that have been described. Thus, a total of 21 subtests was developed, seven for each of the three concepts. All subtests in each of the three batteries were designed as paper-and-pencil tasks that could be group administered.

For each of the batteries, items within the concrete, identity, and classificatory levels were constructed to be more difficult as nonexamples (1) increased in number and (2) shared more relevant and/or irrelevant attributes with the target examples. Specific information regarding the exact number of items used in each subtest of a battery is available in Tables 3, 12, and 21 which are included in the three chapters dealing with results of the assessment of equilateral triangle, cutting tool, and noun. All test items went through expert review and empirical validation while under development.

Participating Children

Over 300 school children from Watertown, Wisconsin participated in each of the three assessment series. The total number of children tested in the three assessments varied slightly: 324 children took part in the equilateral triangle study, 363 in the cutting tool study, and 325 in the noun study. The three populations were not independent; that is, 289 children received all three batteries. Children at four grade levels--kindergarten, third, sixth, and ninth grade--took part in each of the assessment series. Children in the three lower grades were enrolled in four different elementary schools. The ninth-grade students were enrolled in a junior high school. These schools and classrooms were judged to be typical of the particular school system and also of a large number of classrooms in small towns in Wisconsin. Each of the three subject populations is described in greater detail in the chapters presenting results.

Data Collection

The appropriate subtests of the battery were administered to children in intact classrooms, with the exception of kindergarten children. These youngest children were tested in small groups of about five to eight in order to reduce distractibility and, in general, to enable the test administrators to supervise the test-taking situation more closely. Each of the three batteries was administered at a different time within a six-month period. Two test administrators, one male and one female, were responsible for giving all batteries in the three assessment studies. The classroom teacher usually remained in the classroom during the test administration to assist in monitoring the test situation. The same administrators were responsibl~ for scoring the tests and for coding the tes in ~nation for subsequent data analyses.

Treatment of the Data

On each subtest of an assessment battery a subject was scored as having either passed or failed; that is, results of each assessment battery were treated as dichotomous data. Criteria set for each subtest determined passing, or attainment of a subtest. Specific criteria for attainment of each subtest in each of the assessment batteries will be explained in Chapters III, IV, and V, which present, respectively, results of the assessment of equilateral triangle, cutting tool, and noun.

In general, data were quantified by computing frequencies and proportions of subjects at each grade group who attained each concept level and each uses subtest. In addition, certain post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. The predicted relationships between vocabulary and performance on the subtests dealing with the concept levels and uses were evaluated by computing correlation coefficients. Each of the specific predictions outlined in this chapter is evaluated in terms of these descriptive analyses.

III
Results of CLD Assessment Series I: Equilateral Triangle

Overview

In this chapter the child population is briefly described. Specific criteria employed in the study for full attainment of each subtest of the battery are also reported. The results, as they pertain to various predictions based on the CLD model, comprise the major portion of the chapter.

Child Population

Table 2 provides a summary description, according to age and sex, of the 324 children who participated in the first assessment series, equilateral triangle. Inspection of the table shows that 62 children from kindergarten, 86 from third grade, 92 from sixth grade, and 84 from the ninth grade took part in this study. Since intact classrooms were used, the number of boys and girls within each grade is unequal, although the total number of boys and total number of girls, 161 and 163 respectively, is very close. The age range for each grade varied from 13 to 16 months. The smallest range, 13 months, was in the kindergarten group and the largest, 16 months, occurred among the ninth graders.

TABLE 2

NUMBER OF MALES AND FEMALES, MEAN AGE, AND AGE RANGE AT EACH GRADE GROUP

Grade	Males	Females	Mean Age (in years and months)	Age Range (in years and months)
K	32	30	5-10	5-4 to 6-5
3rd	48	38	8-10	8-3 to 9-5
6th	40	52	11-10	11-3 to 12-6
9th	41	43	14-7	14-2 to 15-6

Criteria for Full Attainment

It was reported earlier that one test was used for each level of concept attainment and one test for each concept use. For each of the levels and uses subtests specific criteria determined full attainment. In general, the criterion established for each subtest was that all items, except one, had to be passed. Permitting one error was presumed to provide a reasonable degree of flexibility for possible error in measurement. The criteria established for full attainment are especially important inasmuch as passing the four levels consecutively is considered critical for describing the course of children's conceptual development as presumed by the CLD model.

Table 3 summarizes information describing the seven subtests, including the total number of items in each subtest and the criterion for full attainment of each particular level and use. There are two exceptions to the criteria convention; the classificatory subtest consisted of three items, all of which were required for attainment, and the labels test consisted of seven items, five of which were required for attainment. The criteria for the other levels of attainment and the three uses can be reviewed in Table 3. (Note that the model requires two other kinds of items in the assessment of the formal level; however, at the time of this administration these items were not yet developed.)

Proportion of Each Grade Group Conforming to the Predicted Invariant Sequence

Each successive level of concept attainment is postulated by the CLD model to require the use of one or more new cognitive operations. It is hypothesized that each subtest will be more difficult than the previous subtest because it requires the use of an additional cognitive operation. Thus, the CLD model itself constrains the number of acceptable patterns of success and failure for the four concept levels. Five patterns of passing and failing the four successive levels of attainment are consistent with the model. These are: to fail all four levels (FFFF), to pass the concrete level and fail the other three (PFFF), to pass both the concrete and identity and to fail the last two (PPFF), to pass the first three levels and fail formal (PPPF), and finally to pass all four levels (PPPP).

The first five rows of Table 4 show the number and proportion of each grade group that attained the successive levels according to each of the five patterns predicted by the model. Two hundred ninety-seven of the 324 subjects, or approximately 92%, performed as predicted. More specifically, the following numbers conform to each of the five predicted patterns: 9 FFFF, 5 PFFF,

TABLE 3

NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT FOR EACH CONCEPT LEVEL AND USE

Subtest	Number of Items	Criteria For Full Attainment
1. Concrete	8	7 correct
2. Identity	8	7 correct
3. Classificatory	3	3 correct
4. Formal		
a. Discriminating Attributes	3	2 correct
b. Labels	7	5 correct
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

37 PPFF, 120 PPPF, and 126 PPPP. The rank order of grade groups conforming to predicted patterns are ninth, third, sixth, and kindergarten.

There are 11 patterns of performance that are inconsistent with the model. The number and proportion of children who displayed non-conforming patterns appear at the bottom of Table 4. The 27 children (8%) who did not adhere to the predicted patterns were distributed over nine of the eleven deviating patterns. However, 17 of the exceptions are concentrated in three patterns. Six children passed the identity level who did not pass the concrete level and five individuals passed both the identity and classificatory level who did not pass the concrete level. Finally, six individuals passed the concrete, failed the identity, and then passed the classificatory level.

Inspection of Table 4 also reveals contributions of the four grade groups to non-conforming patterns. A total of 10 kindergarten subjects, six third graders, nine sixth graders and two ninth graders deviated from predicted sequences. Nearly half of the 17 cases that cluster in three patterns of exception, as noted earlier, originate in the kindergarten group.

The large percentage of children who conformed to the predicted patterns is highly supportive of the major proposition that individuals attain concepts in a highly predictable sequence. Although the percentage of children whose performance was consistent with the predicted sequence was very high, it may be informative to examine the protocols of children who showed non-conforming patterns to ascertain how near each child came to passing at the criterion specified for concept attainment.

Table 5 presents frequencies of subjects according to each pattern of exception and number of items correct at each concept level for which attainment criterion was not met. Since non-conforming patterns are those in which a subject fails a level and then goes on to attain one or more higher levels, performances which barely miss the criterion for attainment are the most easily explained. For example, Table 5 shows that about 50% of the subjects who failed the criterion for attainment at the concrete level, but who did attain at a more difficult level, fell short of the criterion (seven items correct) by only one item. Similarly, half the subjects who failed the identity level missed criterion for attainment by only one item, and all subjects who failed the classificatory subtest, but who went on to attain the formal level, fell short by only one item. These "bare miss" deviations from the sequence of predicted attainment are probably most simply interpreted as errors of measurement inevitably associated with each subtest, or as consequences of the stringent criteria established for full attainment. Explanations for protocols that indicate a subject attained a more difficult concept level after falling far short of criterion at a lower level are more problematic. However, measurement error may be again invoked to explain these cases, in addition to such specific situational contingencies as inattentiveness during test-taking and misunderstanding of directions.

Predicted Sequence of Concept Attainment and Difficulty of the Levels

The CLD hypothesis is that the sequence of attainment is invariant because each successively higher concept level requires the use of one or more increasingly complex cognitive operations. As a consequence the items and the total subtest at each successive level are more difficult. It might be argued that the invariant sequence of attainment is not a function of difficulty determined by increasingly complex cognitive operations at the successive concept levels, concrete through formal, but that it is simply a function of increasing test item difficulty unrelated to the operations. In order to ensure that the number of subjects conforming and not conforming to the predicted sequence was not merely due to increasing difficulty of the successive subtests unrelated to the more complex operations, a statistical procedure accounting for independent difficulty level was applied to data from the present assessment.

Computations were performed using the overall grade-group proportions passing and failing each of the four subtests so that a wide range of conceptual attainment would be obtained. These computations yielded expected numbers of subjects following each of the 16 possible patterns of attainment (five acceptable, 11 unacceptable to the model). It was noted that fewer than five subjects were expected to follow each of eight of the 16 patterns. To meet the requirements of the Chi-square test, patterns were combined so that the minimum expected number of subjects in each cell would approximate five. Ten patterns and combinations of patterns resulted and were used for the test. A Chi-square goodness-of-fit test was used to determine whether the obtained number of subjects who followed these patterns differed significantly from the number of subjects expected to follow these patterns.

TABLE 4

NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	K (n=62)	3rd (n=86)	6th (n=92)	9th (n=84)	All Grades (n=324)
FFFF	9 .15	0 .00	0 .00	0 .00	9 .03
PFFF	3 .05	2 .02	0 .00	0 .00	5 .02
PPFF	20 .32	13 .16	3 .03	1 .01	37 .11
PPPF	20 .32	52 .61	36 .39	12 .14	120 .37
PPPP	0 .00	13 .15	44 .48	69 .82	126 .39
Subtotal Conforming	52 .84	80 .93	83 .90	82 .98	297 .92
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	2 .03	0 .00	0 .00	0 .00	2 .01
FFPP	0 .00	1 .01	0 .00	0 .00	1 .00
FPFF	4 .07	0 .00	2 .02	0 .00	6 .02
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	3 .05	1 .01	0 .00	1 .01	5 .02
FPPP	0 .00	0 .00	1 .01	0 .00	1 .00
PFFP	0 .00	0 .00	0 .00	1 .01	1 .00
PFPF	1 .02	3 .04	2 .02	0 .00	6 .02
PFPP	0 .00	0 .00	3 .03	0 .00	3 .01
PPFP	0 .00	1 .01	1 .01	0 .00	2 .01
Subtotal Not Conforming	10 .16	6 .07	9 .10	2 .02	27 .08

TABLE 5

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

N	Pattern of Exception	Number of Items Correct on Concrete Subtest (7 required)						
		0	1	2	3	4	5	6
6	FPFF				2	1		3
2	FFPF	1		1				
1	FFPP							1
5	FPPF			1			2	2
1	FPPP							1
		Number of Items Correct on Identity Subtest (7 required)						
		0	1	2	3	4	5	6
2	FFPF			1	1			
1	FFPP							1
1	PFFP						1	
3	PFPP	1				1		1
6	PFPF	1						5
		Number of Items Correct on Classificatory (3 required)						
		0	1	2				
2	PPFP			2				
1	PFFP			1				

The resulting Chi-square provided convincing evidence that the number of subjects following and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations ($X^2 = 70.64$, d.f. = 5, $p < .001$).

