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ABSTRACT

For this study, the second in the cross sectional series, based on the Conceptual Learning and Development (CLD) model, assessment batteries were developed to determine each child's level of attainment and related use of the concepts "equilateral triangle," "cutting tool," "noun," and "tree." Batteries were designed as paper-and-pencil tasks and were administered to from 349 to 362 children, depending on assessment battery, enrolled in each of four grades: first, fourth, seventh, and tenth. Predictions based on the model about children's conceptual development were strongly supported across concet concepts: (1) The concepts were attained in an invariant sequence at four successive levels: concrete, identity, classificatory, and formal. (2) As the concepts were attained at higher levels, they were used increasingly in cognizing supraordinate-subordinate relationships in a hierarchy, in understanding principles that stated a relationship between the attained concept and one or more other concepts, and 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/BW)

TECHNICAL REPORT NO. 347

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JANUARY 1976

WISCONSIN RESEARCH
AND DEVELOPMENT
CENTER FOR
COGNITIVE LEARNING

Technical Report No. 347

SECOND CROSS-SECTIONAL STUDY OF ATTAINMENT OF THE CONCEPTS "EQUILATERAL TRIANGLE," "CUTTING TOOL," "NOUN," AND "TREE" BY CHILDREN AGE 6 TO 16 OF CITY B

by

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Report from the Project on
Children's Learning and Development

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FUNDING

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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 cross-sectional investigations in the longitudinal assessment; design and results of the first cross-sectional research are reviewed.

For this study, the second in the cross-sectional series, assessment batteries were developed to determine each child's level of attainment and related use of the concepts <u>equilateral triangle</u>, <u>cutting tool</u>, <u>noun</u>, and <u>tree</u>. Batteries were designed as paper-and-pencil tasks and were administered to from 349 to 362 children (depending on assessment battery) enrolled in each of four grades: first, fourth, seventh, and tenth.

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

1. The concepts were attained in an invariant sequence at four successive levels: concrete, identity, classificatory, and formal.

2. As the concepts were attained at 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.

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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 a person's level of mastery of a particular concept will vary depending upon his or her experiences with concept instances and ability to perform the cognitive operations. For example, a four-year-old child and a biologist may both have a concept of <u>tree</u>; although both may perform equally well when asked to identify a few obvious examples and nonexamples of <u>tree</u>, 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 dealing with the internal and external conditions of concept learning. Content analyses of concepts and behavioral analyses of concept learning related to various subject-matter fields have also been conducted. 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 content analyses of concepts and 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 <u>concept</u> 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 regard to concepts as mental constructs, it is noted that maturing individuals attain concepts according to their unique learning experiences and maturational pattern. In turn, the concepts that are attained are used in an individual's 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 formed 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 what they 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 identification of the defining 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 defining and variable 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 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 disciplines.

AN OVERVIEW OF THE CONCEPTUAL LEARNING AND DEVELOPMENT MODEL

Figure 1 shows the structure of the model. Four successively higher levels in the attainment of a given concept are outlined. The four 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 second part of Figure 1 shows the ways in which concepts may be extended and used. Concepts acquired 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, children may walk diagonally across a rectangular block rather than remaining on the sidewalk and walking around a corner of the block. They 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 with both 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.

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

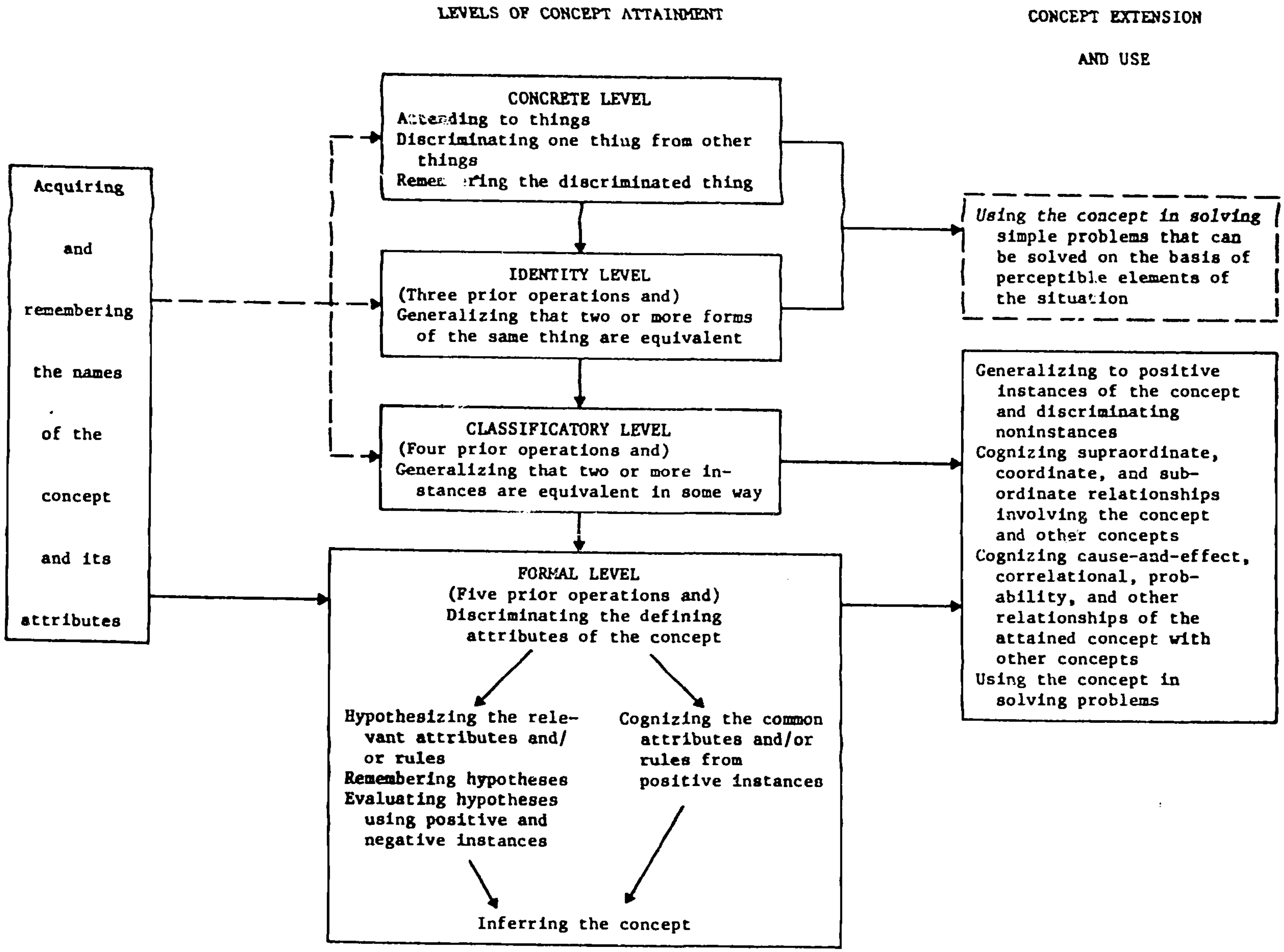

Figure 1. Cognitive operations in concept learning.

not the concept name. The younger the children are when they attain the concept, the less likely they are 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 their 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 beginning 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 or she 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 individuals attend to an object, they discriminate 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 to 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, children learn very early to respond to gross differences in such features of objects as size, shape, color, and texture. As children mature, they become 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 in 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, making the same response to the family poodle when seen from straight ahead, from the side, and from various angles is evidence of the child's 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 identity 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 than 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 classificatory level. Stated differently, persons must be able to cognize various forms of the same objects as equivalent before they are 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 individuals respond to at least two different instances of the same class as equivalent, even though they may not be able to describe the basis for their response. For example, when children treat the family's toy poodle and the neighbor's miniature poodle as poodles, although they may not name the attributes of poodles, they have 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, persons are still at the classificatory level of concept learning when they can correctly classify a larger number of instances as examples and nonexamples, but cannot accurately describe the basis for their 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, maturing children demonstrate a concept of dog at the formal level if, when shown dogs, foxes, and wolves of various sizes and colors, they properly designate the dogs as such, call them "dogs," and name 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 inductively 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, learners guess a possible defining attribute or combination of attributes. They then compare this guess with verified examples and nonexamples of the concept to see whether it is compatible with them. If the guesses are not compatible, they make another guess and evaluate it against further examples and nonexamples. Eventually, they combine the information they have obtained from testing their 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 individuals determine whether or not their hypothesized concepts are 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 instances (examples) and negative instances (nonexamples). These individuals apparently reason like this: Instance 1 has land surrounded by water. It is a member of the class. Instance 2 has land but is not surrounded by water. It is not a member of the class. Therefore, lands surrounded by water belong to the class and lands not surrounded by water do not. Surrounded by water is a defining attribute of the concept. This individual has attained a partial but accurate definition of the concept based on experiences with only one positive and one negative instance.

A second inductive 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, apparently because they are either incapable of getting information from nonexamples or because they cannot carry out the hypothesizing and evaluating operations (Tagatz, 1967). The commonality strategy is the only one possible when only positive instances of the concept are available.

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. That is, concepts may also be learned at the formal level deductively.[1] Many upper elementary, high school, and college students are given the names of concepts and their attributes, verbal definitions, verbal examples, and verbal nonexamples but no actual instances of the concepts. To learn the concept initially they must assimilate this information, remember it, and be able to use it in evaluating examples and nonexamples of the concept as shown in Figure 2. When learners have attained a concept initially through this kind of didactic instruction, they are able to use the concept to identify new examples and nonexamples with which they have had no prior experience. 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 that were given in the definition. Prerequisite to these two operations are discriminating the attributes of the concept and knowing their labels. All of these are listed in Figure 1 as part of the inductive strategy. Thus, when didactic instruction is used, the learner must hypothesize and evaluate regarding examples and nonexamples in order to use the newly learned concepts.

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 individuals 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, 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, Billy might manifest a sequence like this: Billy first encounters a dog. Billy's mother points to the dog and says "dog." Billy then says "dog," and associates the name with his concrete concept of the dog. Next, Billy 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

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[1] In explaining the model earlier, Klausmeier, Ghatala, and Frayer (1974) subsumed the deductive operations under cognizing the common attributes.

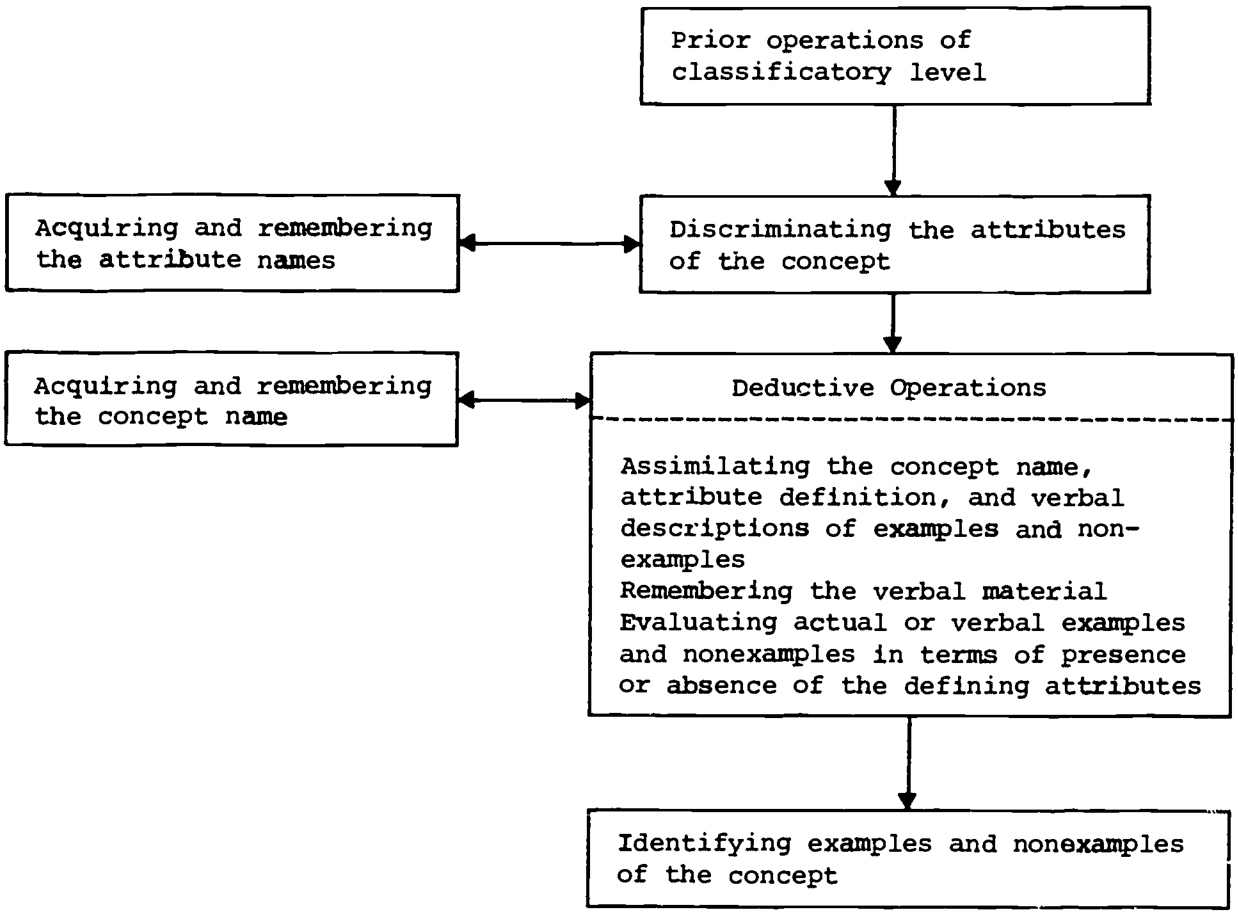

Fig. 2. Cognitive operations and deductive strategies of concept attainment at the formal level.

in the presence of the dog; Billy says the word repeatedly. The word "dog" now comes to represent Billy's concept of the dog at the identity level. Subsequently, Billy 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, with greater maturity, Billy discriminates and learns the societally accepted attributes of the class of things called "dogs" and also learns the names of the attributes. Now Billy'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 (1966, 1970) have theorized concerning the use and extension of attained concepts; however, very little empirical research has been done. In this regard Ausubel (1966) 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 individuals with expectations which help them deal effectively with new instances of it. Once persons identify a plant as poison ivy, they 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 learners 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, the individual's 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 persons, according to verbal instructions, put instances of concepts in their proper groups. For example, upon request persons put 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, they justify each group formed on the basis of the defining attributes of the group. For example, they state 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 knowing 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

There are other statements of relations between or among concepts that are different from relations among supraordinate and subordinate concepts. These additional statements, often termed principles, have been classified by Klausmeier, Ghatala, and Frayer (1974) according to the type of relation that is stated:

1. Cause and effect relationships are statements that may also be expressed in terms of an "if-then" relationship. For example, "tuberculosis is caused by the organism Myobacterium tuberculosis"; "contact with a hot stove produces a blister."

2. Probability statements are principles that express numerically the likelihood of an event's occurrence. For example, "the probability of giving birth to a boy during any given pregnancy is .52"; "provided the coin is fair, the probability of getting a head on only one toss of the coin is .50."

3. Correlational statements describe a relation, often expressed numerically, between two or more objects or events. For example, "if height and weight are measured for a large number of people, the resulting correlation between the two measures is around .50"; "the incidence of lung cancer in women is increasing and the number of women smoking cigarettes is increasing."

4. Axiomatic statements, the most inclusive type of principle, are universally accepted, self-evident truths. Five subclasses have been identified by Bernard (1975): (a) fundamentals, or principles essential to a science, religion, philosophy, or art; (b) laws, or statements of relationship of phenomena that always hold true; (c) rules, or principles in various subject matter domains that prescribe usage, procedure, or conduct; (d) theorems; and (e) axioms, both of which are usually mathematical statements of a relation to be proved or already proved.

Marx (1970) has referred to cause-and-effect, probability, and correlational statements as laws. Gagné (1970) has called these same types of statements principles or rules. In discussing rule learning, Gagné proposed two schemes for classifying rules. The first, based on rule content, divides rules according to those in which the rule relates concepts and designates ideas in contrast to those in which the content functions to guide the individual's response in a specific situation. The second scheme of classification for rules is based on rule structure--either simple or complex. The most simple rules consist of two concepts, arranged in a chain, in the form "if A, then B." Complex rules consist of a larger number of concepts which are often abstract and require subtle discriminations.