Proportion of Grade Groups Attaining the Four Levels

Two related and important predictions regarding sequence of attainment of concept levels can be tested in a cross-sectional study. The first prediction holds that within a grade group the percentage of children passing each successive level should decrease. At the same time, the percentage of children passing a given level should increase as a function of increasing grade group.

Table 6 presents the number and proportion of each grade group that fully attained each concept level and thus provides information relevant to both predictions. Reflecting the accuracy of the first prediction, which asserts that the percentage of children within a single grade passing each successive level will decrease, Table 6 reveals that there is indeed a gradual decrement in the percentage of children at each grade group who pass the four successive concept levels. (One exception to the predicted direction occurred in the kindergarten group where 71% mastered the concrete level and 76%, the identity level. Hereafter, only reversals to predicted directions that are 5% or greater will be specifically noted.) The pattern within each grade group is also observable in the overall percentages for all grades. As shown in the bottom row of Table 6, 93% of the children passed the concrete level; 92%, the identity level; 81%, the classificatory level; and 41%, the formal level.

Cochran Q tests were used to find out if the proportions of subjects fully attaining the four concept levels differed significantly within each of the four grade groups. Significance of the differences among the proportions for each of the four grade groups was beyond the .001 level (Q = 91.72, kindergarten; 155.99, third grade; 89.13, sixth grade; 30.25, ninth grade [d.f. = 3]). McNemar tests were run at the .05 level of significance to determine where specific differences in attainment among the four levels occurred within each of the four grade groups. Six comparisons were possible: concrete with (1) identity, (2) classificatory and (3) formal; identity with (4) classificatory

TABLE 6

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT

Grade	Concrete	Identity	Classificatory	Formal
K(n=62)				
Number	44	47	26	0
Proportion	.71	.76	.42	.00
3rd (n=86)				
Number	84	80	70	15
Proportion	.98	.93	.81	.17
6th (n=92)				
Number	89	87	86	49
Proportion	.97	.95	.93	.53
9th (n=84)				
Number	83	83	82	70
Proportion	.99	.99	.98	.83
All Grades (N=324)				
Number	300	297	264	134
Proportion	.93	.92	.81	.41

and (5) formal; finally, classificatory with (6) formal. Five of the six comparisons differed significantly for the kindergarten grade group, the exception being concrete with identity. In each set of comparisons that did differ significantly, fewer kindergarten children passed the higher concept level. For the third-grade group, the comparison between identity and classificatory differed significantly. For the third-, sixth-and ninth-grade groups, differences between concrete and formal, identity and formal, and classificatory and formal were significant. In each comparison, fewer children attained the higher concept level.

Information in the columns of Table 6 is directly relevant to the second prediction--the percentage of children passing any particular level of concept attainment should increase as a function of increasing grade group. For example, 42% of kindergarten children, 81% of the third graders, 93% of the sixth graders, and 98% of the ninth graders fully attained the concept at the classificatory level.

Chi-square tests were used to ascertain whether the proportions of individual grade groups passing each of the four levels differed significantly from the proportions of the combined grade groups passing each of the four levels of concept attainment. The difference in proportions attaining each of the levels was significant beyond the .001 level (Chi-square = 52.55, concrete; 27.25, identity; 87.53, classificatory; 130.41, formal [d.f. = 3]). A Chi-square analog to Scheffé's theorem was performed to determine where differences between grade groups in attainment of each of the four levels were significant at the .05 level. Significant results were as follows: at the concrete, identity, and classificatory levels, the third-, sixth-, and ninth-grade groups each surpassed attainment of the kindergarten group. At the classificatory level, performances of sixth and ninth graders were also superior when each was compared with performance of third graders. All pair-wise comparisons of grade groups were significantly different at the formal level; that is, the higher the grade group, the greater the proportion of children attaining the formal level.

Quite clearly, both of the predictions dealing with difficulty of the levels receive strong support from the data assessing full attainment of the concept, equilateral triangle.

Relationship Between Full Attainment of Various Levels and Full Attainment of the Various Uses

The CLD model specifies that individuals who have attained a concept only to the concrete or to the identity level may be able to use that concept in cognizing simple perceptual relations among concepts and in solving simple problems of a perceptual kind but that they will not be able to use the concept in understanding supraordinate-subordinate relations, understanding more complex principles, or in solving more complex problems. It also implies that individuals who attain the formal level will perform the uses subtests more effectively than those whose conceptual attainment is only at the classificatory level.

Inspection of Table 7 discloses information bearing on the first prediction. For those five individuals whose highest level of concept attainment was concrete, none passed any concept use subtest. Forty-three children from kindergarten through grade nine passed the identity level as their highest level of attainment. Of these, only three third graders were able to pass a uses subtest (supraordinate-subordinate). That is, in the present research, only 7% of the 43 subjects achieving the identity level successfully mastered any of the uses of the concept equilateral triangle.

Table 7 presents information of special interest for comparing the performances of individuals attaining the classificatory level and those attaining the formal level. According to the CLD model, each of the concept uses should be mastered by a higher percentage of children who perform at the formal level than by children who attain only the classificatory level.

A total of 133 subjects mastered the classificatory level as their highest level and another 134 subjects mastered the formal level, as can be seen in the bottom rows of Table 7. Comparisons between children performing at these two levels in terms of their performance on the three uses subtests are of special interest for both learning theorists and educators.

The supraordinate-subordinate subtest was passed by 8% of those who passed the classificatory level and by 34% of those who passed the formal level. The principles subtest was mastered by 5% of those who passed the classificatory level compared to 43% of those who passed the formal level. Problem solving was passed by only 3% of the subjects whose highest attainment was the classificatory level, whereas 34% of the subjects who passed the formal level were also able to solve problems successfully.

Statistical tests also revealed the overall superiority on uses subtests for children operating at the formal level of concept attainment. For each of the three concept uses, Chi-square tests showed a significant overall advantage (beyond the .001 level) for children performing at the formal level when compared to those performing at the classificatory level (Chi-square = 27.72, supraordinate-subordinate; 53.54, principle; 41.64, problem-solving [d.f. = 1]).

In summary, the data obtained from assessment of equilateral triangle strongly support the prediction that attainment of a concept at the formal level, in comparison with attainment only at the classificatory level, facilitates uses of the concept.

Difficulty of the Three Uses

Table 8 presents the number and proportion of subjects who fully attained each of the three concept uses: supraordinate-subordinate, principle, and problem solving. The prediction was that performance would improve as a function of increasing grade group. Of special interest is the marked improvement that occurred in mastery of the three concept uses between sixth and ninth grade. The large increase in numbers of children who successfully mastered the uses subtests is attributed to some combination of instruction regarding equilateral triangle, as well as to the emergence of cognitive operations specified by the model.

Chi-square tests were run to ascertain the significance of the difference between the proportions of individual grade groups passing each of the three uses and the proportion of the combined grade groups passing each of the three concept uses. The difference in the proportion of subjects attaining each of the uses was significant beyond the .001 level (Chi-square = 48.92, supraordinate-subordinate; 117.88, principle; 81.43, problem-solving [d.f. = 3]). A Chi-square analog to Scheffé's theorem was performed between all pairs of grade groups to determine where the differences in the uses were significant at the .05 level. Statistically significant results were as follows: the ninth grade's mastery of the three concept uses was superior to that of each of the other grade groups. In addition, performance of sixth graders surpassed that of third graders and kindergarteners on the subtest involving principles. Sixth graders were superior to third graders on the problem-solving subtest.

TABLE 7

RELATIONSHIP BETWEEN FULL MASTERY OF VARIOUS LEVELS AND FULL MASTERY OF USES

Grade	Concrete as Highest			Identity as Highest			Classificatory But Not Formal			Formal		
	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.
K												
N Passing Level	3			24			26			0		
N Passing Use	0	0	0	0	0	0	0	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3rd												
N Passing Level	2			13			56			15		
N Passing Use	0	0	0	3	0	0	6	0	0	3	0	0
Proportion	.00	.00	.00	.23	.00	.00	.11	.00	.00	.20	.00	.00
6th												
N Passing Level	0			5			38			49		
N Passing Use	0	0	0	0	0	0	3	2	3	8	12	9
Proportion	.00	.00	.00	.00	.00	.00	.08	.05	.08	.16	.24	.18
9th												
N Passing Level	0			1			13			70		
N Passing Use	0	0	0	0	0	0	1	4	1	34	45	36
Proportion	.00	.00	.00	.00	.00	.00	.08	.31	.08	.49	.64	.51
All Grades												
N Passing Level	5			43			133			134		
N Passing Use	0	0	0	3	0	0	10	6	4	45	57	45
Proportion	.00	.00	.00	.07	.00	.00	.08	.05	.03	.34	.43	.34

TABLE 8

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH OF THE THREE CONCEPT USES

Grade	Supraordinate-Subordinate	Principle	Problem Solving
K (n=62)			
Number	0	0	0
Proportion	.00	.00	.00
3rd (n=86)			
Number	12	0	0
Proportion	.14	.00	.00
6th (n=92)			
Number	11	14	12
Proportion	.12	.15	.13
9th (n=84)			
Number	35	49	37
Proportion	.42	.58	.44
All Grades (N=324)			
Number	58	63	49
Proportion	.18	.19	.15

Examination of Table 8 reveals another point of interest. Eighteen percent of all subjects passed the supraordinate-subordinate subtest, 19% the principle subtest, and 15% the problem-solving subtest. These rather modest attainments must be interpreted in terms of the items used in the subtests, the criteria established for passing the subtests, and the nature or the particular concept, equilateral triangle. Obviously, it should not be assumed that these same results for full attainment would obtain for other concepts.

The prediction that the higher grade groups, compared to the lower, would demonstrate greater mastery of concept uses has received strong support from these data.

Relationship Between Vocabulary Development and Attainment of Concept Levels and Uses

As described earlier, language has been accorded a central role in the learning of concepts by the CLD model as well as several other theories. Figure 1 makes explicit that verbal labels or other symbols may be learned at any of the first three levels and are essential at the formal level of concept attainment. It is presumed also that the acquisition of labels facilitates using the concept in solving problems, understanding principles, and cognizing supraordinate-subordinate relations. This section is specifically addressed to the prediction that having the verbal labels for the concept of equilateral triangle and its attributes will be positively correlated with attainment of the levels and performance on uses subtests.

In order to compute correlation coefficients, a special scaling system was used. For each subject, a point score of 1 was assigned to full attainment of each concept level and each use, and a score of 0 to each when mastery was not attained. The second variable for all computations was the mean performance on the seven-item vocabulary test in which a score of 1 was again assigned to each correctly answered item. Therefore, for each individual, scores on the four concept levels could vary from 0-4; scores on the three concept uses could vary from 0-3; and scores combining levels and uses could vary from 0-7. (Combining levels and uses subtests provided a measure of overall task performance.) Similarly, the scores on the vocabulary test varied from 0, for no labels correct, to a perfect score of 7. For each subject, then, overall performances on concept level subtests, uses subtests, combined levels and uses subtests, and vocabulary were calculated. (Other means of scoring the levels and uses are under empirical study.)

This scoring system generated Table 9 which presents means and standard deviations for levels, uses, levels and uses, and vocabulary scores at each grade group. It can be observed that performance on the vocabulary test improved considerably with increasing grade group. The predicted improvement in concept attainment with increasing grade group is again demonstrated. In addition, older children, compared to younger, obtained higher mean scores on uses subtests, as well as on a combination of levels and uses subtests.

Pearson product-moment correlations (r) were then calculated in order to discover the relationship between vocabulary comprehension and task performance. Table 10 presents, for each grade group, the correlations between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses.

Inspecting this table shows that the correlations within each grade group are fairly modest, especially among the youngest subjects; the low correlations reflect, no doubt, a limited range of performance among the younger children. The vocabulary scores of the kindergarten group, for example, showed little comprehension of verbal labels; the range of attainment on concept levels was small; and no uses subtests were passed. For this grade group, correlations were either zero or of a very low order. Third, sixth, and ninth graders, by contrast, demonstrated an increasing competence with verbal labels, and a wider range of performance on concept attainment and concept uses. Thus, the correlations for these grade groups, although not extremely high, do indicate a positive relationship between test performance and vocabulary scores. In fact, seven of the nine correlations obtained for third, sixth, and ninth grade groups were statistically significant from zero at or beyond the .05 level.

For the total subject population, correlations were considerably higher. Between overall performance on concept level subtests and overall performance on the vocabulary subtest, the correlation was .57. The correlation between overall performance on three concept uses and vocabulary scores was .56 and between overall performance on combined levels and uses and vocabulary scores, .70. These three correlations were statistically significant from 0 at or beyond the .01 level. The predicted relation between vocabulary proficiency and concept attainment and use is clearly supported by the obtained correlations.

TABLE 9

MEANS AND STANDARD DEVIATIONS FOR COMBINED CONCEPT LEVELS, CONCEPT USES, COMBINED LEVELS AND USES, AND VOCABULARY AT EACH GRADE GROUP

Grade	N	Concept Levels: (Maximum score, 4)		Concept Uses: (Maximum score, 3)		Levels and Uses: (Maximum score, 7)		Vocabulary: (Maximum score, 7)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
K	62	2.27	1.19	.00	.00	2.27	1.19	.44	.80
3rd	86	3.50	.72	.14	.35	3.64	.82	2.83	1.65
6th	92	3.80	.50	.40	.74	4.21	.96	4.40	1.74
9th	84	3.90	.40	1.44	1.09	5.35	1.28	5.92	1.36
All Grades	324	3.46	.93	.52	.90	3.98	1.49	3.61	2.41

TABLE 10

PEARSON PRODUCT-MOMENT CORRELATIONS
BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON
CONCEPT LEVELS, CONCEPT USES, AND COMBINED LEVELS AND USES.

Grade Group	N	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K	62	.14	.00	.15
3rd	86	.43**	.06	.40**
6th	92	.18	.38**	.39**
9th	84	.25*	.42**	.44**
All Grades	324	.57**	.56**	.70**

* $p < .05$
** $p < .01$

IV
Results of CLD Assessment Series II: Cutting Tool

Overview

This chapter begins with a description of the child population and the criteria for full attainment of each of the seven subtests used in assessing cutting tool. Results of the assessment, as they bear on specific predictions of the CLD model, are reported in the major part of this chapter.

Child Population

Three hundred and sixty-three children participated in assessment of the concept, cutting tool. Table 11 shows the composition of the total number of subjects according to age and sex. Seventy-six children from kindergarten, 93 from third grade, 101 from sixth grade, and 93 from ninth grade took part in the study. The total number of boys and girls is very close, 181 and 182 respectively; within each grade group boys and girls are not equally represented because intact classrooms were used. Age ranges varied from 13 months, for the third graders, to 16 months, for both sixth and ninth graders.

Criteria for Full Attainment

Criteria were again determined to define full attainment of each of the four concept levels and three uses. In general, attainment on a subtest was permitted only when the subject missed no more than one item, as shown in Table 12. In order to provide some flexibility for possible error of measurement, one error was permissible. For several of the subtests, however, the criterion was lowered somewhat when the number of items on a subtest was fairly large. For example, assessment of the concrete concept level included 12 items, 10 of which were required for full attainment. It should be noted that in addition to tests for discriminating attributes and for knowledge of labels, a definition (required for attainment) was included at the formal level. Items comprising each of the remaining subtests and specific criteria for attainment may be found in Table 12.

Proportion of Each Grade Group Conforming to the Predicted Invariant Sequence

The descriptive data included in this section are addressed to the prediction that the sequence of attainment of the four concept levels is invariant. Only five patterns of passing and failing the four successive levels are compatible with the CLD model (FFFF, PFFF, PPFF, PPPF, and PPPP). Logic generates an additional eleven pass-fail patterns that are deviant, but must be included for an evaluation of the model's power.

The first five rows of Table 13 present the permissible pass-fail patterns and the number and proportion of each grade group falling within each pattern. From the total number of 363 subjects, 340 or about 94% demonstrated attainment in a sequence consistent with the model. Nearly 90% of the 340 subjects who did conform to acceptable patterns can be observed in either the PPPP or the PPPF sequence. The rank order of grade groups conforming to predicted patterns are third, ninth, kindergarten, and sixth.

The number and proportion of children who displayed non-conforming patterns appear in the remainder of Table 13. About 6% (23 subjects) of the total population deviated from the acceptable sequence; all cases fall into one of three deviating patterns, but most (18 out of 23) displayed the PPFP pattern. That is, 78% of the subjects who showed non-conforming patterns passed the concrete and

TABLE 11

NUMBER OF MALES AND FEMALES, MEAN AGE, AND AGE RANGE AT EACH GRADE GROUP

Grade	Males	Females	Mean Age (in years and months)	Age Range (in years and months)
K	38	38	6-0	5-6 to 6-9
3rd	53	40	9-2	8-6 to 9-7
6th	44	57	12-2	11-4 to 12-8
9th	46	47	15-1	14-4 to 15-8

TABLE 12

NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT FOR EACH CONCEPT LEVEL AND USE

Subtest	Number of Items	Criteria For Full Attainment
1. Concrete	12	10 correct
2. Identity	12	10 correct
3. Classificatory	6	5 correct
4. Formal		
a. Discriminating Attributes	5	4 correct
b. Labels	6	5 correct
c. Definition	1	1 correct
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

identity levels, failed classificatory, and went on to attain the formal level.

Sixth graders contributed to eleven of the 23 deviating cases and all of these were subjects who attained the concrete and identity levels, but who passed the formal level after failing the classificatory. Six non-conforming cases showed up among ninth graders, also in the PPFP pattern of exception. Five subjects in the kindergarten group did not conform; only one case of deviation was displayed by the third-grade group.

Although the percentage of children whose performance was consistent with predicted sequence of attainment was very large, examination of the protocols of children whose performance violated the prediction may be instructive; explanations for these anomalous cases may lie in a more thorough scrutiny of their test performance.

Table 14 shows frequencies of subjects according to each pattern of exception and number of items correct at each concept level for which attainment criterion was not met. Three subjects passed the identity level after falling far short of criterion for the concrete

TABLE 13

NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	K (n=76)	3rd (n=93)	6th (n=101)	9th (n=93)	All Grades (n=363)
FFFF	1 .01	0 .00	0 .00	0 .00	1 .00
PFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PPFF	15 .20	15 .16	4 .04	0 .00	34 .09
PPPF	54 .71	42 .45	26 .26	8 .09	130 .36
PPPP	1 .01	35 .38	60 .59	79 .85	175 .48
Subtotal Conforming	71 .93	92 .99	90 .89	87 .94	340 .94
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	0 .00	0 .00	0 .00	0 .00	0 .00
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	3 .04	0 .00	0 .00	0 .00	3 .01
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	0 .00	0 .00	0 .00	0 .00	0 .00
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	2 .03	0 .00	0 .00	0 .00	2 .01
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	1 .01	11 .11	6 .07	18 .05
Subtotal Not Conforming	5 .07	1 .01	11 .11	6 .07	23 .06

TABLE 14

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

N	Pattern of Exception	Number of Items Correct on Concrete Subtest (10 required)									
		0	1	2	3	4	5	6	7	8	9
3	FPFF			1			1	1			
		Number of Items Correct on Identity Subtest (10 required)									
		0	1	2	3	4	5	6	7	8	9
2	PFPF										2
		Number of Items Correct on Classificatory Subtest (5 required)									
		0	1	2	3	4					
18	PPFP					18					

subtest (10 of 12 items were required for attainment). These three subjects were all in the kindergarten group. Explanation for such deviating cases probably must rest, at this point, in presuming inattention to directions or misunderstanding test instructions. Two individuals showed the PFPF pattern of exception and 18 the PPFP pattern. All of these cases failed a level that should have been attained, according to the CLD model, by falling just one item short of criterion, as can be observed in Table 14. Thus, when protocols are examined, it is clear that a predicted pattern was just barely missed. Errors of measurement and stringency of criteria are probably both responsible for such performances.

Predicted Sequence of Concept Attainment and Difficulty of the Levels

The CLD hypothesis is that the sequence of attainment is invariant because each successively higher concept level requires the use of one or more increasingly complex cognitive operations. As a consequence the items and the total subtest at each successive level are more difficult. It might be argued that the invariant sequence of attainment is not a function of difficulty determined by increasingly complex cognitive operations at the successive concept levels, concrete through formal, but that it is simply a function of increasing test item difficulty unrelated to the operations. In order to ensure that the number of subjects conforming and not conforming to the predicted sequence was not merely due to increasing difficulty of the successive subtests unrelated to the more complex operations, a statistical procedure accounting for independent difficulty level was applied to data from the present assessment.

Computations were performed using the overall grade-group proportions passing and failing each of the four subtests so that a wide range of conceptual attainment would be obtained. These computations yielded expected numbers of subjects following each of the 16 possible patterns of attainment (five acceptable, 11 unacceptable to the model). It was noted that fewer than five subjects were expected to follow each of 12 of the 16 patterns. To meet the requirements of the Chi-square test, patterns were combined so that the minimum expected number of subjects in each cell would approximate five. Six patterns and combinations of patterns resulted and were used for the test. A Chi-square goodness-of-fit test was used to determine whether the obtained number of subjects who followed these patterns differed significantly from the number of subjects expected to follow these patterns. The resulting Chi-square provided convincing evidence that the number of subjects following

GPO 807-786-6

and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations (X^2 = 9.53, d.f. = 1, $p < .01$).