Although the various types of statements that express relations among concepts have been classified in slightly different ways by different experts, it is agreed that understanding these statements is critical to thinking and reasoning. Understanding statements of cause and effect or probability, for example, enable the individual to predict consequences from known conditions and to explain newly encountered phenomena. Bruner, Goodnow, and Austin (1956) have pointed out that understanding lawful relationships between or among concepts permits classes of things, rather than isolated, individual things, to be related. Gagné (1970) has suggested that the structurally simple rule "round things roll" is the kind of rule young children learn very early because it consists of concrete concepts having clearly perceptible instances. Once learned, this rule enables the child to predict what will happen to all spherical objects under certain conditions. 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, of course, being able to understand and use a lawful relationship is contingent upon knowing the concepts embedded in the statement. Only then can the rule or axiom or principle be understood and possibly applied to appropriate phenomena.

Using Concepts in Problem-Solving Situations

Problem-solving ability is treated by Klausmeier (1975) as one of the most critical of all outcomes of education; a person who is capable of solving problems can learn independently. A considerable amount of instruction is directed toward teaching students problem-solving skills, and students acquire considerable knowledge through problem solving. Concept learning itself may be regarded as a special case of problem solving.

A situation requiring problem solving is encountered when an individual must respond but does not have immediately available the specific information, concepts, principles, or methods to arrive at a solution. To solve any problem the individual must think adaptively; more specifically, the individual must selectively recall important concepts, principles, and methods needed to solve the problem. Thus, not only may one or more concepts be instrumental in the solution of many kinds of problems, but the more experience an individual has with a given concept, the greater the probability of solving successfully a problem involving that concept.

Much of the organized knowledge concerning the nature of problem solving has been summarized in diverse theories, descriptions of the steps in problem solving, and descriptions of the internal and external conditions of learning. Although varying slightly in their emphases, these theories and descriptions all attest to the importance of problem solving in complex learning and thinking. In turn, theorists have also focused on the role played by concepts in problem solving. For example, Woodruff (1967) has discussed the role of concepts in higher-level mental activities, including problem solving. In accord with his cumulative model of learning, Gagné (1970) has viewed concepts as prerequisite to the learning of rules, and rules as prerequisite to the solving of problems. Gagné has also indicated that one way in which concepts are called into play in solving problems is by the application of principles to the problem-solving situation. For example, principles underlying the concepts of pressure, volume, gravity, and distance can be utilized to determine the height of a mountain by 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 abstracted 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 postulates 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 those 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 modifications 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 being 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 de-emphasizes 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

OBJECTIVES AND METHODOLOGY OF THE LONGITUDINAL/CROSS-SECTIONAL STUDIES OF CHILDREN'S CONCEPTUAL DEVELOPMENT

The first part of this chapter is intended to provide some perspective on the role of this study in a longitudinal assessment program. The plan of the longitudinal research will be outlined. The purposes of the cross-sectional studies, a description of the assessment batteries and their construction, and a brief review of the first cross-sectional study precede a description of the research design and procedures used in the present study.

OVERVIEW OF LONGITUDINAL/CROSS-SECTIONAL STUDIES

The broad purpose of the longitudinal research is to chart the conceptual development of children from about age 5 to 18. This will be accomplished primarily from analyses of longitudinal data collected once each year over a period of several years. Data are obtained from four concept assessment batteries constructed within the framework of the CLD model (Concept Assessment Series I: Equilateral Triangle; II: Cutting Tool; III: Noun; and IV: Tree). 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 program will be examined each year in order to provide a series of cross-sectional studies of children's conceptual learning. This report, based on the second-year assessment in the longitudinal program, is the second such reporting of cross-sectional findings from the larger program. Performances of children on four 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.

Objectives of Longitudinal/Cross-Sectional Studies

The primary objectives of the longitudinal study are (1) to chart the course of children's attainment of selected concepts in various subject fields during their school years, (2) to chart the course of children's uses of the same concepts during their school years, (3) to chart the course of children's development of crucial terminology related to the selected concepts, and (4) to relate the three preceding areas of development. More specifically, 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 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 the development of both to vocabulary acquisition.

The cross-sectional analyses will permit the specification of relative task difficulties (e.g., group means comparisons, intercorrelations, and pass/fail contingency analyses) and the suggestion of the probable order of acquisition of these concept domains. Other goals of the programmatic research, including 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 assessment batteries, (4) to relate children's levels of conceptual development as assessed by these batteries to their school achievement in various subject matters, and (5) to validate the CLD model in terms of its robustness as a framework for research in concept learning, concept development, and related instruction.

Strategy for 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 range of 5 to 18 years with 100 percent 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 this 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 were the site of the initial tryout and validation of the CLD model assessment batteries. Children in the four grade groups (kindergarten, third, sixth, and ninth grades), participating in these studies will 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 socio-economic levels in the U.S. The overall sampling design for the research in Beloit is shown in Table 1.

OVERVIEW OF CROSS-SECTIONAL STUDIES OF CHILDREN'S CONCEPTUAL DEVELOPMENT

The data collected as part of the longitudinal study provide cross-sectional information each year about patterns of conceptual learning and development. The initial data collected in the spring of 1973 were analyzed and reported as the first cross-sectional investigation (see Klausmeier, Sipple, & Allen, 1974). The present study is based similarly on the second year of data collected in the longitudinal program; these data serve as a second cross-sectional study and details of its design are presented in the following sections.

Purposes of Cross-Sectional Studies

The CLD model embodies three major propositions. Specific predictions are related to each proposition. These major propositions and predictions concern hypothesized patterns of children's conceptual learning and development. The purpose of the cross-sectional studies 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 that particular level. Further, it is presumed that to attain

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 effec 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.

a concept at any particular level an individual must be capable of all of the operations at that level and at the prior level and must also have attained the concept at the preceding level.

The major proposition also indicates that many, but not necessarily all, concepts are attained in an invariant sequence. Three conditions are essential for a concept 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 (a) cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept is an element of the hierarchy, (b) understanding principles that state a relationship between the attainee concept and one or more other concepts, and (c) 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. Children who attain a concept to only the concrete and/or identify level will be able to use that concept only in understanding simple perceptual relationships with other object concepts and in solving simple perceptual problems.

5. 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 concept uses.

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 (a) facilitates attainment of the concept at the classificatory level and possibly the other levels, (b) is requisite for attaining the concept at the formal level, and (c) 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 a greater magnitude since large variations among the children both in vocabulary attainment and in attainment of the levels and uses is expected when all the children of the combined grade groups are included.

General Guidelines and Procedures Used in Construction of Assessment Batteries

In addition to the usual criteria of reliability, objectivity, and usability, several additional factors guide 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 there had to be perceptible instances or representations of the particular concept. 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.)

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 battery, 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.

For each concept battery developed, items within the concrete, identity, and classificatory levels were constructed to be more difficult as nonexamples (a) increased in number and (b) shared more relevant and/or irrelevant attributes with the target examples. 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. Test items went through expert review and empirical validation while under development. All subtests in each battery were designed as paper-and-pencil tasks that could be group administered.

Review of First Cross-Sectional Study

A total of 400 children--100 at each of four grade groups (kindergarten, third, sixth, and ninth)--participated in the initial 1973 data collection of the longitudinal study. Two concept assessment batteries were administered to these 400 children. The first cross-sectional study evaluated children's performance on these assessment batteries in terms of the eight specific predictions prescribed by the CLD model.

The CLD batteries used were for the concepts (1) equilateral triangle, from the field of mathematics, (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973) and (2) cutting tool, probably related more to science than to other curriculum areas (Klausmeier, Bernard, Katzenmeyer, & Sipple, 1973). Each battery consisted of one subtest for each of the four levels of concept attainment and one for each of the three uses of an attained concept. Thus a total of 14 tests was developed, 7 for each concept.

Children in the three lower grade groups were enrolled in four different elementary schools. The ninth-grade students were enrolled in a single 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 cities in Wisconsin and other states.

The subtests of the two batteries were administered to children in intact classrooms, except that kindergarten children received the tests in small groups. On each subtest a child's responses were scored as passing or failing, according to specific criteria established for each subtest. Data were quantified by computing frequencies and proportions of children within each grade group who attained each level and each use. Certain post hoc statistical tests were also used where appropriate to evaluate the eight specific predictions described earlier. In general, the predictions derived from the CLD model received strong support from the first cross-sectional study, providing useful information about the probable developmental course of attainment of the two concepts. A complete description of the first cross-sectional study is available (Klausmeier, Sipple, & Allen, 1974).

DESIGN OF SECOND CROSS-SECTIONAL STUDY

The second cross-sectional study was also designed to test the specific predictions derived from the CLD model and, consequently, to determine the normative pattern for concept acquisition. The second cross-sectional study can be viewed as a replication of the first study, providing the opportunity to confirm and extend the first year's findings regarding the course of children's conceptual development.

Assessment Batteries Used

In the present study, four assessment batteries, one for each of four different concepts, were administered. All batteries were developed using the general criteria and procedures described earlier. Two of the concept assessment batteries were in use at the time of the original data collection. These were Concept Assessment Series I: Equilateral Triangle and II: Cutting Tool. CLD Assessment Series III: Noun, had been constructed at the time of the original data collection, but insufficient time was available to administer it in Beloit during the first year of longitudinal assessment. The fourth battery, IV: Tree, was in the process of development during the first-year administration and was only ready for use in the second-year assessment.

Modifications in the original batteries. Several modifications were made in the two original batteries, both in order to add a few components lacking in the formal subtest at the time of the first administration and to correct certain difficulties apparent in the classificatory subtest after the first data collection. In the equilateral triangle battery, modifications were made only in the formal subtest. Two new components required by the model were added: a definition item and five items designed to tap the child's ability to evaluate defining attributes of the concept. Two more items for discriminating attributes were also added to the original three, giving a total of five items for the discriminating attributes component of the formal subtest. The remainder of the equilateral triangle battery was unchanged. Specific composition of this battery regarding number of items composing each subtest is provided in Table 3 in Chapter III.

In the cutting tool battery more extensive changes were made. In general, for every subtest in this battery the most effective items were selected for final use from among those available during the course of construction and development of the battery. Another general criterion used during modification of the cutting tool battery (and construction of all other batteries) was an attempt to maintain the same, or nearly the same, number of items in each subtest in order to increase their psychometric comparability. Thus, across all of the levels subtests of the cutting tool battery the number of items, in general, was increased; in most cases, however, only one to two more items were required to bring the total number of items within a subtest up to the approximate number present in other batteries used in the longitudinal/cross-sectional assessments. As in the equilateral triangle battery, a new component--evaluating the defining attributes--was added to the formal level subtest, as required by the model. The classificatory subtest of the cutting tool battery was changed quite extensively in order to eliminate ambiguous instructions and other ambiguities in items described at length in the first cross-sectional technical report (Klausmeier, Sipple, & Allen, 1974). Similarly, uses subtests in the cutting tool battery were revised to increase accuracy and clarity of items. Specific composition of the entire cutting tool battery regarding number of items comprising each subtest is available in Table 20 in Chapter IV.

New batteries. The two assessment batteries administered for the first time at the second-year data collection were those constructed for the concepts noun, from the field of English language arts (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973b), and tree, a concept from the science field (Klausmeier, Marliave, Katzenmeyer, & Sipple, 1974). The noun battery was administered in Watertown (the site for initial tryout and validation of the assessment batteries) in 1973, but the 1974 administration was its first use in the longitudinal/cross-sectional program in Beloit. The development and final construction of the tree battery was completed during 1973. It was administered for the first time in 1974. All components of the formal level subtest were complete in these two new batteries and number of items at each subtest is approximately the same as for all of the batteries. Information about the exact number of items comprising each subtest in the noun and tree batteries is provided in Tables 37 and 53, respectively appearing in Chapters V and VI.

To summarize, the present cross-sectional study, based on the second year of data collection in the longitudinal program, used four concept assessment batteries: equilateral triangle, cutting tool, noun, and tree. A subtest was constructed for each of the four levels of concept attainment and for each of the three uses of a concept. Thus a total of 28 subtests was developed, 7 for each of the four concepts.

Participating Children

It will be recalled that 400 children, 100 at each of four grade groups, took part in the first assessment. Some of these children were no longer available for participation in the 1974 assessment. Attrition was primarily due to entry into parochial schools or moving out of the city. Of the original 400 children, the number tested in the second year varied from 349 to 362 (i.e., 349 children received all four assessment batteries). The total number of children tested was distributed according to assessment battery as follows: equilateral triangle, 351; cutting tool, 349; noun, 362; and tree, 354. This variation reflected continued subject loss over the six months of data collection. The number of first-, fourth-, seventh-, and tenth-grade children tested was, of course, also unequal. Number of children tested at each grade group varied somewhat for each of the four assessment series, again due to the six-month time spread of the testing. Tables 2, 19, 36, and 52, in Chapters III, IV, V, and VI, respectively, show the exact number of children who participated at each of the four grade groups. Children in the two lower grades were enrolled in 12 different elementary schools. Seventh graders were enrolled at two different junior high schools and tenth graders at a single high school. Each of the subject populations is described in greater detail in the chapters presenting results.

Data Collection

The appropriate subtests of a battery were administered to children in groups of about 30. However, first-grade children were tested in smaller groups of about 5 to 10 in order to reduce distractibility and, in general, to enable the test administrators to monitor the test-taking situation more closely. Each of the four batteries was administered at a different time over a six-month period, lasting approximately from the end of November, 1973, through early May, 1974. Two test administrators, both male, were responsible for giving the batteries in all assessments. The same administrators were responsible for scoring the tests and for coding the test information for subsequent data analyses.

Treatment of 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 and presented in chapters describing results for the four assessment series.

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. These frequencies and proportions were prepared separately for boys, girls, and for boys and girls combined. Preliminary statistical tests were used to determine the existence of any sex differences in attainment of the levels and uses. When no evidence of sex differences was found, data were analyzed for boys and girls combined. Post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and propositions. 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 stated in this chapter is evaluated in terms of these descriptive and statistical analyses.

III

RESULTS OF CLD ASSESSMENT SERIES I: EQUILATERAL TRIANGLE

OVERVIEW

A brief description of the child population precedes a report of the specific criteria used for determining full attainment on each subtest of the battery. The remainder of the chapter is devoted to analyses of results of the assessment in terms of each of the CLD predictions.

CHILD POPULATION

Table 2 presents mean ages and age ranges of the 351 children who participated in Assessment Series I. Data are presented separately for boys and girls, as well as for all children, at each grade group. Inspection shows that the number of children and sex composition varied somewhat among grade groups, although number of boys and girls is the same or very close within any single grade. Number of children varied from 82, for the first-grade group, to 92, for the fourth-grade group. Age range of children within each grade varied from 13 months for first graders to 18 months for seventh graders. Age range for boys and for girls within any single grade group varied very little; mean age for boys and girls was also close within grade group.

CRITERIA FOR FULL ATTAINMENT

In Chapter II it was stated 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, a criterion required that all items of a subtest, except one, had to be passed. One error was permitted in order to make some allowances for error of measurement. These criteria are especially important since passing the four levels of concept attainment in consecutive order is critical to the CLD model.

Table 3 summarizes information concerning number of items and criteria for attainment on each subtest of the battery. There are several exceptions to the criteria convention. The classificatory subtest consisted of three items, all of which were required for attainment. As described earlier, new items and components were added to the formal level subtest. Modification resulted in 18 formal level items (5 discriminating attributes, 7 labels, 5 evaluating defining attributes, and 1 definition). Individual criteria were not established for each of these components; rather, a proportion of all formal level items combined was required in order to meet attainment criterion. The formal level criterion

TABLE 2

TOTAL NUMBER OF CHILDREN, MEAN AGE, AND AGE RANGE AT EACH GRADE GROUP

Grade	Number		Mean Age (in years and months)	Age Range (in years and months)
1	Total	82	6-10	6-3 tc 7-4
	Boys	40	6-10	6-3 to 7-4
	Girls	42	6-10	6-4 to 7-4
4	Total	92	9-10	9-3 to 10-8
	Boys	46	9-10	9-3 to 10-7
	Girls	46	9-10	9-3 to 10-8
7	Total	91	12-10	12-2 to 13-8
	Boys	44	12-10	12-3 to 13-8
	Girls	47	12-9	12-2 to 13-5
10	Total	86	15-9	15-2 to 16-7
	Boys	43	15-9	15-3 to 16-7
	Girls	43	15-8	15-2 to 16-5

was set at passing approximately 80 percent, or 15 of the total 18 formal level items. Number of items comprising each of the subtests, as well as criteria for passing, can be reviewed in Table 3.