Proportion of Grade Groups Attaining the Four Levels

The interrelated predictions that will be evaluated in this section state that within a given grade group the percentage of children passing each successive level should decrease and, at the same time, the percentage of children passing a given level should increase as a function of increasing grade group.

The number and proportion of each grade group that fully attained each concept level are presented in Table 15. Inspection of these data shows that within each grade group, as predicted, fewer children attain concept levels as the levels become more difficult. This trend is especially marked when proceeding from identity to classificatory and from classificatory to formal. For example, about 95% of the kindergarten subjects attained both the concrete level and the identity level; but the percentage attaining the classificatory level declined to 75% and only 1% attained the formal level. Similar patterns occur with each of the other grade groups, as well as in the proportions resulting from combining all grade groups.

Cochran Q tests were used to find out if the proportions of subjects fully attaining the four concept levels differed significantly within each of the four grade groups. Significance of the differences among the proportions for each of the four grade groups was beyond the .01 level (Q = 173.76, kindergarten; 137.95, third grade; 58.46, sixth grade; 14.57, ninth grade [d.f. = 3]). McNemar tests were run at the .05 level of significance to discover where specific differences in attainment among the four levels occurred within each of the four grade groups. Six comparisons were possible: concrete with (1) identity, (2) classificatory and (3) formal; identity with (4) classificatory and (5) formal; finally, classificatory with (6) formal. In the kindergarten, third, and sixth-grade groups, every comparison showed a significant difference except that between concrete and identity levels. That is, every comparison within each of these grade groups indicated fewer children attained the higher concept level. In the ninth-grade group, four comparisons were significantly different in attainment of levels: concrete and classificatory; concrete and formal; identity and classificatory; and identity and formal. Again, the higher the concept level, the fewer the children who attained it.

According to the CLD model, the percentage of children passing any particular level of concept attainment should increase as a function of increasing grade group. The columns of Table 15 reveal a consistent trend, at each concept level, for the percentages attaining a level to increase as grade group increases. This increment is especially pronounced at the formal level in which attainment was demonstrated by 1% of the kindergarten grade group, 39% of the third graders, 70% of the sixth graders and 91% of the ninth graders.

Chi-square tests were used to determine whether the proportions of individual grade groups passing each of the four levels of concept attainment differed significantly from the proportions of the combined grade groups passing each of the four levels. The difference in proportions attaining each of the levels was significant beyond the .05 level (Chi-square = 15.27, concrete; 11.42, identity; 11.33, classificatory; 156.36, formal [d.f. = 3]). In order to discover where differences among grade groups in attainment of each of the four levels were significant at the .05 level, a Chi-square analog to Scheffe's theorem was used. Statistically significant results were as follows: at the concrete and identity levels, third, sixth, and ninth-grade groups each surpassed attainment of kindergartners. At the classificatory level, the ninth-grade group was superior to the kindergarten group. At the formal level, all pair-wise comparisons of grade groups were significantly different; that is, the higher the grade group, the greater the proportion of children attaining the formal level.

The predictions that deal with increasing difficulty of the levels received considerable support from the data assessing full attainment of the concept, cutting tool.

Relationship Between Full Attainment of Various Levels and Full Attainment of the Various Uses

This section is concerned with the two predictions that deal with the relation between level of concept attainment and use of the concept in cognizing supraordinate-subordinate relations, understanding principles, and in solving problems. First, the CLD model predicts that individuals who are able to attain a concept only at the concrete or identity level are restricted in their effective use of the concept; simple problems of a perceptual

TABLE 15

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT

Grade	Concrete	Identity	Classificatory	Formal
K (n=76)				
Number	72	73	57	1
Proportion	.95	.96	.75	.01
3rd (n=93)				
Number	93	93	77	36
Proportion	1.00	1.00	.83	.39
6th (n=101)				
Number	101	101	86	71
Proportion	1.00	1.00	.85	.70
9th (n=93)				
Number	93	93	87	85
Proportion	1.00	1.00	.94	.91
All Grades (n=363)				
Number	359	360	307	193
Proportion	.99	.99	.85	.53

kind may be solved and similar principles may be understood, but more complex problem solving and understanding principles is not predicted.

Consider Table 16. No children attained the concrete level as their highest level. Among those 37 children whose highest level of attainment was identity, there were 16 instances of attainment on uses (nine, supraordinate-subordinate; six, problem-solving; one, principles). Such a large number is, of course, discrepant with the prediction and requires some further attention.

Twelve subjects were responsible for these 16 instances of mastery of uses by identity level attainers. That is, in several cases the _same_ subject attained criterion on more than one uses subtest. A more detailed examination of the protocols of these 12 children may provide some explanation for their performance. Ten of the 12 subjects barely missed criterion for attainment at the classificatory level. Five out of six items were required for mastery; these children passed four out of six. Eleven of these subjects missed the same two specific items of the six included at the classificatory level. These two items, in particular, were difficult because item instructions could have been legitimately interpreted to include responses that were, in fact, scored as incorrect. These ambiguous classificatory items have been revised or discarded for future use in the _cutting tool_ battery. Proficiency on the uses subtests by identity-level children, then, is attributed to their barely missing attainment at the classificatory level, which in turn was due to several ambiguous items.

Comparing performances of individuals attaining the classificatory level with those attaining the formal level permits an evaluation of the second prediction to be considered in this section: concept uses should be mastered by a higher percentage of children attaining the formal level compared to those attaining at the classificatory level. Table 16 shows that the supraordinate-subordinate subtest was passed by 27% of those who attained at the classificatory level and 75% of those at the formal level. The principle subtest was passed by 7% of classificatory attainers compared to 48% of those who attained at the formal level. Finally, 20% of those individuals who attained at the classificatory level, compared to 73% of those attaining at the formal level, were able to solve problems successfully.

For each of the three concept uses, Chi-square tests also showed a significant advantage (beyond the .001 level) for children performing at the formal level when compared to those performing at the classificatory level (Chi-square = 71.09, supraordinate-subordinate; 61.07, principle; 87.59,

TABLE 16

RELATIONSHIP BETWEEN FULL MASTERY OF VARIOUS LEVELS AND FULL MASTERY OF USES

Grade	Concrete as Highest			Identity as Highest			Classificatory But Not Formal			Formal		
	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.
K												
N Passing Level	0			18			56			1		
N Passing Use	0	0	0	0	0	0	6	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.11	.00	.00	.00	.00	.00
3rd												
N Passing Level	0			15			42			36		
N Passing Use	0	0	0	7	1	5	13	2	16	20	7	17
Proportion	.00	.00	.00	.47	.07	.33	.31	.05	.38	.56	.20	.47
6th												
N Passing Level	0			4			26			71		
N Passing Use	0	0	0	2	0	1	12	5	9	53	25	46
Proportion	.00	.00	.00	.50	.00	.25	.46	.19	.35	.75	.35	.65
9th												
N Passing Level	0			0			8			85		
N Passing Use	0	0	0	0	0	0	5	2	1	71	60	77
Proportion	.00	.00	.00	.00	.00	.00	.63	.25	.13	.84	.71	.91
All Grades												
N Passing Level	0			37			132			193		
N Passing Use	0	0	0	9	1	6	36	9	26	144	92	140
Proportion	.00	.00	.00	.24	.03	.16	.27	.07	.20	.75	.48	.73

problem solving [d.f. = 1]).

Data obtained from assessment of cutting tool provide strong support for the prediction that, in comparison with attainment at the classificatory level, attainment of a concept at the formal level has a facilitative effect on ability to use the concept.

Difficulty of the Three Uses

In order to evaluate the prediction that performance on uses subtests would improve as a function of increasing grade group, Table 17 presents the number and proportion of subjects at each grade who fully attained each of the three concept uses: supraordinate-subordinate, principle, and problem solving. Inspection shows that with each successively higher grade group there was a marked increment in percentage of subjects meeting criteria for attainment. For example, 8% of the kindergarten group, 43% of the third graders, 66% of the sixth graders, and 82% of the ninth graders fully attained the supraordinate-subordinate subtest. The same pattern of progression occurred for the other two uses subtests.

Examination of Table 17 also shows that 52% of all subjects passed the supraordinate-subordinate subtest, 28%, principle, and 47%, problem solving. These overall attainments on uses are fairly impressive, but must be considered as specific to the particular concept, subtest items, and criteria for mastery.

Chi-square tests were used to find the significance of the difference between the proportions of individual grade groups passing each of the three uses and the proportion of the combined grade groups passing each of the three concept uses. The difference in the proportion of subjects attaining each of the uses was significant beyond the .001 level (Chi-square = 103.48, supraordinate-subordinate; 112.15, principle; 122.32, problem solving [d.f. = 3]). A Chi-square analog to Scheffé's theorem was performed between all pairs of grade groups to discover where the differences in performance on the uses subtests were significant at the .05 level. Statistically significant results were as follows: for the supraordinate-subordinate subtest, the performances of third-, sixth-, and ninth-grade groups were each superior to that of kindergarteners; both sixth- and ninth-grade groups surpassed the performance of third graders. For the principle subtest, the performance of ninth graders was superior to that of each of the other grade groups; attainment of sixth graders also surpassed third graders and kindergarteners. For the problem-solving subtest, performance of the ninth-grade group was superior to that of each of the other grade groups; the third- and sixth-grade groups also each surpassed the performance of the kindergarten group.

Data obtained from performance on uses subtests of the concept, cutting tool, strongly support the prediction of an increased ability to use the concept with increasing grade group.

Relationship Between Vocabulary Development and Attainment of Concept Levels and Uses

This section of the present report is concerned with the predicted relation between vocabulary proficiency and attainment of the levels and performance of the uses. In order to compute correlation coefficients, the same scaling system was employed for cutting tool as that described in Chapter III for equilateral triangle. The reader is referred to the preceding chapter for a complete description of the scaling system.

Table 18 presents means and standard deviations, based on the scaled scoring system, for levels, uses, combined levels and uses, and vocabulary scores at each grade group. Performance on the six-item vocabulary test of the cutting tool assessment battery was quite proficient at each of the four grade groups, although Table 18 does show some gradual improvement over grades. The predicted improvement in concept attainment with increasing grade group is, of course, apparent in these data based on mean scaled scores as it was in the data based on proportions. Table 18 also shows that, compared to younger children, older children obtained higher mean scores on the uses subtests and on overall test performance (i.e., combining levels and uses).

Pearson product-moment correlations were calculated between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses. These correlations for each grade group and over all grade groups are presented in Table 19. Although fairly modest, eight of the correlations within grade groups were sufficiently high to show statistical significance from zero at or beyond the .01 level. Interestingly, the correlations at the ninth-grade group are very low (and include one negative correlation). Explanation for these low correlations may be found by examination of Table 18 which indicates little variability in obtained mean scores for the ninth graders; variability on the vocabulary test was extremely small. The low correlations obtained for the ninth-grade group reflect this marked lack of variability.