PROPORTION OF EACH GRADE GROUP CONFORMING TO THE PREDICTED INVARIANT SEQUENCE

Basic to the CLD model is the postulate that each successive level of concept attainment requires the use of one or more new cognitive operations. Each subtest will be more difficult than the previous one because it demands at least one additional cognitive operation. The CLD model, then, limits to five the number of acceptable patterns of success and failure for the concept levels. These are: to fail all four levels (FFFF), to pass the concrete level and fail the next three (PFFF), to pass both 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).

Table 4 presents the number and proportion of each grade group that attained the successive levels in accord with the patterns predicted by the model, as well as the number and proportion of each grade group exhibiting patterns nonacceptable to the model. Tables 5 and 6 show the same data separately for boys and for girls. Chi-square tests were performed at the .05 level of statistical significance to discover if any sex differences existed in the subtotals of children conforming

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	5	15 correct
b. Labels	7	or approximately
c. Evaluating Defining Attributes	5	80% of combined
d. Definition	1	Formal items
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

to the five combined predicted patterns. No sex differences were found within grade groups or for all grade groups combined. Since no statistically significant differences between boys and girls in conformity to predicted patterns of attainment were detected, the remainder of this section will focus on Table 4 which presents data for boys and girls combined. Tables 5 and 6 are presented for readers who wish to examine and compare performance data for boys and girls.

The first five rows of Table 4 present the number and proportion of each grade group that attained the successive levels in accord with each of the five patterns predicted by the model. All but ten children, or 97 percent, demonstrated attainment of the levels consistent with the predicted invariant sequence. More specifically, and in order of decreasing frequency, 197 children showed the PPPF pattern; 89, PPPP; 49, PPFF; 4, FFFF; and 2, PFFF. Within grade groups, 97 percent each of the fourth, seventh, and tenth graders, and 99 percent of the first graders, conformed to accepted patterns.

The last 11 rows of Table 4 present the number and proportion of children who displayed nonconforming patterns. Three percent (ten children) of the total subject population did not demonstrate attainment of the levels consistent with the predicted invariant sequence. Seven of these ten children passed the formal level after failing classificatory, contrary to prediction, and three failed the concrete level, but went on to attain the identity and classificatory levels. Deviating children

TABLE 4

Number and Proportion of Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n = 82)	4th (n = 92)	7th (n = 91)	10th (n = 86)	All Grades (N = 351)
FFFF	4 .05	0 .00	0 .00	0 .00	4 .01
PFFF	1 .01	1 .01	0 .00	0 .00	2 .01
PPFF	23 .28	13 .14	9 .10	4 .05	49 .14
PPPF	53 .65	71 .77	47 .52	26 .30	197 .56
PPPP	0 .00	4 .04	32 .35	53 .62	89 .25
Subtotal Conforming	81 .99	89 .97	88 .97	83 .97	341 .97
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	0 .00	0 .00	0 .00	0 .00	0 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	1 .01	2 .02	0 .00	0 .00	3 .01
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	1 .01	3 .03	3 .03	7 .02
Subtotal Not Conforming	1 .01	3 .03	3 .03	3 .03	10 .03

TABLE 5

Number and Proportion of Boys at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n = 40)	4th (n = 46)	7th (n = 44)	10th (n = 43)	All Grades (N = 173)
FFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PFFF	1 .03	0 .00	0 .00	0 .00	1 .01
PPFF	13 .33	9 .20	6 .14	2 .05	30 .17
PPPF	26 .66	34 .74	27 .61	13 .30	100 .58
PPPP	0 .00	1 .02	10 .23	28 .65	39 .23
Subtotal Conforming	40 1.00	44 .96	43 .98	43 1.00	170 .99
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	0 .00	0 .00	0 .00	0 .00	0 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	0 .00	1 .02	0 .00	0 .00	1 .01
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	1 .02	1 .02	0 .00	2 .01
Subtotal Not Conforming	0 .00	2 .04	1 .02	0 .00	3 .02

TABLE 6

Number and Proportion of Girls at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n = 42)	4th (n = 46)	7th (n = 47)	10th (n = 43)	All Grades (N = 178)
FFFF	4 .10	0 .00	0 .00	0 .00	4 .02
PFFF	0 .00	1 .02	0 .00	0 .00	1 .01
PPFF	10 .24	4 .09	3 .06	2 .05	19 .11
PPPF	27 .64	37 .80	20 .43	13 .30	97 .54
PPPP	0 .00	3 .07	22 .47	25 .58	50 .28
Subtotal Conforming	41 .98	45 .98	45 .96	40 .93	171 .96
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	0 .00	0 .00	0 .00	0 .00	0 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	1 .02	1 .02	0 .00	0 .00	2 .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	2 .04	3 .07	5 .03
Subtotal Not Conforming	1 .02	1 .02	2 .04	3 .07	7 .04

were distributed quite evenly across grade groups; three children from each of the three highest grades and one first-grade child did not conform.

The fact that 97 percent of our 351 subjects conformed to the predicted invariant sequence of attainment provides very strong support for the major proposition and first prediction derived from the CLD model.

Table 7 presents frequencies of subjects according to each nonconforming pattern and number of items correct at each concept level for which criterion was not met. Examination of these protocols is useful for suggesting why these children deviated from the predicted invariant sequence of attainment.

TABLE 7

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
3	FPPF						3	
		Number of Items Correct on Classificatory Subtest (3 required)						
		0	1	2				
7	PPFP	2	2	3				

Three children failed the concrete level but went on to attain the identity and classificatory levels. Passing seven of the eight concrete items was required for attainment. All three of these nonconforming children passed five of the eight items--performance that was very close to meeting the requirements for attainment of the concrete level. Seven children appeared in the PPFP pattern. Three of these children passed two of the three test items required for attainment; two others passed one of three; and the remaining two children passed none of the classificatory items but went on to attainment at the formal level. Examination of most of these protocols reveals that attainment of a level that should have been passed, according to the model, was just barely missed. Thus, these deviations are probably most reasonably explained as errors of measurement associated with each subtest, or as a consequence of criterion stringency, or both. The few protocols showing that a child attained a more difficult level after falling far short of criterion at lower levels can probably be reasonably interpreted as cases of inattentiveness during test taking or 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 (5 acceptable, 11 unacceptable to the model). It was noted that fewer than five subjects were expected to follow each of 8 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 and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations ($X^2 = 17.57$, $p < .001$, d.f. = 1).

PROPORTION OF GRADE GROUPS ATTAINING THE FOUR LEVELS

This section will evaluate data relevant to predictions two and three, both of which are derived from the first proposition regarding the predicted invariant sequence of concept attainment. These two predictions are closely related. According to prediction two, within a given grade group the percentage of children passing each successive level of attainment will decrease, and, according to prediction three, the percentage of children passing any given level will increase as a function of increasing grade group.

Data were first examined for any important sex differences in frequencies of children who fully mastered each level of attainment. Chi-square tests revealed that at each level of attainment, within each grade group, and for all grade groups combined, only two sex differences in performance occurred. In the first-grade group more boys than girls attained the concrete level ($X^2 = 5.07$, $p < .05$, d.f. = 1). In the seventh-grade group, more girls than boys attained the formal level ($X^2 = 6.52$, $p < .05$, d.f. = 1). None of the remaining 18 Chi-square tests for sex differences approached statistical significance. Since no strong, systematic sex differences were found in these data, Table 8, combining data for sex, was used for statistical analyses. Tables 9 and 10 show the same data separately for boys and for girls.

Table 8 shows the number and proportion of each grade group that fully attained each concept level. The row entries are relevant to the first prediction addressed in this section. At each grade group, there was a gradual decrease in the proportion of children attaining the successive levels, although at every grade group a high degree of proficiency was demonstrated at the concrete and identity levels. Proportions of the total subject population reflect this consistent finding: 98 percent, concrete; 98 percent, identity; 82 percent, classificatory; and 27 percent, formal.

Cochran Q tests were used to discover if the proportions of children 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 well beyond the .001 level [Q = 184.09, first grade; 216.89, fourth grade; 137.03, seventh grade; 49.19, tenth 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 in 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. For each of the four grade groups, five of the six possible comparisons differed with statistical significance. The only comparison that was not statistically significant was concrete with identity. In each of the remaining comparisons at each grade group, fewer children passed the higher concept level.

The columns of Table 8 contain information relevant to the second prediction addressed in the present section--the percentage of children passing any specific level of concept attainment should increase as a function of increasing grade group. Inspection shows that these data consistently support the second prediction, although seventh and tenth graders perform equally well at the concrete and identity levels. For example, at the formal level the proportion of children showing attainment greatly increases with increasing grade groups.

Chi-square tests were used to find out if 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 differences in proportions attaining each of the levels were significant as follows: X^2 (d.f. = 3) = 10.68, $p < .02$, concrete; 12.69, $p < .01$, identity; 22.05, $p < .001$, classificatory; 120.49, $p < .001$, formal. 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 differences were as follows: At the concrete and identity levels the seventh and tenth graders each surpassed attainment of first graders.

At the classificatory level, fourth-, seventh-, and tenth-grade groups each surpassed attainment of the first-grade group. At the formal level, five of the six pair-wise comparisons differed significantly--the exception being that between first and fourth graders. Thus, as grade group increased, significantly larger numbers of children attained the formal level.

The data relevant to full attainment of the concept equilateral triangle provide strong support for predictions two and three, which deal with difficulty of the successive concept levels.

TABLE 8

Number and Proportion of Each Grade Group that Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n = 82)				
Number	77	77	54	0
Proportion	.94	.94	.66	.00
4th (n = 92)				
Number	90	91	77	5
Proportion	.98	.99	.84	.05
7th (n = 91)				
Number	91	91	79	35
Proportion	1.00	1.00	.87	.38
10th (n = 86)				
Number	86	86	79	56
Proportion	1.00	1.00	.92	.65
All Grades (N = 351)				
Number	344	345	289	96
Proportion	.98	.98	.82	.27

TABLE 9

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n = 40)				
Number	40	39	26	0
Proportion	1.00	.98	.65	.00
4th (n = 46)				
Number	45	46	36	2
Proportion	.98	1.00	.78	.04
7th (n = 44)				
Number	44	44	37	11
Proportion	1.00	1.00	.84	.25
10th (n = 43)				
Number	43	43	41	28
Proportion	1.00	1.00	.95	.65
All Grades (N = 173)				
Number	173	172	140	41
Proportion	.99	.99	.81	.24

RELATIONSHIP BETWEEN FULL ATTAINMENT OF VARIOUS LEVELS AND USES

The fourth prediction derived from the CLD model holds that individuals who have attained a concept only to the concrete or identity levels 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.

The first half of Table 11 presents data relevant to the fourth prediction. Neither of the two children (one boy and one girl) as shown in Tables 12 and 13) whose highest level of attainment was concrete passed a uses subtest. Performance of identity level attainers on uses subtests will be examined next. Table 12 shows that 30 boys

TABLE 10

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n = 42)				
Number	37	38	28	0
Proportion	.88	.90	.67	.00
4th (n = 46)				
Number	45	45	41	3
Proportion	.98	.98	.89	.07
7th (n = 47)				
Number	47	47	42	24
Proportion	1.00	1.00	.89	.51
10th (n = 43)				
Number	43	43	38	28
Proportion	1.00	1.00	.88	.65
All Grades (N = 178)				
Number	172	173	149	55
Proportion	.97	.97	.84	.31

attained identity as their highest level, with five of these boys attaining a uses subtest; Table 13 indicates 19 girls attained identity as their highest level, one of whom attained a uses subtest. A Chi-square test revealed that the sex difference was not significant. Of the 49 children, then, whose highest level of attainment was identity, 6 attained uses subtests (3 supraordinate-subordinate, 1 principle, and 2 problem solving). In general, we may conclude that these data support the fourth prediction of the CLD model: attainment of a concept to only the concrete or identity levels severely limits mastery of the uses of a concept.

Reviewing the fifth prediction, the model holds that a higher proportion of children who attained the formal level, in comparison to the classificatory, will master the three concept uses. In the

TABLE 11

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: All Subjects

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.
1st												
N Passing Level	1			23			54			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
4th												
N Passing Level	1			13			73			5		
N Passing Use	0	0	0	2	0	0	10	1	11	2	0	2
Proportion	.00	.00	.00	.15	.00	.00	.14	.01	.15	.40	.00	.40
7th												
N Passing Level	0			9			47			35		
N Passing Use	0	0	0	1	0	2	7	7	9	6	15	23
Proportion	.00	.00	.00	.11	.00	.22	.15	.15	.19	.17	.43	.66
10th												
N Passing Level	0			4			26			56		
N Passing Use	0	0	0	0	1	0	6	5	10	37	44	48
Proportion	.00	.00	.00	.00	.25	.00	.23	.19	.38	.66	.79	.86
All Grades												
N Passing Level	2			49			200			96		
N Passing Use	0	0	0	3	1	2	23	13	30	45	59	73
Proportion	.00	.00	.00	.06	.02	.04	.12	.07	.15	.47	.61	.76

TABLE 12

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Boys

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.
1st												
N Passing Level	1			13			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
4th												
N Passing Level	0			9			35			2		
N Passing Use	0	0	0	1	0	0	4	0	5	2	0	0
Proportion	.00	.00	.00	.11	.00	.00	.11	.00	.14	1.00	.00	.00
7th												
N Passing Level	0			6			27			11		
N Passing Use	0	0	0	1	0	2	4	5	7	1	5	8
Proportion	.00	.00	.00	.17	.00	.33	.15	.19	.26	.09	.86	.96
10th												
N Passing Level	0			2			13			28		
N Passing Use	0	0	0	0	1	0	3	2	5	21	24	27
Proportion	.00	.00	.00	.00	.50	.00	.23	.15	.38	.75	.86	.96
All Grades												
N Passing Level	1			30			101			41		
N Passing Use	0	0	0	2	1	2	11	7	17	24	29	35
Proportion	.00	.00	.00	.07	.03	.07	.11	.07	.17	.59	.71	.85

TABLE 13

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Girls

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.
1st												
N Passing Level	0			10			28			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
4th												
N Passing Level	1			4			38			3		
N Passing Use	0	0	0	1	0	0	6	1	6	0	0	2
Proportion	.00	.00	.00	.25	.00	.00	.16	.03	.16	.00	.00	.67
7th												
N Passing Level	0			3			20			24		
N Passing Use	0	0	0	0	0	0	3	2	2	5	10	15
Proportion	.00	.00	.00	.00	.00	.00	.15	.10	.10	.21	.42	.63
10th												
N Passing Level	0			2			13			28		
N Passing Use	0	0	0	0	0	0	3	3	5	16	20	21
Proportion	.00	.00	.00	.00	.00	.00	.23	.23	.38	.57	.71	.75
All Grades												
N Passing Level	1			19			99			55		
N Passing Use	0	0	0	1	0	0	12	6	13	21	30	38
Proportion	.00	.00	.00	.05	.00	.00	.12	.06	.13	.38	.55	.69

second half of Table 11 we find data against which to test this specific prediction. A total of 200 children mastered the classificatory level as their highest level of attainment, and 96 attained the formal level. Comparisons between children performing at these two levels with reference to their mastery of the concept uses are of special interest not only to the CLD model but to educators and learning theorists as well.

Preliminary Chi-square tests conducted at the .05 level showed that no significant sex differences existed in attainment of each of the uses among formal level attainers and in attainment of the uses among classificatory level attainers. The data in Table 11, combining data over sex, were therefore used for analysis.

Of the classificatory attainers, 12 percent mastered the supraordinate-subordinate subtest; 7 percent, principles; and 15 percent, problem solving. These data are in contrast to performance of formal attainers: 47 percent passed the supraordinate-subordinate subtest; 61 percent, principles; and 76 percent, problem solving. Chi-square tests showed a significant overall advantage in attainment of uses (beyond the .001 level) for children performing at the formal level when compared to those performing at the classificatory level [X^2 = 45.87, supraordinate-subordinate; 106.43, principles; 106.54, problem solving (d.f. = 1)].

To review and summarize this section, data obtained from assessment of equilateral triangle provide strong support for both predictions under scrutiny. When a concept is attained to only the concrete or identity levels, use of the concept is curtailed. When a concept is attained to the formal level, compared to the classificatory level, use of the concept is greatly facilitated.

DIFFICULTY OF THE THREE USES

The sixth prediction derived from the CLD model, and testable in a cross-sectional study, states that performance on these uses subtests will improve as a function of increasing grade group. Table 14 presents the number and proportion of each grade group that fully mastered each of the three concept uses: supraordinate-subordinate, principles, and problem solving. Tables 15 and 16 show the same data for boys and for girls separately. Preliminary Chi-square tests revealed no sex differences in mastery of any of the uses at any of the grade groups or for combined grades. Analyses are, therefore, based on the combined data.

Consistent with the prediction, Table 14 shows a notable improvement in performance in each higher grade group (although fourth and seventh graders do equally well on the supraordinate-subordinate subtest and first and fourth graders demonstrate an equal inability to master the principles subtest). The problem-solving subtest best exemplifies the marked improvement in mastery with increasing grade group: 0 percent of first graders, 14 percent of fourth graders, 37 percent of seventh graders, and 67 percent of tenth graders fully attained this concept use. Noteworthy also is the consistent, sharp improvement in mastery of each of the three uses

TABLE 14

Number and Proportion of Each Grade Group that Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n = 82)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n = 92)			
Number	14	1	13
Proportion	.15	.01	.14
7th (n = 91)			
Number	14	22	34
Proportion	.15	.24	.37
10th (n = 86)			
Number	43	50	58
Proportion	.50	.58	.67
All Grades (N = 351)			
Number	71	73	105
Proportion	.20	.21	.30

from seventh- to tenth-grade groups. The marked improvement in attainment can be attributed both to specific mathematical instruction and to emergence of cognitive operations specified by the model. Table 14 indicates, in addition, that for the total subject population 20 percent mastered the supraordinate-subordinate subtest; 21 percent, principles; and 30 percent, problem solving.

Chi-square tests were used to ascertain statistically significant differences 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 uses. The difference in proportions of subjects attaining each of the uses was significant beyond the .001 level [X^2 = 70.79, supraordinate-subordinate; 116.66, principles; 106.11, problem solving (d.f. = 3)]. A Chi-square analog to Scheffé's

TABLE 15

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n = 40)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n = 46)			
Number	7	0	5
Proportion	.15	.00	.11
7th (n = 44)			
Number	6	10	17
Proportion	.14	.23	.39
10th (n = 43)			
Number	24	27	32
Proportion	.56	.63	.74
All Grades (N = 173)			
Number	37	37	54
Proportion	.21	.21	.31

theorem was performed between all pairs of grade groups to determine where the differences in each use were significant at the .05 level. For the supraordinate-subordinate subtest, the performance of the tenth-grade group differed significantly from that of each of the other three grade groups. For both the principles and problem solving subtests every pair-wise comparison between grade groups differed significantly except that between first and fourth grades. That is, with increasing grade groups a statistically significant improvement in attainment occurred on principles and problem-solving subtests.

We may conclude that the prediction of increasing mastery of uses as a function of increased grade group has received strong and consistent support from these data.

TABLE 16

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n = 42)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n = 46)			
Number	7	1	8
Proportion	.15	.02	.17
7th (n = 47)			
Number	8	12	17
Proportion	.17	.26	.36
10th (n = 43)			
Number	19	23	26
Proportion	.44	.53	.60
All Grades (N = 178)			
Number	34	36	51
Proportion	.19	.20	.29

RELATIONSHIP BETWEEN VOCABULARY DEVELOPMENT AND ATTAINMENT OF CONCEPT LEVELS AND USES

The final section of the present chapter is concerned with the last two of our eight predictions. It is expected that having the verbal labels for the concept equilateral triangle and its attributes will be positively correlated with attainment of levels and performance on the uses subtests within individual grade groups. Across combined grade groups, vocabulary scores and attainment of levels and uses subtests should show an even higher positive correlation.

In order to compute correlation coefficients, a special scaling system was devised. For each subject, a point score of one was assigned to full attainment of each concept level and each use, and a score of zero to each when mastery was not attained. The second variable for all computations was mean performance on the seven-item vocabulary test in which a score of one 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 zero, for no labels correct, to a perfect score of seven. For each subject, then, overall performances on concept level subtests, concept uses subtests, combined levels and uses subtests, and vocabulary were calculated.

This scoring system generated Table 17 which presents means and standard deviations for levels, uses, combined levels and uses, and vocabulary scores at each grade group and for all grades. In addition, mean scaled scores were computed for boys and girls separately. The predicted improvement in concept attainment and performance on uses with increasing grade group is, of course, demonstrated in these data based on mean scaled scores as it was in the data based on proportions. Mean scores on the vocabulary test also show a gradual improvement with increasing grade group. Mean scaled scores for boys and girls are very similar on each measure, as well as on vocabulary.

TABLE 17

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.
1st	82	2.54	.76	.00	.00	2.54	.76	2.55	1.45
4th	92	2.86	.48	.30	.57	3.16	.82	3.71	1.61
7th	91	3.25	.63	.77	.87	4.02	1.25	5.18	1.60
10th	86	3.57	.58	1.76	1.23	5.33	1.63	5.91	1.44
All Grades	351	3.06	.72	.71	1.04	3.77	1.55	4.36	1.99
All Boys	173	3.03	.65	.74	1.07	3.77	1.56	4.26	1.95
All Girls	178	3.08	.79	.68	1.01	3.76	1.55	4.45	2.03

Pearson product-moment correlations (r) were then calculated in order to discover the relationship between vocabulary comprehension and task performance. For each grade group, all grades combined, and all boys and all girls, Table 18 presents the correlations between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses.

Tests for any statistical significance, at the .05 level, between the correlations for boys and girls on each of the three performance measures revealed no sex differences. The correlations within each grade group are quite modest, especially for the first- and fourth-grade groups. The very low or zero order correlations for the younger subjects reflect a limited range of performance. The range of attainment on concept levels was small, few or no uses subtests were passed, and comprehension of verbal labels was comparatively limited. Seventh and tenth graders, by contrast, showed increasing competence with verbal labels and a wider range of performance on concept attainment and uses. The correlations for these grade groups indicate, in general, a positive and substantial relationship between test performance and vocabulary scores. The relationship is especially strong at the tenth-grade group. Seven of the nine correlations obtained for fourth-, seventh-, and tenth-grade groups were statistically significant from zero at or beyond the .05 level.

TABLE 18

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
1st	82	.17	.00	.17
4th	92	.09	.23*	.21
7th	91	.57**	.45**	.60**
10th	86	.66**	.59**	.68**
All Grades	351	.58**	.60**	.67**
All Boys	173	.56**	.62**	.66**
All Girls	178	.59**	.59**	.69**

*p < .05

**p < .01

Correlations were generally higher for the total subject population, as well as for all boys and all girls. The correlation was .58 between overall performance on concept level subtests and overall performance on the vocabulary subtest. The correlation between overall performance on three concept uses and vocabulary scores was .60 and between overall performance on combined levels and uses and vocabulary scores, .67. Each of these three correlations was statistically significant from zero at or beyond the .01 level, as were correlations for all boys and all girls. The expected relation between vocabulary proficiency and concept attainment and use specified in our two final predictions is clearly supported by the correlational data.

IV

RESULTS OF CLD ASSESSMENT SERIES II: CUTTING TOOL

OVERVIEW

This chapter will be devoted to presentation and analyses of data obtained from the cutting tool battery in order to test each of the eight CLD predictions concerning conceptual development. First, a short description of the child population and specific criteria used for determining full attainment on each subtest of the battery are provided.

CHILD POPULATION

Table 19 presents mean ages and age ranges for the 349 children who participated in Assessment Series II. With each grade group, data are presented for all subjects and then for boys and girls,

TABLE 19

Total Number of Children, Mean Age, and Age Range at Each Grade Group

Grade	Number	Mean Age (in years and months)	Age Range (in years and months)
1	Total 80	7 - 0	6 - 5 to 7 - 6
	Boys 40	7 - 0	6 - 5 to 7 - 6
	Girls 40	7 - 0	6 - 6 to 7 - 6
4	Total 92	10 - 0	9 - 5 to 10 - 10
	Boys 46	10 - 0	9 - 5 to 10 - 9
	Girls 46	10 - 0	9 - 5 to 10 - 10
7	Total 91	13 - 0	12 - 4 to [illegible] - 10
	Boys 44	13 - 0	12 - 5 to 13 - 10
	Girls 47	12 - 11	12 - 4 to 13 - 7
10	Total 86	15 - 11	15 - 5 to 16 - 9
	Boys 43	15 - 11	15 - 5 to 16 - 9
	Girls 43	15 - 10	15 - 4 to 16 - 7

separately. The total number of children varied at each grade group: 80 first graders, 92 fourth graders, 91 seventh graders, and 86 tenth graders participated in the assessment. Equal numbers of boys and girls were represented at each grade group with the exception of seventh grade, in which 44 boys and 47 girls were tested. Age range varied from 13 months, in the first-grade group, to 18 months in the seventh-grade group; mean age and age range for boys and girls within grade group varied little.

CRITERIA FOR FULL ATTAINMENT

Criteria for full attainment of each of the first three concept levels and three uses followed the convention described earlier of permitting only one error within the items of any one subtest. Table 20 specifies these criteria. At the formal level the criterion for attainment required correct responses on 15 of the total 18 items; i.e., about 80 percent of the combined formal subtest items were required for full mastery.

TABLE 20

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. Discrim. Attributes	6	15 items correct or approximately 80% of combined formal items
b. Labels	5	
c. Evaluating Defining Attributes	6	
d. Definition	1	
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

PROPORTION OF EACH GRADE GROUP CONFORMING TO THE PREDICTED INVARIANT SEQUENCE

Descriptive data will be presented in this section in order to evaluate the first prediction derived from the CLD model. Since sequence of attainment of the four concept levels is presumed to be invariant, only five patterns of attainment are acceptable. The number and proportion of children at each grade group who attained the successive levels in the five patterns consistent with the CLD model are presented in the first five rows of Table 21.

Tables 22 and 23 present the same data for boys and girls separately. Chi-square tests were performed at the .05 level of statistical significance to discover if any sex differences existed in the subtotals of children conforming to the five predicted patterns of attainment. No statistically significant sex differences were observed within grade groups or for all grade groups combined. Therefore, the remainder of this section will deal with Table 21, combining data for boys and girls.

No children failed all four levels and none passed the concrete level while failing the three higher levels. Twenty-one children passed concrete and identity, but failed classificatory and formal levels. Children who passed the three lower levels but failed the formal numbered 119, and an additional 198 children passed all four concept levels. Thus a total of 338 children, or 97 percent, conformed to the predicted invariant sequence of attainment on the cutting tool battery. Reading across the columns of Table 21 that summarize performance within grade group, it is apparent that the percentage of children attaining the concept in accord with the model's prediction was very close: 94 percent of the first graders, 97 percent of the fourth graders, 98 percent of the seventh graders, and 99 percent of the tenth graders conformed. The remainder of Table 21 shows the number and proportion of children whose performance followed each of the 11 patterns of attainment that are not consistent with the model. Three percent (11 subjects) of the total 349 children departed from the predicted sequence of attainment and these children fell in just 3 of the 11 possible deviating patterns. Nine subjects passed the formal level after failing the classificatory level. These children were distributed over the four grade groups although the largest number of PPFP deviants was found in the first-grade group. One first grader also failed every level but classificatory (FFPF), and one fourth-grade child passed identity and classificatory but failed concrete and formal (FPPF).

Table 24 presents frequencies of subjects for each pattern of exception observed in the present assessment and number of items correct at each concept level for which attainment criterion was not met. Examination of these protocols may help to explain their occurrence. Inspection of Table 24 reveals that of the nine children who attained the concept levels in the PPFP pattern of exception, seven just barely missed meeting the mastery criterion by passing six items when seven items were required. The remaining two subjects fell somewhat farther short of criterion.

TABLE 21

Number and Proportion of Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=80)	4th (n=92)	7th (n=91)	10th (n=86)	All Grades (N=349)
FFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PPFF	5 .06	5 .05	8 .09	3 .03	21 .06
PPPF	39 .49	41 .45	27 .30	12 .14	119 .34
PPPP	31 .39	43 .47	54 .59	70 .81	198 .57
Subtotal Conforming	75 .94	89 .97	89 .98	85 .99	338 .97
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	1 .01	0 .00	0 .00	0 .00	1 .00
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	0 .00	0 .00	0 .00	0 .00	0 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	0 .00	1 .01	0 .00	0 .00	1 .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	4 .05	2 .02	2 .02	1 .01	9 .03
Subtotal Not Conforming	5 .06	3 .03	2 .02	1 .01	11 .03

TABLE 22

Number and Proportion of Boys at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=40)	4th (n=46)	7th (n=44)	10th (n=[illegible]3)	All Grades (N=173)
FFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PPFF	1 .03	3 .07	5 .11	3 .07	12 .07
PPPF	21 .53	15 .33	16 .36	7 .16	59 .34
PPPP	16 .40	25 .54	22 .50	32 .74	95 .55
Subtotal Conforming	38 .95	43 .93	43 .98	42 .98	166 .96
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	0 .00	0 .00	0 .00	0 .00	0 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	0 .00	1 .02	0 .00	0 .00	1 .01
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	2 .05	2 .04	1 .02	1 .02	6 .03
Subtotal Not Conforming	2 .05	3 .07	1 .02	1 .02	7 .04

TABLE 23

Number and Proportion of Girls at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=40)	4th (n=46)	7th (n=47)	10th (n=43)	All Grades (N=176)
FFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PPFF	4 .10	2 .04	3 .06	0 .00	9 .05
PPPF	18 .45	26 .57	11 .23	5 .12	60 .34
PPPP	15 .38	18 .39	32 .68	38 .88	103 .59
Subtotal Conforming	37 .93	46 1.00	46 .98	43 1.00	172 .98
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	1 .03	0 .00	0 .00	0 .00	1 .01
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	0 .00	0 .00	0 .00	0 .00	0 .00
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	2 .05	0 .00	1 .02	0 .00	3 .02
Subtotal Not Conforming	3 .08	0 .00	1 .02	0 .00	4 .02

TABLE 24

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 Subtest	0	1	2	3	4	5	6
9	PPFP	Classificatory Subtest (7 required)					1	1	7
1	FFPF	Concrete Subtest (7 required)					1		
		Identity Subtest (7 required)				1			
1	FPPF	Concrete Subtest (7 required)							1

The first grader in the FFPF pattern of exception missed criterion for attainment of the concrete level by passing four items when six were required. This same child passed only three of the six items required for attainment at the identity level. The performance of this child seems to indicate a lack of attention or misunderstanding of directions on the concrete and identity subtests.

The fourth grader who exhibited the FPPF pattern just barely missed criterion for mastery at the concrete level, as shown in Table 24. Six items were passed when seven were required.

In summary, the majority of the 11 nonconforming children fell in patterns of exception because they just barely missed criterion for attainment on a lower subtest. Such cases are probably most reasonably explained as consequences of measurement error, stringency of criteria, or both. Those cases that fell far short of criterion we ascribe, at least for the present, to inattentiveness or to misunderstanding of the test instructions.

PREDICTED SEQUENCE OF CONCEPT ATTAINMENT AND DIFFICULTY OF THE LEVELS

In this administration of the cutting tool battery, it was not possible to statistically confirm that conformity to the predicted sequence of attainment was not merely due to increasing difficulty of the successive subtests unrelated to the increasingly complex cognitive operations. It was noted that fewer than five subjects were expected to follow each of 12 of the 16 patterns. Therefore, it was statistically inappropriate to perform the Chi-square goodness-of-fit test due to the insufficient cell frequencies.

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 25. Tables 26 and 27 present the same data separately for boys and for girls. Chi-square tests were used to find out if any statistically significant sex differences occurred in attainment of the concept levels. These tests revealed that within grade groups and for all grade groups combined only one statistically significant difference in mastery existed. At the classificatory level the Chi-square for the tenth-grade group indicated superior attainment for girls at the .05 level of significance ($X^2 = 4.195$, d.f. = 1).

Since no strong, systematic sex differences were found, the data in Table 25 were used to evaluate our second and third interrelated predictions regarding invariant sequence of attainment. Prediction two states that within a given grade group the percentage of children passing each successive level of attainment will decrease, and the third prediction maintains that the percentage of children passing any given level will increase as a function of increasing grade group.

Inspection of the row entries of Table 25 shows that within each grade group, as predicted, fewer children in general attained concept levels as the levels increased in difficulty. One minor reversal occurred at the fourth-grade group: 99 percent of the children attained the concrete level and 100 percent attained the identity level. In fact, performance of all children is equally proficient at the concrete and identity levels; the decline is marked only when proceeding from identity to classificatory to formal levels.