Compared to within-grade group correlations, those obtained for the total subject population were of a greater magnitude, as predicted, and all were statistically significant from zero at or beyond the .01 level. The correlation between vocabulary and overall performance on concept level subtests was .51. Vocabulary correlated .43 with overall performance on concept uses, and .52 with overall performance on levels and uses. The predicted relationship between vocabulary proficiency and concept attainment and use receives strong support from these data.

TABLE 17

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH OF THE THREE CONCEPT USES

Grade	Supraordinate-Subordinate	Principle	Problem Solving
K (n=76)			
Number	6	0	0
Proportion	.08	.00	.00
3rd (n=93)			
Number	40	10	38
Proportion	.43	.11	.41
6th (n=101)			
Number	67	30	56
Proportion	.66	.30	.55
9th (n=93)			
Number	76	62	78
Proportion	.82	.67	.84
All Grades (n=363)			
Number	189	102	172
Proportion	.52	.28	.47

TABLE 18

MEANS AND STANDARD DEVIATIONS FOR COMBINED CONCEPT LEVELS, CONCEPT USES, LEVELS AND USES, AND VOCABULARY AT EACH GRADE GROUP

Grade Group	N	Concept Levels: (Maximum Score, 4)		Concept Uses: (Maximum Score, 3)		Levels and Uses: (Maximum Score, 7)		Vocabulary: (Maximum Score, 6)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
K	76	2.67	.67	.08	.27	2.75	.73	4.72	1.39
3rd	93	3.22	.70	.95	.86	4.16	1.23	5.22	1.22
6th	101	3.55	.57	1.51	1.00	5.07	1.31	5.65	.93
9th	93	3.85	.36	2.32	.81	6.17	1.01	5.96	.20
All Grades	363	3.36	.72	1.28	1.13	4.63	1.64	5.42	1.11

TABLE 19

PEARSON PRODUCT-MOMENT CORRELATIONS BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES IN CONCEPT LEVELS, CONCEPT USES, AND COMBINED LEVELS AND USES

Grade Group	N	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K	76	.41**	.20	.43**
3rd	93	.35**	.30**	.41**
6th	101	.44**	.31**	.43**
9th	93	-.09	.15	.09
All Grades	363	.51**	.43**	.52**

** $p < .01$

V
Results of CLD Assessment Series III: Noun

Overview

The present chapter first describes the child population, and then presents the specific criteria determining full attainment of each of the seven subtests in the battery. Results of the assessment of noun, as they bear on specific predictions of the CLD model, comprise the major portion of this chapter.

Child Population

Table 20 shows that 325 children participated in this assessment: 59 kindergarteners, 88 third graders, 91 sixth graders, and 87 ninth graders. The total number of boys and girls, 163 and 162 respectively, is very close although within grade groups the number of boys and girls is not equal because intact classrooms were used. Age range varied from 14 months for the two youngest grade groups to 17 months for the nintn-grade group.

Criteria for Full Attainment

The number of items included in each subtest and the criterion determining full attainment on each subtest are presented in Table 21. In general, attainment of a subtest was permitted only when the subject missed no more than one item; permitting one error made some allowance for possible error of measurement. The subtest at the formal level also included a definition which was required for attainment of that level. Composition of the remaining subtests, along with criteria for passing, can be found in Table 21.

Proportion of Each Grade Group Conforming to the Predicted Invariant Sequence

In this section, descriptive data are considered in order to evaluate the prediction that the sequence of attainment of the four concept levels is invariant. The number and proportion of subjects at each grade group who attained the successive levels according to the five patterns that are consistent with the model are presented in the first five rows of Table 22. Three hundred and nineteen subjects, or about 98%, conformed to the model. More specifically, the five predicted patterns included the following numbers: 42 FFFF, 16 PFFF, 95 PPFF, 141 PPPF, and 25 PPPP. Rank order of grade groups conforming to predicted patterns are sixth, third, ninth, and kindergarten.

The number and proportion of subjects who performed according to the 11 patterns of performance that are inconsistent with the model are presented in the remainder of Table 22. Of the six children (2%) who deviated, three showed the FPFF and three the PPFP patterns of exception. Two kindergarten children, one third grader, one sixth grader, and two ninth graders failed to conform to predicted patterns.

Table 23 presents frequencies of subjects for each pattern of exception observed in the present assessment. Examination of these five protocols may be helpful in determining why performance did not conform to the predicted sequence. Three subjects (all from the two youngest grade groups) passed the identity level after failing the concrete level. Inspection of Table 23 shows that these three children just missed criterion for attainment on the concrete subtest. One sixth grader and two ninth graders failed the classificatory level, but went on to pass formal. Examination of Table 23 indicates that two of these individuals barely missed the criterion for attainment on the classificatory subtest, and one individual fell further short of criterion. It seems most reasonable to diagnose all six cases of non-conformity to the model as due to either measurement error, stringency of criteria, or both.

TABLE 20

NUMBER OF MALES AND FEMALES, MEAN AGE, AND AGE RANGE AT EACH GRADE GROUP

Grade	Males	Females	Mean Age (in years and months)	Age Range (in years and months)
K	31	28	6-3	5-8 to 6-10
3rd	49	39	9-4	8-7 to 9- 9
6th	39	52	12-4	11-6 to 12-10
9th	44	43	15-2	14-5 to 15-10

TABLE 21

NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT
FOR EACH CONCEPT LEVEL AND USE

Subtest	Number of Items	Criteria for Full Attainment
1. Concrete	8	7 correct
2. Identity	8	7 correct
3. Classificatory	8	7 correct
4. Formal		
a. Discriminating attributes	4	3 correct
b. Labels	9	7 correct
c. Concept definition	1	1 correct
5. Principle	4 pairs	3 correct
6. Problem Solving	4	3 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

Predicted Sequence of Concept Attainment and Difficulty of the Levels

The CLD hypothesis is that the sequence of attainment is invariant because each successively higher concept level requires the use of one or more increasingly complex cognitive operations. As a consequence the items and the total subtest at each successive level are more difficult. It might be argued that the invariant sequence of attainment is not a function of difficulty determined by increasingly complex cognitive operations at the successive concept levels, concrete through formal, but that it is simply a function of increasing test item difficulty unrelated to the operations. In order to ensure that the number of subjects conforming and not conforming to the predicted sequence was not merely due to increasing difficulty of the successive subtests unrelated to the more complex operations, a statistical procedure accounting for independent difficulty level was applied to data from the present assessment.

GPO 807-766-5

TABLE 22

NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	K (n=59)	3rd (n=88)	6th (n=91)	9th (n=87)	All Grades (n=325)
FFFF	40 .68	1 .01	1 .01	0 .00	42 .13
PFFF	16 .27	0 .00	0 .00	0 .00	16 .05
PPFF	1 .02	57 .65	24 .26	13 .15	95 .29
PPPF	0 .00	29 .33	64 .70	48 .55	141 .43
PPPP	0 .00	0 .00	1 .01	24 .28	25 .08
Subtotal Conforming	57 .97	87 .99	90 .99	85 .98	319 .98
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	0 .00	0 .00	0 .00	0 .00	0 .00
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	2 .03	1 .01	0 .00	0 .00	3 .01
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	0 .00	0 .00	0 .00	0 .00	0 .00
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	0 .00	0 .00	0 .00	0 .00	0 .00
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	0 .00	1 .01	2 .02	3 .01
Subtotal Not Conforming	2 .03	1 .01	1 .01	2 .02	6 .02

TABLE 23

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

		Number of Items Correct on Concrete Subtest (7 required)						
N	Pattern of Exception	0	1	2	3	4	5	6
3	FPFF						1	2
		Number of Items Correct on Classificatory Subtests (7 required)						
		0	1	2	3	4	5	6
3	PPFP					1		2

Computations were performed using the overall grade-group proportions passing and failing each of the four subtests so that a wide range of conceptual attainment would be obtained. These computations yeilded expected numbers of subjects following each of the 16 possible patterns of attainment (five acceptable, 11 unacceptable to the model). It was noted that fewer than five subjects were expected to follow each of the 16 patterns. To meet the requirements of the Chi-square test, patterns were combined so that the minimum expected number of subjects in each cell would approximate five. Ten patterns and combinations of patterns resulted and were used for the test. A Chi-square goodness-of-fit test was used to determine whether the obtained number of subjects who followed these patterns differed significantly from the number of subjects expected to follow these patterns. The resulting Chi-square provided convincing evidence that the number of subjects following and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations ($X^2 = 350.94$, d.f. = 5, $p < .01$).

Proportion of Grade Groups Attaining the Four Levels

The number and proportion of each grade group that fully attained each concept level are presented in Table 24. These data will be employed to evaluate two interrelated predictions: within a given grade group the percentage of children passing each successive level should decrease and, at the same time, the percentage of children passing a given level should increase as a function of increasing grade group.

Inspection of Table 24 shows that within each grade group, as predicted, fewer children attain concept levels as the levels become more difficult. The pattern obtained within each of the four grade groups is reflected also in the data for combined grades: 86% of the subjects attained the concrete level; 82%, identity; 51%, classificatory; and 9%, formal.

Cochran Q tests were used to find out if the proportions of subjects fully attaining the four concept levels differed significantly within each of the four grade groups. Significance of the differences among the proportions for each of the grade groups was beyond the .01 level (Q = 40.97, kindergarten; 211.51, third grade; 213.47, sixth grade; 148.63, ninth grade [d.f. = 3]). McNemar tests were run at the .05 level of significance to discover where specific differences in attainment among the four levels occurred within each of the four grade groups. Six comparisons were possible: concrete with (1) identity, (2) classificatory and (3) formal; (4) identity with classificatory and (5) formal; finally, (6) classificatory with formal. For the kindergarten group, three comparisons showed a significant difference: fewer kindergarten children attained the identity, classificatory, and formal levels when each was compared with the concrete level. In the third-, sixth-, and ninth-grade groups, every comparison showed a significant difference except that between concrete and

TABLE 24

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT

Grade	Concrete	Identity	Classificatory	Formal
K (n=59)				
Number	17	3	0	0
Proportion	.29	.05	.00	.00
3rd (n=88)				
Number	86	87	29	0
Proportion	.98	.99	.33	.00
6th (n=91)				
Number	90	90	65	2
Proportion	.99	.99	.71	.02
9th (n=87)				
Number	87	87	72	26
Proportion	1.00	1.00	.83	.30
All Grades (n=325)				
Number	280	267	166	28
Proportion	.86	.82	.51	.09

identity levels. That is, every comparison within each of these three grade groups indicated significantly fewer children attained the higher concept level.

According to prediction, the percentage of children passing any given level of concept attainment should increase as a function of increasing grade group. Information in the columns of Table 24 is relevant to this prediction. For example, 0% of the kindergarten group, 33% of the third grade, 71% of the sixth grade, and 83% of the ninth graders attained the concept at the classificatory level. A similar pattern of progression exists also for the formal level, although at the concrete and identity levels any pattern is obscured by the uniformly high level of attainment by all grade groups except kindergarten.