Cochran Q tests were used to discover 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 = 104.53, first grade; 117.86, fourth grade; 82.56, seventh grade; 35.47, tenth grade (d.f. = 3)]. McNemar tests were run at the .05 level of significance to find out 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

TABLE 25

Number and Proportion of Each Grade Group that Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=80)				
Number	79	79	71	35
Proportion	.99	.99	.89	.44
4th (n=92)				
Number	91	92	85	45
Proportion	.99	1.00	.92	.49
7th (n=91)				
Number	91	91	81	56
Proportion	1.00	1.00	.89	.62
10th (n=86)				
Number	86	86	82	71
Proportion	1.00	1.00	.95	.83
All Grades (N=349)				
Number	347	348	319	207
Proportion	.99	.99	.91	.59

with (4) classificatory and (5) formal; finally, classificatory with (6) formal. In the first-grade group every comparison showed a significant difference except that of concrete and identity. In the fourth-grade group, all comparisons were significantly different except those of concrete and identity and concrete and classificatory. In the seventh-grade group only the comparison of concrete and identity failed to reach statistical significance, and in the tenth-grade group only the comparisons of concrete and identity and concrete and classificatory were not significantly different. In each of these statistically significant comparisons, fewer children attained the higher concept level. These findings provide strong evidence for the prediction that at any given grade group fewer children fully attain the successive concept levels.

TABLE 26

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=40)				
Number	40	40	37	18
Proportion	1.00	1.00	.93	.45
4th (n=46)				
Number	45	46	41	27
Proportion	.98	1.00	.89	.59
7th (n=44)				
Number	44	44	38	23
Proportion	1.00	1.00	.86	.52
10th (n=43)				
Number	43	43	39	33
Proportion	1.00	1.00	.91	.77
All Grades (N=173)				
Number	172	173	155	101
Proportion	.99	1.00	.90	.58

The columns of Table 25 are relevant to the second prediction addressed in this section. The percentage of children passing any given level of concept attainment should increase as a function of increasing grade group. Inspection shows, however, that at the first three concept levels mastery was about equally proficient regardless of grade group. In addition, at the classificatory level a reversal to the prediction occurred: percentages of seventh graders and first graders attaining t. e concept were identical, and fourth graders surpassed both in percentage of attainment. Only at the highest level of attainment did the data conform to the predicted progression: 44 percent of first graders, 49 percent of fourth graders, 52 percent of seventh graders, and 83 percent of tenth graders mastered the <u>cutting tool</u> concept at the formal level.

TABLE 27

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=40)				
Number	39	39	34	17
Proportion	.98	.98	.85	.43
4th (n=46)				
Number	46	46	44	18
Proportion	1.00	1.00	.96	.39
7th (n=47)				
Number	47	47	43	33
Proportion	1.00	1.00	.91	.70
10th (n=43)				
Number	43	43	43	38
Proportion	1.00	1.00	1.00	.88
All Grades (N=176)				
Number	175	175	164	106
Proportion	.99	.99	.93	.60

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. Not unexpectedly, only one Chi-square, at the formal level, achieved statistical significance ($X^2 = 31.59$, d.f. = 3, $p < .001$). A Chi-square analog to Scheffé's theorem was used to discover where differences among grade groups in attainment of the formal level were significant at the .05 level. Results showed that formal level mastery of the tenth-grade group was superior to that of each of the three lower grade groups. We must conclude, then, that the prediction regarding increased mastery of any given concept level with increasing grade group has not received unequivocal support although there is statistical corroboration at the formal level. Explanation for the lack of consistent evidence for the prediction undoubtedly lies in the facility with which children of all grade groups mastered the cutting tool concept. That is, lack of evidence for progressive attainment of concept levels with increasing grade group reflects a "ceiling effect," such that most children from first to tenth grade have mastered the cutting tool concept to the classificatory level. For example, 89 percent of even the very youngest children fully attained the concept at the classificatory level; virtually no variability occurred across grade groups in attainment of concrete and identity levels, and very little at the classificatory level. The marginal evidence in support of prediction three must, of course, be interpreted within the context of the particular concept being assessed.

RELATIONSHIP BETWEEN FULL ATTAINMENT OF VARIOUS LEVELS AND USES

Predictions four and five deal with the relationship between level of concept attainment and use of the concept. The former specifies that individuals who have attained a concept only to the concrete or identity level may be able to use that concept in cognizing simple perceptual relationships among concepts and in solving problems of a perceptual kind, but that they will not be able to use the concept in understanding supraordinate-subordinate relationships, understanding more complex principles, or in solving more complex problems. The fifth prediction is that concept uses will be mastered by a larger percentage of children attaining the formal level, compared to those children whose highest level of attainment is classificatory.

The first half of Table 28 is relevant to the fourth prediction. (Tables 29 and 30 show these data separately for boys and girls. Preliminary Chi-square tests conducted at the .05 level of statistical significance revealed no sex differences among identity level attainers in mastery of uses.) No children passed concrete as their highest level of attainment. Twenty-one children passed identity as their highest level and among these children, 17 instances of mastery on uses subtests occurred (eight supraordinate-subordinate, one principles, eight problem solving). Thirteen children were responsible for these 17 instances of mastery of uses by identity level attainers; that is, there were three cases in which the same child attained criterion on more than one uses subtest. Further detailed examination of the performances of these 13 children showed that more than half of them (8 of the 13) just barely missed attainment at the classificatory level. The criterion permitted one error; these children missed two items. The 5 remaining children fell somewhat farther short of criterion. Concept uses mastery by identity level attainers thus seems largely due to near-mastery at the classificatory level.

Comparing performances of individuals attaining the classificatory level with those attaining the formal level permits an evaluation of the fifth prediction. The second half of Table 28 presents the relevant data. (Preliminary Chi-square tests run at the .05 level of statistical significance revealed no sex differences

TABLE 28

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: All Subjects

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.
1st												
N Passing Level	0			5			40			35		
N Passing Use	0	0	0	2	0	4	18	2	10	16	0	20
Proportion	.00	.00	.00	.40	.00	.80	.45	.05	.25	.46	.00	.57
4th												
N Passing Level	0			5			42			45		
N Passing Use	0	0	0	2	0	1	29	2	23	35	11	37
Proportion	.00	.00	.00	.40	.00	.20	.69	.05	.55	.78	.24	.82
7th												
N Passing Level	0			8			27			56		
N Passing Use	0	0	0	2	0	1	14	2	5	44	24	40
Proportion	.00	.00	.00	.25	.00	.13	.52	.07	.19	.79	.43	.71
10th												
N Passing Level	0			3			12			71		
N Passing Use	0	0	0	2	1	2	7	0	3	65	49	54
Proportion	.00	.00	.00	.67	.33	.67	.58	.00	.25	.92	.69	.76
All Grades												
N Passing Level	0			21			121			207		
N Passing Use	0	0	0	8	1	8	68	6	41	160	84	151
Proportion	.00	.00	.00	.38	.05	.38	.56	.05	.34	.77	.41	.73

TABLE 29

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Boys

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.
1st												
N Passing Level	0			1			21			18		
N Passing Use	0	0	0	0	0	0	8	0	4	11	0	8
Proportion	.00	.00	.00	.00	.00	.00	.38	.00	.19	.61	.00	.44
4th												
N Passing Level	0			3			16			27		
N Passing Use	0	0	0	1	0	1	12	2	9	20	5	23
Proportion	.00	.00	.00	.33	.00	.33	.75	.13	.56	.74	.19	.85
7th												
N Passing Level	0			5			16			23		
N Passing Use	0	0	0	1	0	1	7	1	3	20	12	16
Proportion	.00	.00	.00	.20	.00	.20	.44	.06	.19	.87	.52	.70
10th												
N Passing Level	0			3			7			33		
N Passing Use	0	0	0	2	1	2	2	0	1	29	26	27
Proportion	.00	.00	.00	.67	.33	.67	.29	.00	.14	.88	.79	.82
All Grades												
N Passing Level	0			12			60			101		
N Passing Use	0	0	0	4	1	4	29	3	17	80	43	74
Proportion	.00	.00	.00	.33	.08	.33	.48	.05	.28	.79	.43	.73

TABLE 30

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Girls

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.
1st												
N Passing Level	0			4			19			17		
N Passing Use	0	0	0	2	0	4	10	2	6	5	0	12
Proportion	.00	.00	.00	.50	.00	1.00	.53	.11	.32	.29	.00	.71
4th												
N Passing Level	0			2			26			18		
N Passing Use	0	0	0	1	0	0	17	0	14	15	6	14
Proportion	.00	.00	.00	.50	.00	.00	.65	.00	.54	.83	.33	.78
7th												
N Passing Level	0			3			11			33		
N Passing Use	0	0	0	1	0	0	7	1	2	24	12	24
Proportion	.00	.00	.00	.33	.00	.00	.64	.09	.18	.73	.36	.73
10th												
N Passing Level	0			0			5			38		
N Passing Use	0	0	0	0	0	0	5	0	2	36	23	27
Proportion	.00	.00	.00	.00	.00	.00	1.00	.00	.40	.95	.61	.71
All Grades												
N Passing Level	0			9			61			106		
N Passing Use	0	0	0	4	0	4	39	3	24	80	41	77
Proportion	.00	.00	.00	.44	.00	.44	.64	.05	.39	.75	.39	.73

in attainment of uses for classificatory level attainers or for formal level attainers.) One hundred twenty-one children attained the classificatory level as their highest attainment level, and 207 attained the formal level. Fifty-six percent of the classificatory level children passed the supraordinate-subordinate subtest compared to 77 percent of formal level children. Five percent of the classificatory attainers passed principles compared to 41 percent of formal attainers. Finally, 34 percent of classificatory attainers passed the problem-solving subtest, whereas 73 percent of children attaining at the fo[illegible] level mastered this uses subtest.

For each of the three conc[illegible]s, Chi-square tests confirmed a significant advantage in per[illegible] on uses (beyond the .001 level) for children attaining a[illegible] formal level compared to those attaining at the classificatory level [$X^2 = 16.04$, supraordinate-subordinate; 48.67, principles; 48.01, problem solving (d.f. = 1)].

In [illegible]mary, data obtained from the cutting tool assessment batte[illegible] [illegible]pport both predictions addressed in this section: attainment [illegible] concrete or identity levels restricts use of the concept; [illegible]ment at the formal level, compared to the classificatory level, renders strong advantage in using a concept.

DIFFICULTY OF THE THREE USES

The sixth prediction of the CLD model holds that performance on the uses subtests will improve as a function of increasing grade group. Table 31 presents the number and proportion of children at each grade who fully mastered each of the three concept uses: supraordinate-subordinate, principles, and problem solving. To determine if any statistically significant sex difference existed, preliminary Chi-square tests were conducted using Tables 32 and 33, which present data separately for boys and for girls. Two of the 15 Chi-squares were significant at the .05 level: first-grade girls performed better than first-grade boys on the problem-solving subtest ($X^2 = 5.12$, d.f. = 1) and at the tenth grade, girls performed better than boys on the supraordinate-subordinate subtest ($X^2 = 6.20$, d.f. = 1). There were no statistically significant sex differences in attainment of uses for all grade groups combined. Since only two sex differences were detected, subsequent analyses used the combined data in Table 31.

Inspection reveals some departure from the prediction on the supraordinate-subordinate and problem-solving subtests. On both of these subtests performance of the fourth-grade group was somewhat superior to that of the seventh-grade group. Among even the youngest children, however, mastery of uses was notable: in the first-grade group, 45 percent attained supraordinate-subordinate and 43 percent problem solving. The large numbers of children who demonstrated classificatory level attainment of the cutting tool concept--regardless of grade group--has been discussed in an earlier section. It is not unexpected that such competence facilitated mastery of concept uses.

TABLE 31

Number and Proportion of Each Grade Group that Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=80)			
Number	36	2	34
Proportion	.45	.03	.43
4th (n=92)			
Number	66	13	61
Proportion	.72	.14	.66
7th (n=91)			
Number	60	26	46
Proportion	.66	.29	.51
10th (n=86)			
Number	74	50	59
Proportion	.86	.58	.69
All Grades (N=349)			
Number	236	91	200
Proportion	.68	.26	.57

Performance on the principles subtest, however, did show substantial and consistent improvement, as predicted, with increasing grade group: 3 percent of first graders, 14 percent of fourth graders, 29 percent of seventh graders, and 58 percent of the tenth graders fully attained the principles subtest. Summary data in Table 31 also show that 68 percent of all subjects fully mastered the supraordinate-subordinate subtest, 26 percent principles, and 57 percent problem solving. These data indicate an impressive degree of proficiency on the uses subtests, especially on the supraordinate-subordinate and problem-solving subtests. These findings must, of course, be viewed 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

TABLE 32

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=40)			
Number	19	0	12
Proportion	.48	.00	.30
4th (n=46)			
Number	33	7	33
Proportion	.72	.15	.72
7th (n=44)			
Number	28	13	20
Proportion	.64	.30	.45
10th (n=43)			
Number	33	27	30
Proportion	.77	.63	.70
All Grades (N=173)			
Number	113	47	95
Proportion	.65	.27	.55

each of the three concept uses. The difference in the proportions of subjects attaining each of the uses was significant beyond the .001 level [X^2 = 32.86, supraordinate-subordinate; 76.04, principles; 16.40, 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 findings were as follows: on the supraordinate-subordinate subtest, performances of the fourth-, seventh-, and tenth-grade groups were each superior to that of the first graders; tenth graders were also superior to seventh graders in attainment on this subtest. On the principles subtest, performances of the seventh- and tenth-grade groups were each superior to that of first graders; tenth graders also surpassed fourth- and seventh-grade

TABLE 33

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=40)			
Number	17	2	22
Proportion	.43	.05	.55
4th (n=46)			
Number	33	6	28
Proportion	.72	.13	.61
7th (n=47)			
Number	32	13	26
Proportion	.68	.28	.55
10th (n=43)			
Number	41	23	29
Proportion	.95	.53	.67
All Grades (N=176)			
Number	123	44	105
Proportion	.70	.25	.60

groups in mastery of principles. On the problem-solving subtest two of the six comparisons were significant: the tenth-grade group and the fourth-grade group surpassed the first-grade group in meeting the criterion for full attainment.

Statistical evaluation of performance data on the uses subtests provides supportive evidence for the sixth prediction regarding increasing mastery of uses with increasing grade group. As assessed by these data, prediction six therefore held up quite well despite the facility with which two of the uses were mastered, especially by the three highest grade groups. On the problem-solving subtest, percentages of attainment exhibited by fourth, seventh, and tenth graders were very close. Again, it is important to note that these results must be interpreted within the context of the specific concept, subtest items, and criteria for mastery.

RELATIONSHIP BETWEEN VOCABULARY DEVELOPMENT AND ATTAINMENT OF CONCEPT LEVELS AND USES

The final section of this chapter is addressed to the last two predictions regarding the relationship between vocabulary proficiency and attainment of levels and performance on the uses subtests. Vocabulary scores and scores based on the attainment of the four levels and three uses are predicted to show a positive correlation within grade groups. The same scores should also show a positive and higher correlation across combined grade groups. In order to compute correlation coefficients, the same scaling system was used for cutting tool as that described in Chapter III for equilateral triangle.

Table 34 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; for combined grade groups; and for all boys and all girls separately. Performance on the six-item vocabulary test of the cutting tool assessment battery indicates quite uniform proficiency across grade groups. Some slight

TABLE 34

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, 6)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
1st	80	3.30	.64	.90	.74	4.20	1.05	4.38	.85
4th	92	3.40	.61	1.52	.88	4.92	1.24	4.53	.88
7th	91	3.51	.66	1.45	1.10	4.96	1.56	4.37	1.10
10th	86	3.78	.49	2.13	1.00	5.91	1.31	4.84	.46
All Grades	349	3.50	.63	1.51	1.03	5.01	1.43	4.53	.88
All Boys	173	3.47	.63	1.47	1.08	4.95	1.49	4.50	.93
All Girls	176	3.52	.62	1.55	.98	5.07	1.38	4.57	.83

improvement occurred with increasing grade group, except for the drop in performance of seventh-grade children. Data in Table 34 demonstrate consistent increasing attainment on concept levels and combined levels and uses with increasing grade group. Mean scaled scores on concept uses show the same sort of pattern as that for vocabulary: performance of the seventh-grade group fell below that of the fourth-grade group. These data, of course, parallel the findings already discussed in earlier sections. Mean scores for boys and girls were very similar, with girls' scores slightly higher on every measure.