Chi-square tests were used to determine whether the proportions of individual grade groups passing each of the four levels differed significantly from the proportions of the combined grade groups passing each of the four levels of concept attainment. The difference in proportions attaining each of the levels was significant beyond the .001 level (Chi-square = 198.88, concrete; 292.09, identity; 1?3.19, classificatory; 68.61, formal [d.f. = 3]). In order to discover where differences between grade groups in attainment of each of the four levels were significant at the .05 level, a Chi-square analog to Scheffé's theorem was used. Statistically significant results were as follows: at both the concrete and identity levels, third-, sixth-, and ninth-grade groups each surpassed the attainment of kindergarteners. Third-, sixth-, and ninth-grade groups each surpassed the attainment of kindergarteners at the classificatory level as well; in addition, classificatory attainments of sixth and ninth graders were each superior to that of third graders. At the formal level, the ninth-grade group surpassed attainments of each of the three lower-grade groups.

The predictions that deal with increasing difficulty of the levels of concept attainment received strong support from data assessing mastery of the concept, noun.

Relationship Between Full Attainment of Various Levels and Full Attainment of the Various Uses

This section will deal with two specific predictions that were stated more fully in Chapter II: first, a higher proportion of children who attain a concept at the formal level, in comparison with those who attain at the classificatory level, will also master each of the three concept uses. Second, children who attain a concept to only the concrete and/or identity levels will be able to use that concept to solve only simple problems of a perceptual type and to understand similar principles.

Data in Table 25 indicate that 16 children passed the concrete level as their highest level of attainment; no uses subtests were passed by these subjects. Ninety-eight children attained the identity level as their highest attainment level; 24 of these children were able to pass the problem-solving subtest, one the principle subtest, and none the supraordinate-subordinate subtest. These data attest to the limited use of a concept when a concept is attained only at the lower levels.

Comparing performances on uses subtests of subjects attaining at the classificatory level and subjects attaining at the formal level addresses directly the presumed efficacy in using a given concept that accompanies attainment at the formal level. A total of 141 subjects attained the classificatory level as their highest level and 28 subjects attained the formal level, as can be observed at the bottom of Table 25. The supraordinate-subordinate subtest was passed by 2% of those at the classificatory level, compared to 11% of those at the formal level. The principle subtest was passed by 18% and 86%, respectively, of classificatory and formal attainers. Problem solving was passed by 55% of those whose highest level was classificatory, whereas 93% of the subjects who passed the formal level were also to solve problems successfully.

For each of the three concept uses, Chi-square tests also revealed a significant superiority (beyond the .05 level) in those children performing at the formal level compared to those performing at the classificatory level (Chi-square = 5.03, supraordinate-subordinate; 50.75, principle; 13.91, problem solving [d.f. = 1]).

In summary, the data obtained from assessment of noun provide strong support for the prediction that attainment of a concept at the formal level, compared with attainment at the classificatory level, greatly facilitates use of the concept.

Difficulty of the Three Uses

It has been predicted that the number and proportion of children who master each concept use will increase as a function of increasing grade group. Table 26 shows that performance on uses subtests did improve with increasing grade group. Although the progression is weak for the supraordinate-subordinate subtest, substantial increases are apparent in the proportion of children who pass both the principle and problem-solving subtests as grade group increases. Between sixth and ninth grade, considerable improvement occurred in mastery of these two concept uses.

Examination of Table 26 also reveals that 2% of all subjects passed the supraordinate-subordinate subtest; 16%, principle; and 39%, problem solving. These overall attainments are fairly modest and must be evaluated within the context of the particular concept being assessed and battery used.

Chi-square tests were run to ascertain the significance of the difference between the proportions of individual grade groups passing each of the three uses and the proportion of the combined grade groups passing each of the three concept uses. The difference in the proportion of subjects attaining each of the uses was significant beyond the .05 level (Chi-square = 10.35, supraordinate-subordinate; 86.91, principle; 129.88, problem solving [d.f. = 3]). A Chi-square analog to Scheffé's theorem was performed between all pairs of grade groups to discover where the differences in performance on the uses subtests were significant at the .05 level. Statistically significant results were as follows: for the supraordinate-subordinate subtest, the ninth-grade's mastery was superior to that of the third-grade group. For the principle subtest, performance of the ninth-grade group surpassed that of each of the three lower grade groups. Performance of the ninth-grade group was also superior to that of each of the three lower-grade groups on the problem-solving subtest. In addition, the sixth-grade group showed a significant superiority when compared to both third grade and kindergarten groups on the problem-solving subtest.

Data obtained from performance on uses subtests of the concept, noun, provide considerable support for the prediction of an increased ability to use the concept with increasing grade group.

Relation Between Vocabulary Development and Attainment of Concept Levels and Uses

Vocabulary scores have been predicted to correlate positively with attainment on the four concept levels and three uses for both individual grade groups and for combined grade groups.

In order to address this prediction, a

TABLE 25

RELATIONSHIP BETWEEN FULL MASTERY OF VARIOUS LEVELS AND FULL MASTERY OF USES

Grade	Concrete as Highest			Identity as Highest			Classificatory But Not Formal			Formal		
	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.
K												
N Passing Level	16			3			0			0		
N Passing Use	0	0	0	0	0	0	0	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3rd												
N Passing Level	0			58			29			0		
N Passing Use	0	0	0	0	0	5	0	1	6	0	0	0
Proportion	.00	.00	.00	.00	.00	.09	.00	.03	.21	.00	.00	.00
6th												
N Passing Level	0			24			64			2		
N Passing Use	0	0	0	0	0	9	0	10	37	1	0	2
Proportion	.00	.00	.00	.00	.00	.38	.00	.16	.58	.50	.00	1.00
9th												
N Passing Level	0			13			48			26		
N Passing Use	0	0	0	0	1	10	3	15	35	2	24	24
Proportion	.00	.00	.00	.00	.08	.77	.06	.31	.73	.08	.92	.92
All Grades												
N Passing Level	16			98			141			28		
N Passing Use	0	0	0	0	1	24	3	26	78	3	24	26
Proportion	.00	.00	.00	.00	.01	.24	.02	.18	.55	.11	.86	.93

TABLE 26

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH OF THREE CONCEPT USES

Grade	Supraordinate-Subordinate	Principle	Problem Solving
K (n=59)			
Number	0	0	0
Proportion	.00	.00	.00
3rd (n=88)			
Number	0	1	11
Proportion	.00	.01	.13
6th (n=91)			
Number	1	10	48
Proportion	.01	.11	.53
9th (n=87)			
Number	5	40	69
Proportion	.06	.46	.79
All Grades (n=325)			
Number	6	51	128
Proportion	.02	.16	.39

special scaling system was devised to obtain a score for each subject on each of four measures: a nine-item vocabulary test, concept levels, uses, and combined levels and uses. A detailed account of the scoring system is provided in Chapter III which describes this method as it was applied to data from the <u>equilateral</u> <u>triangle</u> concept. The same procedure was used for the present concept, <u>noun</u>.

Based on this scoring system, means and standard deviations for the levels, uses, levels and uses, and vocabulary scores at each grade group are shown in Table 27. Inspection reveals that vocabulary became much more proficient with increasing grade group. The same strong trend, showing increasingly high scores with increasing grade group can be observed for concept attainment, concept uses, and overall task performance scores (i.e., levels and uses combined).

Pearson product-moment correlations (r) were calculated to determine the relationship between vocabulary proficiency and task performance. For each grade group, the correlations obtained between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses are presented in Table 28.

It can be observed that correlations within grade groups are moderately low or zero for the youngest children. Absence of a statistical relationship between vocabulary and task performance for the kindergarten grade group reflects a very limited range of performance among these youngest subjects. Table 27 shows that kindergarten children passed no uses subtests and no vocabulary items; the range of attainment on concept levels was very small. The correlations, in general, gain in magnitude with increasing grade group for third-, sixth-, and ninth-grade groups. The older children not only demonstrated an increasing competence with vocabulary, but also exhibited a wider range of performance on concept attainment and concept uses. All correlations obtained for these grade groups were sufficiently high to reach statistical significance from zero at or beyond the .05 level.

As predicted, the correlations obtained for the total subject population were higher than those obtained within grade groups and all three were statistically significant from zero at or beyond the .01 level. Correlation between overall concept attainment and vocabulary was .67, between overall performance on uses and vocabulary, .75, and between combined levels and uses and vocabulary, .79.

The predicted relation between comprehension of labels and concept attainment and use is supported by the correlational data obtained for the concept, noun.

TABLE 27

MEANS AND STANDARD DEVIATIONS FOR COMBINED CONCEPT LEVELS, CONCEPT USES, COMBINED LEVELS AND USES, AND VOCABULARY AT EACH GRADE GROUP

Grade Group	N	Concept Levels: (Maximum Score, 4)		Concept Uses: (Maximum Score, 3)		Levels and Uses: (Maximum Score, 7)		Vocabulary: (Maximum Score, 9)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
K	59	.34	.51	.00	.00	.34	.51	.00	.00
3rd	88	2.30	.55	.14	.35	2.43	.71	2.08	1.52
6th	91	2.71	.54	.65	.66	3.36	.96	2.68	2.06
9th	87	3.12	.64	1.31	.81	4.49	1.22	5.52	2.62
All Grades	325	2.28	1.12	.57	.77	2.85	1.67	2.79	2.68

TABLE 28

PEARSON PRODUCT-MOMENT CORRELATIONS BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON CONCEPT LEVELS, CONCEPT USES, AND COMBINED LEVELS AND USES

Grade Group	N	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K	59	.00	.00	.00
3rd	88	.34**	.26*	.40**
6th	91	.29**	.55**	.54**
9th	87	.55**	.67**	.72**
All Grades	325	.67**	.75**	.79**

* p < .05
** p < .01

GPO 831-786-4

VI
Summary and Conclusions

In this chapter a brief summary of the study precedes a discussion of results of all three assessment batteries as they bear on our conclusions concerning each of the eight CLD predictions.

Summary

The CLD model encompasses three major propositions dealing with patterns of children's conceptual learning and development. Related to each proposition there are several specific predictions. Inasmuch as the major propositions and predictions are discussed in some detail in prior chapters, the predictions are stated in summary fashion as follows:

1. All children of all grade groups will conform to five acceptable patterns of mastery of four concept levels.
2. The number and proportion of children within a grade group who pass each successive level of concept attainment will decrease.
3. The number and proportion of children of successively higher grade groups mastering each concept level will increase.
4. A higher proportion of children who attain a concept at the formal level in comparison with those who attain at the classificatory level will also master each of the three concept uses.
5. Children who attain a concept to only the concrete and/or identity level will be able to use that concept only in understanding simple perceptual relationships with other objects and in solving simple perceptual problems.
6. The number and proportion of children of successively higher grade groups who master each concept use will increase.
7. Vocabulary scores and scores based on attainment of the four levels and the three uses will correlate positively within grade groups.
8. Vocabulary scores and scores based on the levels and uses will correlate positively for the combined grade groups.