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. Correlations for each grade group, overall grade groups, and for all boys and all girls, are shown in Table 35. They were used to evaluate our final two predictions. No statistically significant differences

TABLE 35

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
1st	80	.43**	.00	.27*
4th	92	.49**	.32**	.47**
7th	91	.57**	.45**	.55**
10th	86	.46**	.20	.33**
All Grades	349	.51**	.33**	.46**
All Boys	173	.48**	.29**	.41**
All Girls	176	.55**	.37**	.51**

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

were found between the three sets of correlations for boys and girls. Nine of the 12 correlations within grade groups were sufficiently high to achieve statistical significance from zero at or beyond the .01 level. One additional correlation was significant at the .05 level. Fewest significant correlations occurred between vocabulary scores and scores for concept uses.

Correlations obtained for the total subject population were not consistently or notably greater in magnitude than those within grade groups, but all were statistically significant from zero at or beyond the .01 level, as were correlations for boys and for girls. The correlation between vocabulary and overall performance in concept levels subtests was .51; vocabulary correlated .33 with overall performance on concept uses, and .67 with overall performance on levels and uses. In general, the predicted relationship between vocabulary proficiency and concept attainment and use has been supported by these data.

V

RESULTS OF CLD ASSESSMENT SERIES III: NOUN

OVERVIEW

In this chapter the child population is briefly described. Specific criteria employed in the study for full attainment of each subtest of the noun battery are also reported. Results of the assessment as they pertain to each of the specific predictions derived from the CLD model comprise the major portion of the chapter.

CHILD POPULATION

Table 36 presents mean ages and age ranges of the 362 children who participated in Assessment Series III. At each grade group,

TABLE 36

Total Number of Children, Mean Age, and Age Range at Each Grade Group

Grade	Number	Mean Age (in years and months)	Age Range (in years and months)
1	Total 83	6 - 7	6 - 0 to 7 - 1
	Boys 41	6 - 7	6 - 0 to 7 - 1
	Girls 42	6 - 7	6 - [illegible] to 7 - 1
4	Total 95	9 - 7	9 - 0 to 10 - 5
	Boys 47	9 - 7	9 - 0 to 10 - 4
	Girls 48	9 - 8	9 - 0 to 10 - 5
7	Total 93	12 - 7	11 - 11 to 13 - 5
	Boys 45	12 - 7	12 - 0 to 13 - 5
	Girls 48	12 - 6	11 - 11 to 13 - 2
10	Total 91	15 - 6	14 - 11 to 16 - 4
	Boys 45	15 - 6	15 - 0 to 16 - 4
	Girls 46	15 - 5	14 - 11 to 16 - 2

data are presented separately for boys and girls, as well as for all children. This table shows that number of children and composition by sex, though varying somewhat for each grade, was very comparable. Number of children varied from 83, in the first-grade group, to 95, in the fourth-grade group. Mean ages and age range for boys and girls within any single grade group varied little; age range of children within each grade varied from 13 months for first graders to 18 months for seventh graders.

CRITERIA FOR FULL ATTAINMENT

Criteria for full attainment of each of the first three concept levels and the three concept uses followed the convention of permitting only one error within the items of any one subtest. These criteria are specified exactly in Table 37. At the formal level, the criterion for attainment required correct responses on 20 of the 25 items; 80 percent of the combined formal subtest items were required for full mastery.

TABLE 37

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. Discrim. Attributes	7	20 items correct or approximately 80% of combined Formal items
b. Labels	9	
c. Evaluating Defining Attributes	8	
d. Definition	1	
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Superordinate-Subordinate	4 pairs	3 correct

PROPORTION OF EACH GRADE GROUP CONFORMING TO THE PREDICTED INVARIANT SEQUENCE

In accord with the first prediction derived from the CLD model, the number of acceptable pass/fail patterns for the four concept levels is limited to five. These five acceptable patterns of attaining concept levels are presented in Table 38, along with the number and proportion of each grade group observed in each pattern. The last 11 rows of Table 38 list all possible patterns of attainment of the four concept levels that are not consistent with the CLD model. Inspection shows that every one of the 362 children who participated in the assessment of noun followed one of the five acceptable patterns. Tables 39 and 40 present the same data for readers who wish to inspect these results separately by sex. Percentages of boys and girls in each of the expected patterns are very comparable. The unanimous conformity to predicted patterns made it unnecessary to examine data for sex differences in subtotals of children observed in acceptable versus nonacceptable patterns. Table 38, combining data across sex, shows that 41 percent of all children were observed in the PPFF pattern, 32 percent in PPPF, 12 percent in PFFF, 8 percent in PPPP, and 7 percent in FFFF. Support for the prediction that all children of all grade groups will conform to five acceptable patterns of mastery of the four concept levels was unequivocal.

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 (5 acceptable, 11 unacceptable to the model). It was noted that fewer than 5 subjects were expected to follow each of 8 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

TABLE 38

Number and Proportion of Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=83)	4th (n=95)	7th (n=93)	10th (n=91)	All Grades (N=362)
FFFF	27 .33	0 .00	0 .00	0 .00	27 .07
PFFF	40 .48	3 .03	0 .00	0 .00	43 .12
PPFF	16 [illegible]	76 .80	34 .37	23 .25	149 .41
PPPF	0 .00	16 .17	56 .60	43 .47	115 .32
PPPP	0 .00	0 .00	3 .03	25 .27	28 .08
Subtotal Conforming	83 1.00	95 1.00	93 1.00	91 1.00	362 1.00
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	0 .00	0 .00	0 .00	0 .00	0 .00
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	0 .00	0 .00	0 .00
Subtotal Not Conforming	0 .00	0 .00	0 .00	0 .00	0 .00

TABLE 39

Number and Proportion of Boys at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=41)	4th (n=47)	7th (n=45)	10th (n=45)	All Grades (N=178)
FFFF	15 .37	0 .00	0 .00	0 .00	15 .08
PFFF	20 .49	2 .04	0 .00	0 .00	22 .12
PPFF	6 .15	38 .81	21 .47	12 .27	77 .44
PPPF	0 .00	7 .15	23 .51	24 .53	54 .30
PPPP	0 .00	0 .00	1 .02	9 .20	10 .06
Subtotal Conforming	41 1.00	47 1.00	45 1.00	45 1.00	178 1.00
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	0 .00	0 .00	0 .00	0 .00	0 .00
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	0 .00	0 .00	0 .00
Subtotal Not Conforming	0 .00	0 .00	0 .00	0 .00	0 [illegible]

TABLE 40

Number and Proportion of Girls at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=42)	4th (n=48)	7th (n=48)	10th (n=46)	All Grades (N=184)
FFFF	12 .29	0 .00	0 .00	0 .00	12 .06
PFFF	20 .48	1 .02	0 .00	0 .00	21 .11
PPFF	10 .24	38 .79	13 .27	11 .23	72 .39
PPPF	0 .00	9 .19	33 .69	19 .41	61 .33
PPPP	0 .00	0 .00	2 .04	16 .34	18 .10
Subtotal Conforming	42 1.00	48 1.00	48 1.00	46 1.00	184 1.00
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	0 .00	0 .00	0 .00	0 .00	0 .00
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	0 .00	0 .00	0 .00
Subtotal Not Conforming	0 .00	0 .00	0 .00	0 .00	0 .00

approximate five. Nine 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 ($X^2 = 122.47$, d.f. = 4, $p < .001$).

PROPORTION OF GRADE GROUPS ATTAINING THE FOUR LEVELS

This section will evaluate evidence for predictions two and three--closely related predictions which involve the hypothesized invariant sequence of concept attainment. Within a given grade group the percentage of children passing each successive level of attainment will decrease, according to prediction two; percentage of children passing any given level will increase as a function of increasing grade group, according to prediction three. Pertinent data appear in Table 41.

TABLE 41

Number and Proportion of Each Grade Group that Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=83)				
Number	56	16	0	0
Proportion	.67	.19	.00	.00
4th (n=95)				
Number	95	92	16	0
Proportion	1.00	.97	.17	.00
7th (n=93)				
Number	93	93	59	3
Proportion	1.00	1.00	.63	.03
10th (n=91)				
Number	91	91	68	25
Proportion	1.00	1.00	.75	.27
All Grades (N=362)				
Number	335	292	143	28
Proportion	.93	.81	.40	.08

Data in Tables 42 and 43, presenting data separately by sex, were examined initially to determine if differences existed in frequencies of boys and girls mastering each concept level. Chi-square tests revealed no statistically significant differences either within grade groups or for all grades combined. Table 41, combining data across sex, will therefore be the one of primary interest. It presents the number and proportion of children, at each grade group and for all subjects, who fully mastered each concept level. At any single grade group, and in accord with the first prediction of concern in the present section, the row entries indicate a consistent decrease in percentage of children passing the successive levels of concept attainment. At the seventh- and tenth-grade groups it is noted that 100 percent of the children attained both concrete and identity levels. For all grades combined, decrease in attainment of levels was marked: concrete, 93 percent; identity, 81 percent; classificatory, 40 percent; formal, 8 percent.

TABLE 42

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=41)				
Number	26	6	0	0
Proportion	.63	.15	.00	.00
4th (n=47)				
Number	47	45	7	0
Proportion	1.00	.96	.15	.00
7th (n=45)				
Number	45	45	24	1
Proportion	1.00	1.00	.53	.02
10th (n=45)				
Number	45	45	33	9
Proportion	1.00	1.00	.73	.20
All Grades (N=178)				
Number	163	141	64	10
Proportion	.92	.79	.36	.06

TABLE 43

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=42)				
Number	30	10	0	0
Proportion	.71	.24	.00	.00
4th (n=48)				
Number	48	47	9	0
Proportion	1.00	.98	.19	.00
7th (n=48)				
Number	48	48	35	2
Proportion	1.00	1.00	.73	.04
10th (n=46)				
Number	46	46	35	16
Proportion	1.00	1.00	.76	.35
All Grades (N=184)				
Number	172	151	79	18
Proportion	.93	.82	.43	.10

Cochran Q tests were used to discover if the proportions of children 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 well beyond the .001 level [Q = 136.70, first grade; 247.40, fourth grade; 213.63, seventh grade; 157.72, tenth grade (d.f. = 3)]. McNemar tests were run at the .05 level of statistical significance to determine where specific differences in attainment among the four levels occurred in 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. At the first grade group, five of the six possible comparisons differed significantly. The only comparison that was not statistically significant was classificatory with formal. At the fourth-, seventh-, and tenth-grade groups, five of the six comparisons differed significantly, the exception being the concrete with identity comparison at each of these grade groups. In all of the statistically significant comparisons at each grade group, fewer children passed the higher concept level.

Information in the columns of Table 41 enables us to determine whether or not the percentage of children passing any given concept level increased as a function of increasing grade group. Examination shows that at every level there was an increase in percentage of children attaining that level as grade group increased. Exceptions occurred only at the concrete and identity levels, where virtually all children of the three highest grade groups attained the level, and at the formal level, where first and fourth graders demonstrated no success.

Chi-square tests were used to determine if 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 differences in proportions attaining each of the levels were significant well beyond the .001 level [X^2 = 98.07, concrete; 260.57, identity; 144.15, classificatory; 67.25, 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 differences were as follows: at concrete, identity, and classificatory levels, fourth, seventh, and tenth graders each surpassed attainment of first graders. At the classificatory level, in addition, seventh and tenth graders each surpassed attainment of fourth graders. At the formal level, performance of the tenth-grade group was superior to that of each of the three lower grade groups. Thus, as grade group increased, significantly larger numbers of children attained each concept level.

As assessed by these data, predictions two and three, which deal with difficulty of the successive concept levels, have been supported.

RELATIONSHIP BETWEEN FULL ATTAINMENT OF VARIOUS LEVELS AND USES

The fourth prediction derived from the CLD model states that children who attain a concept to only the concrete or identity levels will be able to use that concept only in understanding simple perceptual relations with other object concepts and in solving simple perceptual problems.

From Table 44 it can be observed that of the 43 children whose highest level of attainment was concrete, none passed a uses subtest. Of the 149 children whose highest level of attainment was identity, there were 15 instances of mastery of uses: 4 supraordinate-subordinate, 2 principles, and 9 problem solving. These 15 instances of attainment represented the performance of 12 children; a tenth-grade, identity level girl successfully mastered all three concept uses. Preliminary Chi-square tests, however, revealed no

TABLE 44

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: All Subjects

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.
1st												
N Passing Level	40			16			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
4th												
N Passing Level	3			76			16			0		
N Passing Use	0	0	0	0	0	0	0	0	1	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.00
7th												
N Passing Level	0			34			56			3		
N Passing Use	0	0	0	2	0	5	2	5	7	2	2	2
Proportion	.00	.00	.00	.06	.00	.15	.04	.09	.13	.67	.67	.67
10th												
N Passing Level	0			23			43			25		
N Passing Use	0	0	0	2	2	4	6	4	8	13	11	15
Proportion	.00	.00	.00	.09	.09	.17	.14	.09	.19	.52	.44	.60
All Grades												
N Passing Level	43			149			115			28		
N Passing Use	0	0	0	4	2	9	8	9	16	15	13	17
Proportion	.00	.00	.00	.03	.01	.06	.07	.08	.14	.54	.46	.61

sex differences in identity level attainers' performance on uses subtests; data for boys and for girls are presented separately in Tables 45 and 46. In general, we may conclude that the fourth prediction is supported by data presented in Table 44: attainment of a concept to only the first two levels of mastery severely limits success in using a concept.

The fifth prediction derived from the CLD model holds that a higher proportion of children who attained at the formal level, in comparison to the classificatory, will master the three concept uses. The second half of Table 44 summarizes the relevant data. Data in Tables 45 and 46 were used to determine if any statistically significant sex differences existed at the .05 level in classificatory level attainers' mastery of uses and in formal level attainers' mastery of uses. None were found.

Table 44 shows that a total of 115 children mastered the classificatory level as their highest level of attainment and 28 mastered the formal level. Comparisons between children attaining at these two levels, as it influenced success in mastery of uses, is critical to an evaluation of the fifth prediction.

Of the classificatory attainers, 7 percent mastered the supraordinate-subordinate subtests; 8 percent, principles; and 14 percent, problem solving. In contrast, of the formal level attainers, 54 percent mastered the supraordinate-subordinate subtest; 46 percent, principles; and 61 percent, problem solving. Chi-square tests statistically confirmed a significant overall advantage, well beyond the .001 level, in performance on the uses subtests for children attaining at the formal level, compared to those whose highest level of mastery was classificatory [X^2 = 36.25, supraordinate-subordinate; 25.78, principles; 27.78, problem solving (d.f. = 1)].

Both of the predictions under review in this section received strong support from descriptive and statistical evaluation. Use of the noun concept was limited if the concept was mastered at concrete or identity levels only. Use of the concept was greatly facilitated by attainment of noun at the formal level, in comparison to attainment at the classificatory level.

DIFFICULTY OF THE THREE USES

In this section the focus will be on whether or not children's performance on the uses of the noun concept improved as grade group increased. Data used to address this sixth prediction are presented in Table 47, which summarizes the number and proportion of each grade group that fully mastered each of the three concept uses: supraordinate-subordinate, principles, and problem solving. Tables 48 and 49 present the same data separately for boys and for girls. Chi-square tests revealed no sex differences in mastery of any of the uses at any grade group or for combined grade groups. Attention will be devoted, therefore, to combined data in Table 47.

Supportive of the prediction, data indicate a gradual improvement in mastery of each use as grade group increased (although first

TABLE 45

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Boys

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.
1st												
N Passing Level	20			6			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
4th												
N Passing Level	2			38			7			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
7th												
N Passing Level	0			21			23			1		
N Passing Use	0	0	0	1	0	1	2	1	3	1	1	1
Proportion	.00	.00	.00	.05	.00	.05	.09	.04	.13	1.00	1.00	1.00
10th												
N Passing Level	0			12			24			9		
N Passing Use	0	0	0	0	1	1	2	1	4	6	5	6
Proportion	.00	.00	.00	.00	.08	.08	.08	.04	.17	.67	.56	.67
All Grades												
N Passing Level	22			77			54			10		
N Passing Use	0	0	0	1	1	2	4	2	7	7	6	7
Proportion	.00	.00	.00	.01	.01	.03	.07	.04	.13	.70	.60	.70

TABLE 46

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Girls

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.
1st												
N Passing Level	20			10			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
4th												
N Passing Level	1			38			9			0		
N Passing Use	0	0	0	0	0	0	0	0	1	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.11	.00	.00	.00
7th												
N Passing Level	0			13			33			2		
N Passing Use	0	0	0	1	0	4	0	4	4	1	1	1
Proportion	.00	.00	.00	.08	.00	.31	.00	.12	.12	.50	.50	.50
10th												
N Passing Level	0			11			19			16		
N Passing Use	0	0	0	2	1	3	4	3	4	7	6	9
Proportion	.00	.00	.00	.18	.09	.27	.21	.16	.21	.44	.38	.56
All Grades												
N Passing Level	21			72			61			18		
N Passing Use	0	0	0	3	1	7	4	7	9	8	7	10
Proportion	.00	.00	.00	.04	.01	.10	.07	.11	.15	.44	.39	.56

TABLE 47

Number and Proportion of Each Grade Group that Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=83)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n=95)			
Number	0	0	1
Proportion	.00	.00	.01
7th (n=93)			
Number	6	7	14
Proportion	.06	.08	.15
10th (n=91)			
Number	21	17	27
Proportion	.23	.19	.30
All Grades (N=362)			
Number	27	24	42
Proportion	.07	.07	.12

and fourth graders had no success on either the supraordinate-subordinate or the principles subtests). On the problem solving subtest, for example, no first graders, one percent of the fourth-grade group, 15 percent of the seventh-grade group, and 30 percent of the tenth-grade group fully attained this concept use. On each of the uses subtests, improvement in mastery was marked from seventh to tenth grade. For the total child population, 7 percent attained supraordinate-subordinate; 7 percent, principles; 12 percent, problem solving.

Chi-square tests were used to ascertain statistically significant differences 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 uses. The difference in

TABLE 48

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=41)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n=4/)			
Number	0	0	0
Proportion	.00	.00	.00
7th (n=45)			
Number	4	2	5
Proportion	.09	.04	.11
10th (n=45)			
Number	8	7	11
Proportion	.18	.16	.24
All Grades (N=178)			
Number	12	9	16
Proportion	.07	.05	.09

proportions of subjects attaining each of the uses was significant well beyond the .001 level [X^2 = 46.08, supraordinate-subordinate; 34.11, principles; 51.25, 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 each of the uses were significant at the .05 level. Results showed that for each of the uses, performance of the tenth-grade group was superior to each of the three lower grade groups. In addition, on the problem-solving subtest, a larger number of seventh graders fully mastered this use than either fourth or first graders. Thus, with increasing grade group there is statistical evidence for increasing success on uses attainment, and we conclude that the sixth prediction has received strong support from assessment of the noun battery.

TABLE 49

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=42)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n=48)			
Number	0	0	1
Proportion	.00	.00	.02
7th (n=48)			
Number	2	5	9
Proportion	.04	.10	.19
10th (n=46)			
Number	13	10	16
Proportion	.28	.22	.35
All Grades (N=184)			
Number	15	15	26
Proportion	.08	.08	.14

RELATIONSHIP BETWEEN VOCABULARY DEVELOPMENT AND ATTAINMENT OF CONCEPT LEVELS AND USES

The final section of this chapter is concerned with the last two of our eight predictions. According to prediction seven, having the verbal labels for the concept and its attributes should correlate positively with attainment of levels and performance on uses subtests within grade groups. Prediction eight holds that across combined grade groups, vocabulary scores and attainment on levels and uses should show an even higher positive correlation. In order to compute correlation coefficients, the same scaling system was used for noun as that described in Chapter III.

Table 50 presents means and standard deviations, based on the scaled scoring system, for levels, uses, combined levels and uses

TABLE 50

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, 14)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
1st	83	.87	.71	.00	.00	.87	.71	.04	.19
4th	95	2.14	.43	.01	.10	2.15	.46	1.93	1.52
7th	93	2.67	.54	.29	.58	2.96	.90	3.47	2.15
10th	91	3.02	.73	.71	.97	3.74	1.46	5.02	2.38
All Grades	362	2.20	1.00	.26	.64	2.46	1.41	2.67	2.55
All Boys	177	2.12	.99	.21	.60	2.33	1.38	2.49	2.50
All Girls	185	2.29	1.01	.30	.67	2.59	1.43	2.84	2.59

(a measure of overall task performance), and vocabulary scores at each grade group and for combined grade groups. In addition, the same scores are shown for all boys and all girls, separately. The mean scores for boys and for girls, though similar, show a slight superiority in girls' performance. The predicted improvement in concept attainment and use with increasing grade group is, of course, evident in these mean scaled scores as it was in data based on proportions. Mean vocabulary scores steadily improved with increasing grade group.

Pearson product-moment correlations (r) were then calculated in order to determine the relationship between vocabulary comprehension and task performance. Table 51 presents the correlations between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses for each grade group, all grades combined, and separately for all boys and all girls.

Tests for any statistical significance, at the .05 level, between the correlations for boys and girls on each of the three performance measures revealed no sex differences. The zero or very low order correlations at the two lowest grade groups reflect a limited range of performance. From Table 50 it can be seen that

TABLE 51

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
1st	83	.04	.00	.04
4th	95	.00	.07	.02
7th	93	.36*	.39*	.47*
10th	91	.63*	.65*	.75*
All Grades	362	.70*	.60*	.77*
All Boys	177	.68*	.61*	.75*
All Girls	185	.71*	.59*	.78*

*p < .01

range of attainment on concept levels was small, few or no uses were mastered, and vocabulary proficiency was limited. Seventh- and tenth-grade groups, by contrast, showed increasing competence with verbal labels and a wider range of performance on concept attainment and uses. Correlations for these grade groups indicate a positive and substantial relationship, especially for tenth graders, between test performance and vocabulary scores. All correlations for seventh- and tenth-grade groups were statistically significant from zero ($p < .01$).

Correlations for all grades combined were very high, as were correlations for total boys and total girls. The correlation between overall performance on concept levels and vocabulary use was .70; between concept uses and vocabulary, .60; and between combined levels and uses and vocabulary, .75. Each of these three correlations was statistically significant from zero ($p < .01$), as were the correlations for boys and girls. We conclude that there is a strong and positive relationship between vocabulary proficiency and concept attainment and use, as specified in our two final predictions.

VI

RESULTS OF CLD ASSESSMENT SERIES IV: TREE

OVERVIEW

A brief description of the child population is followed by a report of the subtests used in the assessment series and the criteria employed for full attainment. Results of the assessment, as they bear on the eight specific predictions of the CLD model, are reported in the remainder of the chapter.

CHILD POPULATION

Three hundred and fifty-four children participated in Assessment Series IV. Table 52 presents mean ages and age ranges for all subjects and for boys and girls separately at each of four grade groups. Eighty-three first graders, 93 fourth graders, 91 seventh graders, and 87 tenth graders participated in assessment of the

TABLE 52

Total Number of Children, Mean Age, and Age Range at Each Grade Group

Grade	Number	Mean Age (in years and months)	Age Range (in years and months)
1	Total 83	6 - 9	6 - 2 to 7 - 3
	Boys 41	6 - 9	6 - 2 to 7 - 3
	Girls 42	6 - 9	6 - 3 to 7 - 3
4	Total 93	9 - 9	9 - 2 to 10 - 7
	Boys 46	9 - 9	9 - 2 to 10 - 6
	Girls 47	9 - 9	9 - 2 to 10 - 7
7	Total 91	12 - 9	12 - 1 to 13 - 7
	Boys 44	12 - 9	12 - 2 to 13 - 7
	Girls 47	12 - 8	12 - 1 to 13 - 4
10	Total 87	15 - 8	15 - 1 to 16 - 6
	Boys 43	15 - 8	15 - 2 to 16 - 6
	Girls 44	15 - 7	15 - 1 to 16 - 4

tree concept. Within each grade group roughly the same numbers of boys and girls were represented. Mean ages and age range for boys and girls within grade groups are either identical or very close. Age ranges varied from 13 months in the first-grade group to 18 months in the seventh-grade group.

CRITERIA FOR FULL ATTAINMENT

Criteria established for full attainment of each of the first three concept levels and three uses, as shown in Table 53, followed the convention described in earlier chapters--only one error was permitted within the items of any one subtest. At the formal level the criterion for mastery required correct responses on 28 of the total 35 items, i.e., about 80 percent of the combined formal subtest items were required for mastery.

TABLE 53

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. Discrim. Attributes	10	28 items correct or approximately 80% of Combined Formal items
b. Labels	14	
c. Evaluating Defining Attributes	10	
d. Definition	1	
5. Principle	10 pairs	8 correct
6. Problem Solving	10	8 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

separately for boys and for girls. Chi-square tests, performed at the .05 level of statistical significance, revealed no sex differences in the subtotals of children, within grade groups or for all grade groups combined, in conformity to the five combined predicted patterns. The remainder of this section will, therefore, focus on Table 54, combining data across sex.

Inspection of the first five rows of Table 54 shows that one first grader failed all four levels and four passed the concrete level only. Across all grade groups, 53 children (15 percent) passed the first two levels and failed the last two. The majority of children displayed either the PPPF pattern (44 percent) or the PPPP pattern (37 percent). In all, 98 percent of the child population, or 346 of the total 354 subjects, conformed to an attainment sequence predicted by the CLD model. Examination of the subtotals within grade groups shows that conformity to predicted patterns was uniformly high at first, fourth, seventh, and tenth grades.

Two percent (eight children) of the total child population displayed nonconforming patterns. Of the 11 possible patterns of exception, 4 were observed: two children failed all levels except identity; one child failed concrete, but passed identity and classificatory; two children passed concrete, failed identity, and went on to attain classificatory; three children passed all levels except classificatory. Nonconformity was observed in all grades, but most deviation occurred in the two lower grade groups.

The fact that 98 percent of the total child population conformed to the predicted invariant sequence of attainment provides very strong support for the major proposition and first prediction derived from the CLD model.

Table 57 presents frequencies of subjects according to each pattern of exception and number of items correct at each concept level for which criterion was not met. Examination of these protocols may suggest why these children deviated from the predicted invariant sequence of attainment. Inspection of Table 57 shows that three children attained higher levels after failing to meet requirements for attainment at the concrete level. Seven of the eight concrete items were required for mastery and all of these deviating children passed six of the eight concrete items--falling just one item short of criterion.

TABLE 54

Number and Proportion of Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=83)	4th (n=93)	7th (n=91)	10th (n=87)	All Grades (N=354)
FFFF	1 .01	0 .00	0 .00	0 .00	1 .00
PFFF	4 .05	0 .00	0 .00	0 .00	4 .01
PPFF	29 .35	10 .11	12 .13	2 .02	53 .15
PPPF	46 .55	68 .73	32 .35	11 .13	157 .44
PPPP	0 .00	12 .13	46 .51	73 .84	131 .37
Subtotal Conforming	80 .96	90 .97	90 .99	86 .99	346 .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	1 .01	1 .01	0 .00	0 .00	2 .01
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	1 .01	0 .00	0 .00	0 .00	1 .00
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	1 .01	1 .01	0 .00	0 .00	2 .01
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	1 .01	1 .01	1 .01	3 .01
Subtotal Not Conforming	3 .04	3 .03	1 .01	1 .01	8 .02

TABLE 55

Number and Proportion of Boys at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=41)	4th (n=46)	7th (n=44)	10th (n=43)	All Grades (N=174)
FFFF	1 .02	0 .00	0 .00	0 .00	1 .01
PFFF	1 .02	0 .00	0 .00	0 .00	1 .01
PPFF	14 .34	5 .11	8 .18	2 .05	29 .17
PPPF	25 .61	34 .74	16 .36	6 .14	81 .47
PPPP	0 .00	5 .11	20 .45	34 .79	59 .34
Subtotal Conforming	41 1.00	44 .96	44 1.00	42 .98	171 .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	0 .00	1 .02	0 .00	0 .00	1 .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	1 .02	0 .00	1 .02	2 .01
Subtotal Not Conforming	0 .00	2 .04	0 .00	1 .02	3 .02

TABLE 56

Number and Proportion of Girls at the Four Grade Groups Conforming and Not Conforming to Predicted Sequence of Attainment

Pass-Fail Sequence	1st (n=42)	4th (n=47)	7th (n=47)	10th (n=44)	All Grades (N =180)
FFFF	0 .00	0 .00	0 .00	0 .00	0 .00
PFFF	3 .07	0 .00	0 .00	0 .00	3 .02
PPFF	15 .36	5 .11	4 .09	0 .00	24 .13
PPPF	21 .50	34 .72	16 .34	5 .11	76 .42
PPPP	0 .00	7 .15	26 .55	39 .89	72 .40
Subtotal Conforming	39 .93	46 .98	46 .98	44 1.00	175 .97
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	1 .02	0 .00	0 .00	0 .00	1 .01
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	1 .02	0 .00	0 .00	0 .00	1 .01
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	1 .02	1 .02	0 .00	0 .00	2 .01
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	0 .00	1 .02	0 .00	1 .01
Subtotal Not Conforming	3 .07	1 .02	1 .02	0 .00	5 .C

TABLE 57

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
2	FPFF							2
1	FPPF							1
		Number of Items Correct on Identity Subtest (7 required)						
		0	1	2	3	4	5	6
2	PFPF							2
		Number of Items Correct on Classificatory Subtest (7 required)						
		0	1	2	3	4	5	6
3	PPFP						1	2

The two children who passed concrete, failed identity, and went on to attain the classificatory level also fell just one item short of meeting criterion for attainment at the identity level. The three children observed in the PPFP pattern of exception similarly came very close to meeting criterion for mastery at the classificatory level. In every case of deviation, then, it seems reasonable to conclude that errors of measurement associated with each subtest, stringency of criterion, or both, were responsible for observed nonconformity.

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 (5 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 and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations ($X^2 = 33.08$, d.f. = 1, $p < .001$).

PROPORTION OF GRADE GROUPS ATTAINING THE FOUR LEVELS

Predictions two and three, addressed in this section, are closely related: prediction two maintains that within a given grade group the percentage of children passing each successive level of attainment will decrease; prediction three states that the percentage of children passing any given level will increase as a function of increased grade group.

Data were examined initially to ascertain whether or not sex differences existed in frequencies of children who fully attained each concept level. Chi-square tests, conducted at the .05 level of statistical significance, revealed that at each level of attainment, both within grade groups and for all grade groups combined, no sex differences in concept mastery occurred. Subsequent analyses, therefore, used Table 58, combining data for boys and girls; Tables 59 and 60 have been included for readers who are interested in examining these data separately.

Table 58 shows the number and proportion of each grade group, and of all grade groups combined, that fully attained each concept level. Inspection of the row entries discloses that within every grade group the proportion of children attaining each successive level of concept attainment did indeed decrease. The only exception to this finding was the similar performance of the higher grade groups at the concrete and identity levels; otherwise the decrease was marked and consistent. For example, within the first-grade group, 96 percent attained the concrete level; 93 percent, identity; 58 percent, classificatory, and 0 percent, formal. The same decrement in proportions of children attaining the successive levels is reflected in data for all grades combined: concrete, 99 percent; identity, 98 percent; classificatory, 82 percent; and formal, 38 percent.

TABLE 58

Number and Proportion of Each Grade Group that Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=83)				
Number	80	77	48	0
Proportion	.96	.93	.58	.00
4th (n=93)				
Number	92	92	81	13
Proportion	.99	.99	.87	.14
7th (n=91)				
Number	91	91	78	47
Proportion	1.00	1.00	.86	.52
10th (n=87)				
Number	87	87	84	74
Proportion	1.00	1.00	.97	.85
All Grades (N=354)				
Number	350	347	291	134
Proportion	.99	.98	.82	.38

Cochran Q tests were used to discover if the proportions of children 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 well beyond the .001 level [Q = 178.77, first grade; 129.97, fourth grade; 105.53, seventh grade; 31.09, tenth 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 and (5) formal; finally, classificatory with (6) formal. For the first-, fourth-, and seventh-grade groups, five of the six possible comparisons differed with statistical significance. Only the concrete with identity comparison showed no statistically significant difference. In all of the other comparisons, fewer children

TABLE 59

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=41)				
Number	40	39	25	0
Proportion	.98	.95	.61	.00
4th (n=46)				
Number	45	46	39	6
Proportion	.98	1.00	.85	.13
7th (n=44)				
Number	44	44	36	20
Proportion	1.00	1.00	.82	.45
10th (n=43)				
Number	43	43	40	35
Proportion	1.00	1.00	.93	.81
All Grades (N=174)				
Number	172	172	140	61
Proportion	.99	.99	.80	.35

passed the higher concept level. In the tenth-grade group, three of the six comparisons were statistically significant; fewer children attained formal when compared to each of the three lower concept levels.