The preceding predictions were tested, using three specially constructed assessment batteries. One battery was used for each concept: equilateral triangle, cutting tool, and noun. Each battery also had one subtest for each of the four levels of concept attainment and for each of three uses of an attained concept. Thus, a total of 21 tests was developed, seven for each of the three concepts.

Children at four grade levels--kindergarten, third, sixth, and ninth--participated in the study. Children in the three lower grades were enrolled in four different elementary schools. The ninth-grade students were enrolled in a junior high school. The schools and classrooms in which the children were enrolled were judged to be typical of the particular school system and also of a large number of classrooms in small towns of Wisconsin and other states.

The tests of the various batteries were administered to children in intact classroom groups, except that, kindergarten children received the tests in small groups of about five to eight. On each subtest a child's responses were scored as passing or failing. Criteria were set to determine passing and failing as has been reported in chapters III, IV, and V. The data were quantified by computing frequencies and proportions of subjects within each grade group who attained each concept level and each use. *Post hoc* statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. The predicted relationship between vocabulary and performance was evaluated by correlation coefficients.

Conclusions

Results of the three assessments have been presented and discussed separately in the preceding chapters. Now we will consider the concepts simultaneously both in order that our conclusions regarding the eight predictions can be stated with a greater degree of generality and confidence and so that relevant cross-concept comparisons can be made. Each prediction is stated, and the evidence based on all three concepts is summarized and discussed.

1. All children of all grade groups will conform to five acceptable patterns of mastery of the four concept levels. This prediction was supported by results obtained for the individual concepts assessed in the present study. Table 29 summarizes the relevant information for all three concepts. Inspection of this table shows that 92% of all the children conformed to the predicted pass/fail patterns for equilateral triangle, 94% for cutting tool, and 98% for noun. Presented together, these large percentages provide strong support for the prediction of invariant sequence of attainment.

   Table 30 presents the frequencies of the total subject population who did not conform to the predicted patterns. Twenty-seven children (8%) deviated from the predicted sequence in the assessment of equilateral triangle. Similarly, 6% did not conform on cutting tool and 2% did not conform on noun. Those subjects not conforming on the equilateral triangle task were distributed over most of the 11 pass/fail patterns. Those not conforming on cutting tool are concentrated in three patterns and the exceptions on noun in two patterns. Further examination of protocols from children who did not conform to the five predicted patterns revealed no overlap among the three concepts. That is, all 27 children who were exceptions on the equilateral triangle task conformed to acceptable patterns on the other two tasks; the 23 individuals who were the exceptions on cutting tool were conformers on the other two tasks. This independence suggests that the exceptions to the predicted patterns are probably the result of errors of measurement or problems associated with the criteria established for concept level attainment rather than true exceptions in terms of sequential development. Had the same children deviated on all three concepts we would, of course, conclude that these children were not in fact conforming to the hypothesized invariant sequence of conceptual development.
2. The number and proportion of children within a single grade group who passed each successive level of concept attainment will decrease. We have seen that this prediction was upheld uniformly for the four grade groups when each of the three concepts was examined individually. Table 31 enables us to make cross-concept comparisons for the proportion of each grade group that fully mastered each level of attainment. It may be seen that there could have been 48 exceptions to this prediction. In fact, only three minor reversals exist. In the kindergarten group 71% passed the concrete level of equilateral triangle and 76% passed the identity level. In the kindergarten group also 95% passed the concrete level of cutting tool and 96% passed the identity. The other exception to the predicted direction involves noun; 98% of the third graders passed the concrete level and 99% passed the identity level. That these few minor exceptions occurred at all is most probably due to error of measurement and problems associated with the criteria established for passing the various levels.
3. The number and proportion of successively higher grade groups mastering each concept level will increase. This prediction was also upheld for each of the three concepts. The columns of Table 31 summarize the relevant data. Again, 48 exceptions might have occurred. In fact, there was only one minor reversal to the predicted direction. Ninety-eight percent of the third grade children, compared to 97% of the sixth grade, passed the concrete level of equilateral triangle.
4. A higher proportion of children who attain a concept at the formal level in comparison with those who attain it at the classificatory level will also master each of the three uses. This prediction was upheld.

TABLE 29

PROPORTION OF TOTAL SUBJECT POPULATION CONFORMING TO PREDICTED PASS-FAIL PATTERNS OF ATTAINMENT: COMPARING EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

	Concept		
Pass-Fail Sequence	Equilateral Triangle (N=324)	Cutting Tool (N=363)	Noun (N=325)
FFFF	.03	.00	.13
PFFF	.02	.00	.05
PPFF	.11	.09	.29
PPPF	.37	.36	.43
PPPP	.39	.48	.08
Total	.92	.94	.98

TABLE 30

FREQUENCIES OF TOTAL SUBJECT POPULATION SHOWING PASS-FAIL PATTERNS OF EXCEPTION: COMPARING EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

Pass-Fail Pattern of Exception	Equilateral Triangle (N=324)	Cutting Tool (N=363)	Noun (N=362)	Total
FFFP				0
FFPF	2			2
FFPP	1			1
FPFF	6	3	3	12
FPFP				0
FPPF	5			5
FPPP	1			1
PFFP	1			1
PFPF	6	2		8
PFPP	3			3
PPFP	2	18	3	23
Total	27	23	6	
Percentage of Total Population	.08	.06	.02	

Summarizing data for all three concepts, Table 32 shows the proportion of children who passed the four levels and who also passed various uses. There are nine possible exceptions to the prediction that children who attain a concept at the formal level, compared to those attaining at the classificatory level, demonstrate superior performance on the concept uses. Inspection of the bottom half of Table 32 shows there were no exceptions to this prediction. Moreover, the differences in the actual size of the percentages are consistently large. For example, data for equilateral triangle show that a marked advantage in mastery of uses occurred for individuals attaining at the formal level: 34% passed the supraordinate-subordinate subtest, compared to 8% of classificatory attainers; 43% passed the principles subtest, compared to 5% of classificatory attainers; and 34% passed the problem solving subtest, compared to 3% of classificatory attainers.

5. Children who attain a concept to only the concrete and/or the identity level will be able to use that concept only in understanding simple perceptual relationships with other object concepts and in solving simple perceptual problems. This prediction was supported in general, although some exceptions occurred for two of the concepts. Table 32 shows that the exceptions were as follows: 24% (9 out of 37) of the children who passed the identity level of cutting tool and 7% (3 out of 43) who passed the identity level of equilateral triangle also passed the supraordinate-subordinate test.
6. The number and proportion of children of successively higher grade groups who master each concept use will increase. This prediction was upheld. Table 33 shows that 36 exceptions might have occurred. Inspection shows there was only one minor reversal. Fourteen percent of the third graders mastered the supraordinate-subordinate test for equilateral triangle, whereas only 12% of the sixth graders passed. In addition to the fact that only one minor exception occurred, it is noted that improvement in mastery of the various uses markedly increased with increasing grade group. For example, for the supraordinate-subordinate subtest of cutting tool the progression was as follows: kindergarten .08, third grade .43, sixth .66, and ninth grade .82.
7. Vocabulary scores and scores based on the attainment of the four levels and the three uses will correlate positively within grade group. This prediction was supported by data for each concept assessed in the present study. Table 34 summarizes, for all three concepts, the 36 correlations obtained between vocabulary scores and scores on levels, uses, and combined levels and uses at each grade group. Table 34 shows one exception to the prediction: the correlation between vocabulary and attainment of concept levels was -.09 for the ninth graders who performed on the cutting tool assessment battery. In general, however, the size of the correlations within the various grade groups was considerably higher than anticipated. Twenty-four of the total 36 correlations were statistically significant from zero at or beyond the .05 level; actual values ranged from .26 to .72. For both equilateral triangle and noun concepts, relatively low or zero order correlations occurred in the kindergarten group; range of performance on vocabulary scores and on the levels and uses subtests was very small for this grade group. For cutting tool, another set of low correlations was found among the ninth graders. Here also, as explained in chapter IV, lack of variability was responsible; the ninth graders demonstrated uniformly high scores on the vocabulary test for cutting tool and also on the levels and uses subtests.
8. Vocabulary scores and scores based on the attainment of the four levels and the three uses will be positively correlated and higher across combined grade groups. This prediction received strong support from all three sets of data, as summarized in Table 35. The highest set of correlations for combined grade groups was obtained for noun and the lowest for cutting tool. In general, the nine correlations entered in this table are notably larger in magnitude than those obtained within grade groups and are statistically significant from zero at or beyond the .01 level.

TABLE 31

PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT: COMPARING EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

Grade Group	Concrete	Identity	Classificatory	Formal
K				
N = 62 Equilateral Triangle	.71	.76	.42	.00
76 Cutting Tool	.95	.96	.75	.01
59 Noun	.29	.05	.00	.00
3rd				
N = 86 Equilateral Triangle	.98	.93	.81	.17
93 Cutting Tool	1.00	1.00	.83	.39
88 Noun	.98	.99	.33	.00
6th				
N = 92 Equilateral Triangle	.97	.95	.93	.53
101 Cutting Tool	1.00	1.00	.85	.70
91 Noun	.99	.99	.71	.02
9th				
N = 84 Equilateral Triangle	.99	.99	.98	.83
93 Cutting Tool	1.00	1.00	.94	.91
87 Noun	1.00	1.00	.83	.30

TABLE 32

RELATIONSHIP BETWEEN FULL MASTERY OF LEVELS AND FULL MASTERY OF USES: COMPARING PROPORTIONS OF TOTAL SUBJECT POPULATION PASSING USES FOR EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

Grade	Concrete as Highest			Identity as Highest			Classificatory as Highest			Formal as Highest		
	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.
N Passing Level	5			43			133			134		
N Passing Use	0	0	0	3	0	0	10	6	4	45	57	45
Equilateral Triangle	.00	.00	.00	.07	.00	.00	.08	.05	.03	.34	.43	.34
N Passing Level	0			37			132			193		
N Passing Use	0	0	0	9	1	6	36	9	26	144	92	140
Cutting Tool	.00	.00	.00	.24	.03	.16	.27	.07	.20	.75	.48	.73
N Passing Level	16			98			141			28		
N Passing Use	0	0	0	0	1	24	3	26	78	3	24	26
Noun	.00	.00	.00	.00	.01	.24	.02	.18	.55	.11	.86	.93

TABLE 33

PROPORTION OF EACH GRADE GROUP
THAT FULLY MASTERED EACH OF THE THREE CONCEPT USES:
COMPARING EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

Grade Group	Supraordinate-Subordinate	Principle	Problem Solving
K			
N = 62 Equilateral Triangle	.00	.00	.00
76 Cutting Tool	.08	.00	.00
59 Noun	.00	.00	.00
3rd			
N = 86 Equilateral Triangle	.14	.00	.00
93 Cutting Tool	.43	.11	.41
88 Noun	.00	.01	.13
6th			
N = 92 Equilateral Triangle	.12	.15	.13
101 Cutting Tool	.66	.30	.55
91 Noun	.01	.11	.53
9th			
N = 84 Equilateral Triangle	.42	.58	.44
93 Cutting Tool	.82	.67	.84
87 Noun	.06	.46	.79

TABLE 34

PEARSON PRODUCT-MOMENT CORRELATIONS AT EACH GRADE GROUP BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON CONCEPT LEVELS, CONCEPT USES, AND COMBINED LEVELS AND USES: COMPARING EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

Grade Group	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K			
N = 62 Equilateral Triangle	.14	.00	.15
76 Cutting Tool	.41**	.20	.43**
59 Noun	.00	.00	.00
3rd			
N = 86 Equilateral Triangle	.43**	.06	.40**
93 Cutting Tool	.35**	.30**	.41**
88 Noun	.34**	.26*	.40**
6th			
N = 92 Equilateral Triangle	.18	.38**	.39**
101 Cutting Tool	.44**	.31**	.43**
91 Noun	.29**	.55**	.54**
9th			
N = 84 Equilateral Triangle	.25*	.42**	.44**
93 Cutting Tool	-.09	.15	.09
87 Noun	.55**	.67**	.72**

*p < .05
**p < .01

TABLE 35

CORRELATIONS FOR TOTAL SUBJECT POPULATION BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON LEVELS, USES, AND COMBINED LEVELS AND USES: COMPARING EQUILATERAL TRIANGLE, CUTTING TOOL, AND NOUN

Concept	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
N = 324 Equilateral Triangle	57*	.56*	.70*
N = 363 Cutting Tool	.51*	.43*	.52*
N = 325 Noun	.67*	75*	.79*

*p < .01

GPO 001-188-3

References

Ausubel, D. P. The psychology of meaningful verbal learning. New York: Grune & Stratton, 1963.

Ausubel, D. P. Meaningful reception learning and the acquisition of concepts. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966. Pp. 157-175.

Bourne, L. E., Jr., Ekstrand, B. R., & Dominowski, R. L. The psychology of thinking. Englewood Cliffs, N.J.: Prentice-Hall, 1971.

Bourne, L. E., Jr., & Restle, F. Mathematical theory of concept identification. Psychological Review, 1959, 66(5) 278-296.

Bruner, J. S. The course of cognitive growth. American Psychologist, 1964, 19, 1-15.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. A study of thinking. New York: Wiley, 1956.

Bruner, J. S., Olver, R. R., Greenfield, P. M., et al. Studies in cognitive growth. New York: Wiley, 1966.

Campbell, D., & Stanley, J. Experimental and quasi-experimental designs for research on teaching. In N. Gage (Ed.), Handbook of research on teaching. Chicago: Rand McNally, 1963. Pp. 171-246.

Carroll, J. B. Words, meanings, and concepts. Harvard Educational Review, 1964, 34, 178-202.

Deese, J. Meaning and change of meaning. American Psychologist, 1967, 22, 641-651.

Elkind, D. Conservation and concept formation. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development: Essays in honor of Jean Piaget. London and New York: Oxford University Press, 1969, Pp. 171-189.

Feldman, K. V. The effects of number of positive and negative instances, concept definition, and emphasis of relevant attributes on the attainment of mathematical concepts. Technical Report No. 243. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1972.

Flavell, J. H. Concept development. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1. New York: Wiley. 1970, Pp. 983-1059.

Gagné, R. M. The learning of principles. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966, Pp. 81-95.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart and Winston, 1970.

Gesell, A. Infancy and human growth. New York: Macmillan, 1928.

Gesell, A. The embryology of behavior: The beginnings of the human mind. New York: Harper, 1945.

Gibson, E. I. Principles of perceptual learning and development. New York: Appleton, 1969.

Golub L. S., Fredrick, W., Nelson, N., & Frayer, D. A. Selection and analysis of language arts concepts for inclusion in tests of concept attainment. Working Paper No. 59. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1971.

Goodnow, J. J. Problems in research on culture and thought. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development. New York: Oxford University Press, 1969, Pp. 439-462.

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.

Hooper, F. H., & Klausmeier, H. J. Description and rationale for a longitudinal assessment of children's cognitive development and concept learning. Working Paper No. 113. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973.

Hunt, E. B. Concept learning: An information-processing problem. New York: Wiley, 1962.

Inhelder, B., & Piaget, J. The early growth of logic in the child: Classification and seriation. New York: Harper & Row, 1964.

Kagan, J. A developmental approach to conceptual growth. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966, Pp. 97-116.

Kagan, J., Moss, H. A., & Sigel, I. E. Psychological significance of styles of conceptualization. Monograph of the Society for Research in Child Development, 1963, 28(Whole No. 86), Pp. 73-112.

Klausmeier, H. J. Cognitive operations in concept learning. Educational Psychologist, November 1971, Pp. 1 and 3-8.

Klausmeier, H. J., Bernard, M. E., Katzenmeyer, C. G., & Sipple, T. S. Development of Conceptual Learning and Development Assessment Series II: Cutting Tool. Working Paper No. 120. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973.

Klausmeier, H. J., Davis, J. K., Ramsay, J. G., Fredrick, W. C., & Davies, M.H. Concept learning and problem solving: A bibliography, 1950-1964. Wisconsin Research and Development Center for Cognitive Learning, Technical Report No. 1, 1965.

Klausmeier, H. J., Ghatala, E. S., & Frayer, D. A. Conceptual learning and development: A cognitive view. New York: Academic Press, 1974.

Klausmeier, H. J., Ingison, L. J., Sipple, T. S., & Katzenmeyer, C. G. Development of Conceptual Learning and Development Assessment Series I: Equilateral Triangle. Working Paper No. 119. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973. (a)

Klausmeier, H. J., Ingison, L. J., Sipple, T. S., & Katzenmeyer, C. G. Development of Conceptual Learning and Development Assessment Series III: Noun. Working Paper No. 121. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973. (b)

Klausmeier, H. J., & Meinke, D. L. Concept attainment as a function of instructions concerning the stimulus material, a strategy, and a principle for securing information. Journal of Educational Psychology, 1968, 59, 215-222.

Kofsky, E. A scalogram study of classificatory development. Child Development, 1966, 37, 191-204.

Levine, M. Mediating processes in humans at the outset of discrimination learning. Psychological Review, 1963, 70, 254-276.

Levine, M. Hypothesis behavior by humans during discrimination learning. Journal of Experimental Psychology, 1966, 71, 331-336.

Luria, A. R. The role of speech in the regulation of normal and abnormal behavior. New York: Liveright, 1961.

Markle, S. M., & Tiemann, P. W. Really understanding concepts: Or in frumious pursuit of the jabberwock. Champaign, Ill.: Stipes, 1969.

Marx, M. H. (Ed.) Learning: Theories. New York: Macmillan, 1970.

Osgood, C. E. Method and theory in experimental psychology. New York: Oxford University Press, 1953.

Piaget, J. Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. New York: Wiley, 1970, Pp. 703-732.

Romberg, T. A., Steitz, J., & Frayer, D. A. Selection and analysis of mathematics concepts for inclusion in tests of concept attainment. Working Paper No. 55. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1971.

Staats, A. Child learning, intelligence and personality. New York: Harper & Row, 1971.

Swanson, J. E. The effects of number of positive and negative instances, concept definition, and emphasis of relevant attributes on the attainment of three environmental concepts by sixth-grade children. Technical Report No. 244. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1972.

Tabachnick, B. R., Weible, E., & Frayer, D. A. Selection and analysis of social studies concepts for inclusion in tests of concept attainment. Working Paper No. 53. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1970.

Tagatz, G. E. Effects of strategy, sex, and age on conceptual behavior of elementary school children. Journal of Educational Psychology, 1967, 58, 103-109.

Tennyson, R. D., & Boutwell, R. C. A quality control design and evaluation model for hierarchical sequencing of programmed instruction. National Society for Programmed Instruction Journal, 1971, 10, 5-10.

Trabasso, T., & Bower, G. Attention in Learning. New York: Wiley, 1968.

Vernon, M. D. Perception through experience. New York: Barnes & Noble, 1970.

Voelker, A. M., Sorenson, J. S., & Frayer, D. A. Selection and analysis of classificatory science concepts by intermediate-grade children. Working Paper No. 57. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1971.

Vygotsky, L. S. (translated by E. Hanfmann & G. Vakar) Thought and language. Cambridge, Mass.: M.I.T. Press, 1962.

Williams, C. F. A model of memory in concept learning. Cognitive Psychology, 1971, 2, 158-184.

Woodruff, A. D. Basic concepts of teaching. (Concise ed.) San Francisco: Chandler Publishing, 1961.

Woodruff, A. D. Cognitive models of learning and instruction. In L. Siegel (Ed.), Instruction: Some contemporary viewpoints. San Francisco: Chandler Publishing, 1967, Pp. 55-98.

Zeaman, D., & House, B. J. The role of attention in retardate discrimination learning. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963, Pp. 159-223.

GPO 807-759-2

National Evaluation Committee

Helen Bain
Past President
National Education Association

Lyle E. Bourne, Jr.
Institute for the Study of Intellectual Behavior
University of Colorado

Sue Buel
Dissemination and Installation Services
Northwest Regional Educational Laboratory

Francis S. Chase
Professor Emeritus
University of Chicago

George E. Dickson
College of Education
University of Toledo

Chester W. Harris
Graduate School of Education
University of California

Hugh J. Scott
Consultant
National Evaluation Committee

H. Craig Sipe
Department of Instruction
State University of New York

G Wesley Sowards
Dean of Education
Florida International University

Joanna Williams
Professor of Psychology and Education
Columbia University

Executive Committee

William R. Bush
Director, Program Planning and Management
Deputy Director, R & D Center

M. Vere DeVault
Professor
School of Education

Herbert J. Klausmeier
Principal Investogator
R & D Center

Joel R. Levin
Principal Investigator
R & D Center

Donald N. McIsaac
Associate Dean, School of Education
University of Wisconsin

Richard A. Rossmiller, Committee Chairman
Director
R & D Center

Len VanEss
Associate Vice Chancellor
University of Wisconsin-Madison

Dan Woolpert
Director, Management Systems
R & D Center

Faculty of Principal Investigators

Vernon L. Allen
Professor
Psychology

B. Dean Bowles
Associate Professor
Educational Administration

Frank H. Farley
Associate Professor
Educational Psychology

Marvin J. Fruth
Associate Professor
Educational Administration

John G Harvey
Associate Professor
Mathematics

Frank H. Hooper
Associate Professor
Child Development

Herbert J. Klausmeier
V. A. C. Henmon Professor
Educational Psychology

Gisela Labouvie
Assistant Professor
Educational Psychology

Joel R. Levin
Associate Professor
Educational Psychology

L. Joseph Lins
Professor
Institutional Studies

James Lipham
Professor
Educational Administration

Wayne Otto
Professor
Curriculum and Instruction

Robert Petzold
Professor
Curriculum and Instruction

Thomas A. Romberg
Associate Professor
Curriculum and Instruction

Dennis W. Spuck
Assistant Professor
Educational Administration

Richard L. Venezky
Associate Professor
Computer Science

Larry M. Wilder
Assistant Professor
Communication Arts