Examining the columns of Table 58 enables us to determine if the percentage of children passing any single level of concept attainment increased as a function of increasing grade group. Inspection immediately discloses that these data support prediction three. One minor reversal occurred at the classificatory level: 87 percent of fourt graders and 86 percent of seventh graders attained this level. Otherwise the proportions of children attaining a given level increased in accordance with the prediction. For example, at the formal level, the progression was as follows: 0 percent of the first graders, 14 percent of the fourth graders, 52 percent of the seventh graders,

TABLE 60

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each Level of Attainment

Grade	Concrete	Identity	Classificatory	Formal
1st (n=42)				
Number	40	38	23	0
Proportion	.95	.90	.55	.00
4th (n=47)				
Number	47	46	42	7
Proportion	1.00	.98	.89	.15
7th (n=47)				
Number	47	47	42	27
Proportion	1.00	1.00	.89	.57
10th (n=44)				
Number	44	44	44	39
Proportion	1.00	1.00	1.00	.89
All Grades (N=180)				
Number	178	175	151	73
Proportion	.99	.97	.84	.41

and 85 percent of the tenth graders fully mastered the highest level of concept attainment.

Chi-square tests were used to find out if 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 differences in proportions attaining three of the levels were significant at or beyond the .01 level [X^2 = 15.79, identity; 48.23, classificatory; 162.86, formal (d.f. = 3)]. The differences in proportions of individual grade groups attaining the concrete level did not reach statistical significance. A Chi-square analog to Scheffé's theorem was performed to determine where differences between grade groups in attainment of identity, classificatory, and formal levels were significant at the .05 level. At both identity and classificatory levels attainment of tenth, seventh, and fourth graders each surpassed attainment of the first-grade group. At the formal level, five of the six pair-wise comparisons differed significantly, (the exception being that between first and fourth graders); that is, the higher the grade group, the greater the proportion of children attaining the formal level.

To review and summarize, data assessing full attainment of the concept tree provide strong evidence supporting the prediction that within any given grade, the proportion of children passing the successive concept levels will decrease. The prediction stating that mastery of any given level of concept attainment increases with increasing grade group has been upheld by these data, although the prediction was not statistically supported at the concrete level.

RELATIONSHIP BETWEEN FULL ATTAINMENT OF VARIOUS LEVELS AND USES

This section will evaluate data relevant to predictions four and five. The fourth prediction states that individuals who have attained a concept only to the concrete or 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.

The first half of Table 61 presents data necessary to evaluate prediction four. These data are shown separately for boys and for girls in Tables 62 and 63. One boy and three girls attained concrete as their highest level of concept mastery; no uses subtests were passed by these four children. Fifty-five children (30 boys and 25 girls) attained identity as their highest level. Again, no uses subtests were mastered by identity level attainers. The fourth prediction, then, was borne out by data from the tree assessment.

According to prediction five, a higher proportion of children who attained at the formal level, in comparison to the classificatory, should master the three concept uses. The second half of Table 61 contains the relevant data. The second half of Table 62 and the second half of Table 63 present the same data separately for boys and for girls. Chi-square tests, conducted at the .05 level of statistical significance, disclosed that among the classificatory level attainers no sex differences existed in mastery of uses subtests. Among formal level attainers, however, two of the three Chi-squares were statistically significant and both indicated superior performance for boys. More formal level boys attained the principles subtest when compared to formal level girls ($X^2 = 6.34$, d.f. = 1). More formal level boys also attained the problem solving subtest when compared to formal level girls ($X^2 = 7.55$, d.f. = 1). From Table 62, we find that of the 81 boys attaining at the classificatory level, 9 (11 percent) mastered supraordinate-subordinate and none attained principles or problem solving. Of the 61 formal level attainers, 51 percent mastered supraordinate-subordinate; 57 percent, principles; and 28 percent, problem solving. Table 63 reveals that of the 79 classificatory level girls, 4 (5 percent) mastered supraordinate-subordinate and none attained principles

TABLE 61

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: All Subjects

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.
1st												
N Passing Level	4			30			48			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
4th												
N Passing Level	0			11			69			13		
N Passing Use	0	0	0	0	0	0	8	0	0	1	2	0
Proportion	.00	.00	.00	.00	.00	.00	.12	.00	.00	.08	.15	.00
7th												
N Passing Level	0			12			32			47		
N Passing Use	0	0	0	0	0	0	2	0	0	20	12	6
Proportion	.00	.00	.00	.00	.00	.00	.06	.00	.00	.43	.26	.13
10th												
N Passing Level	0			2			11			74		
N Passing Use	0	0	0	0	0	0	3	0	0	45	47	18
Proportion	.00	.00	.00	.00	.00	.00	.27	.00	.00	.61	.64	.24
All Grades												
N Passing Level	4			55			160			134		
N Passing Use	0	0	0	0	0	0	13	0	0	66	61	24
Proportion	.00	.00	.00	.00	.00	.00	.08	.00	.00	.49	.46	.18

TABLE 62

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Boys

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.
1st												
N Passing Level	1			14			25			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
4th												
N Passing Level	0			6			34			6		
N Passing Use	0	0	0	0	0	0	7	0	0	0	2	0
Proportion	.00	.00	.00	.00	.00	.00	.21	.00	.00	.00	.33	.00
7th												
N Passing Level	0			8			16			20		
N Passing Use	0	0	0	0	0	0	0	0	0	7	9	4
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.35	.45	.20
10th												
N Passing Level	0			2			6			35		
N Passing Use	0	0	0	0	0	0	2	0	0	24	24	13
Proportion	.00	.00	.00	.00	.00	.00	.33	.00	.00	.69	.69	.37
All Grades												
N Passing Level	1			30			81			61		
N Passing Use	0	0	0	0	0	0	9	0	0	31	35	17
Proportion	.00	.00	.00	.00	.00	.00	.11	.00	.00	.51	.57	.28

TABLE 63

Relationship Between Full Mastery of Various Levels and Full Mastery of Uses: Girls

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.
1st												
N Passing Level	3			16			23			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
4th												
N Passing Level	0			5			35			7		
N Passing Use	0	0	0	0	0	0	1	0	0	1	0	0
Proportion	.00	.00	.00	.00	.00	.00	.03	.00	.00	.14	.00	.00
7th												
N Passing Level	0			4			16			27		
N Passing Use	0	0	0	0	0	0	2	0	0	13	3	2
Proportion	.00	.00	.00	.00	.00	.00	.13	.00	.00	.48	.11	.07
10th												
N Passing Level	0			0			5			39		
N Passing Use	0	0	0	0	0	0	1	0	0	21	23	5
Proportion	.00	.00	.00	.00	.00	.00	.20	.00	.00	.54	.59	.13
All Grades												
N Passing Level	3			25			79			73		
N Passing Use	0	0	0	0	0	0	4	0	0	35	26	7
Proportion	.00	.00	.00	.00	.00	.00	.05	.00	.00	.48	.36	.10

or problem solving. Of the 73 formal level girls, 48 percent mastered supraordinate-subordinate; 36 percent, principles; and 10 percent, problem solving.

Chi-square tests, conducted separately on data for boys and for girls, confirmed a significant overall advantage in attainment of uses for children performing at the formal level, compared to those performing at the classificatory level. Results for boys were as follows: X^2 (d.f. = 1) = 27.12, supraordinate-subordinate; 61.68, principles; 25.64, problem solving; $p < .001$. Results for girls were as follows: X^2 (d.f. = 1) = 35.58, supraordinate-subordinate, $p < .001$; 33.94, principles, $p < .001$; 7.94, problem solving, $p < .005$.

Returning to Table 61, combining data for boys and girls, we observe that of the classificatory level attainers, 8 percent mastered the supraordinate-subordinate subtest, compared to 49 percent of the formal level attainers. Forty-six percent of formal level children, compared to 0 percent of classificatory level children, mastered principles. Similarly, 18 percent of formal level children were successful in attaining criterion for mastery on problem solving, whereas none of the classificatory level children were able to do so.

Data obtained from assessment of the tree concept provide clear support for predictions four and five. No mastery of uses was observed when the concept was attained to only the concrete or identity levels. Performance on concept uses markedly improved when the concept was mastered at the formal level, as compared to the classificatory level.

DIFFICULTY OF THE THREE USES

For each grade group, Table 64 presents number and proportion of subjects who fully mastered each of the three concept uses: supraordinate-subordinate, principles, and problem solving. Tables 65 and 66 show the same data for boys and girls separately. In order to determine if any statistically significant sex differences occurred in these data, Chi-square tests were conducted at the .05 level for each concept use within grade groups and for all grades combined. Three of the 15 Chi-squares were statistically significant: at the seventh grade more boys than girls attained the principles subtest [X^2 = 3.93 (d.f. = 1)]; at the tenth grade more boys than girls attained the problem-solving subtest [X^2 = 4.72 (d.f. = 1)]; for all grades combined more boys than girls also attained the problem-solving subtest [X^2 = 4.84 (d.f. = 1)]. Although just 3 of the Chi-squares were statistically significant, all indicated superior performance among boys. Earlier we found that among formal level attainers, performance of boys on two of the uses was superior, with statistical significance, to that of girls. In view of the systematic nature of these results, it was judged appropriate to evaluate performance on the uses subtests separately for boys and girls. Data summarized in Tables 65 and 66 were therefore used to address the sixth prediction, which

TABLE 64

Number and Proportion of Each Grade Group that Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=83)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n=93)			
Number	9	2	0
Proportion	.10	.02	.00
7th (n=91)			
Number	22	12	6
Proportion	.24	.13	.07
10th (n=87)			
Number	48	47	18
Proportion	.55	.54	.21
All Grades (N=354)			
Number	79	61	24
Proportion	.22	.17	.07

states that performance on the uses subtests will improve as a function of increasing grade group.

Consistent with prediction six, both of these tables show that the proportion of children attaining each of the three uses subtests increased considerably as grade group increased. The only exceptions to a steady progression in mastery occurred on the problem-solving subtest for boys (first and fourth graders exhibited equal inability to master this use) and on problem solving and principles for girls (first and fourth graders demonstrated no mastery). On the supraordinate-subordinate subtest the increase in competence that accompanied each higher grade was substantial for girls, as well as for boys: inspection of Tables 65 and 66 reveals that in general, mastery of uses progresses in similar patterns for boys and for girls.

TABLE 65

Number and Proportion of Boys at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=41)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n=46)			
Number	7	2	0
Proportion	.15	.04	.00
7th (n=44)			
Number	7	9	4
Proportion	.16	.20	.09
10th (n=43)			
Number	26	24	13
Proportion	.60	.56	.30
All Grades (N=174)			
Number	40	35	17
Proportion	.23	.20	.10

Chi-square tests, conducted separately on data for boys and girls, were used to ascertain statistically significant differences between proportions of individual grade groups passing each of the three uses and the proportion of the combined grade groups passing each of the three uses. The difference in proportions of boys attaining each of the uses was significant beyond the .001 level [X^2 = 49.17, supraordinate-subordinate; 51.55, principles; 29.87, 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 each use were significant at the .05 level. Results for each of the concept uses showed that mastery of the tenth-grade boys was superior to that of each of the three lower grade groups.

The difference in proportions of girls attaining each of the uses was significant as follows: X^2 = 43.73, supraordinate-subordinate,

TABLE 66

Number and Proportion of Girls at Each Grade Group Who Fully Mastered Each of the Three Concept Uses

Grade	Supraordinate-Subordinate	Principle	Problem Solving
1st (n=42)			
Number	0	0	0
Proportion	.00	.00	.00
4th (n=47)			
Number	2	0	0
Proportion	.04	.00	.00
7th (n=47)			
Number	15	3	2
Proportion	.32	.06	.04
10th (n=44)			
Number	22	23	5
Proportion	.50	.52	.11
All Grades (N=180)			
Number	39	26	7
Proportion	.22	.14	.04

$p < .001$; 68.45, principles, $p < .001$; 10.20, problem solving, $p < .025$ (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 each use were significant at the .05 level. Results showed that mastery of the supraordinate-subordinate subtest by tenth-grade girls was significantly superior to that of fourth-grade and first-grade girls. In addition, seventh-grade girls surpassed attainment of fourth graders and first graders. On principles, mastery of the tenth-grade girls was superior to that of each of the three lower grade groups. On problem solving, tenth-grade girls surpassed attainment of fourth- and first-grade groups.

In summary, the data analyzed separately for boys and girls clearly support the prediction of increasing mastery of uses as grade group increased. Inspection of performance data in Table 64, combining data across sex, confirms the pattern of steady progression in mastery of each of the three concept uses with increasing grade group. Table 64 summarizes these performance data for all grades: 22 percent of all children attained the supraordinate-subordinate subtest; 17 percent, principles; and 7 percent, problem solving.

RELATIONSHIP BETWEEN VOCABULARY DEVELOPMENT AND ATTAINMENT OF CONCEPT LEVELS AND USES

Of the eight predictions derived from the CLD model, two remain for evaluation. Both concern the relation between vocabulary proficiency and attainment of levels and performance of the uses subtests. Prediction seven states that vocabulary scores and scores based on the attainment of the four levels and three uses will correlate positively within grade group. Prediction eight holds that the same scores will show a positive and higher correlation across combined grade groups. In order to compute correlation coefficients, the same scaling system was used for tree as that described in Chapter III for equilateral triangle.

Table 67 presents means and standard deviations, based on the scaled scoring system, for all grades combined, and for all boys and all girls. The predicted improvement in concept attainment and performance on uses subtests as grade group increases was, of course, demonstrated in these data based on mean scaled scores just as it was in data based on proportions. Mean scores based on the 14-item vocabulary test indicated a steady increase in proficiency with increasing grade group. Total mean scaled scores for boys and girls were very similar on each measure, as well as on vocabulary.

Pearson product-moment correlations (r) were calculated in order to discover the relationship between vocabulary comprehension and task performance. For each grade group, all grades combined, and all boys and all girls, Table 68 presents correlations between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses. Tests for any statistical significance, at the .05 level, between the correlations for boys and girls on each of the three performance measures revealed no sex differences.

The correlations within grade groups were rather variable in size. Generally, the smaller correlations were obtained from the lowest grade groups. The zero order or very low correlations between vocabulary scores and concept uses for first- and fourth-grade groups reflect a limited range of performance, as can be observed by reviewing Table 67. Correlations for seventh- and tenth-grade groups were of a much greater magnitude, reflecting increased competence with verbal labels and a wider range of performance on concept levels and uses. Of the 12 correlations computed within grade groups, 10 were statistically significant from zero at or beyond the .01 level.

As predicted, correlations were generally higher for combined grade groups than for individual grade groups. The correlation was .72 between overall performance on concept levels subtests and overall

TABLE 67

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, 14)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
1st	83	2.47	.67	.00	.00	2.47	.67	4.08	2.36
4th	93	2.99	.54	.12	.32	3.11	.68	7.30	2.80
7th	91	3.37	.71	.44	.75	3.81	1.25	9.49	2.79
10th	87	3.82	.45	1.30	1.11	5.11	1.35	11.40	2.10
All Grades	354	3.17	.77	.46	.85	3.63	1.42	[illegible]	3.63
All Boys	174	3.13	.77	.53	.93	3.66	1.50	8.19	3.77
All Girls	180	3.21	.77	.40	.77	3.61	1.33	8.05	3.61

performance on the verbal labels. Overall performance on concept uses correlated .56 with vocabulary and overall performance on combined levels and uses correlated .73 with vocabulary scores. Each of these three correlations was statistically significant from zero at or beyond the .01 level. All correlations for boys and for girls were also statistically significant ($p < .01$). The correlational data summarized in Table 68 clearly support the predicted relationship between vocabulary proficiency and concept attainment and use.

TABLE 68

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
1	83	.31*	.00	.31*
4	93	.36*	.18	.37*
7	91	.71*	.37*	.63*
10	87	.59*	.57*	.67*
All Grades	354	.72*	.56*	.73*
All Boys	174	.69*	.58*	.71*
All Girls	180	.76*	.54*	.75*

* $p < .01$

VII

SUMMARY AND CONCLUSIONS

In this chapter a brief summary of the study precedes a discussion of results of all four 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. Since the major propositions and predictions are discussed in some detail in prior chapters, the predictions are briefly summarized 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 single grade group who fully master 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. 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 problems.
5. A higher proportion of children who attain a concept at the formal level, in comparison with those who attain at the classificatory level, will master each of the three concept uses.
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 attainment of the four levels and three uses will be positively and highly correlated across combined grade groups.

The preceding predictions were tested, using four specially constructed assessment batteries. One battery was used for each concept: equilateral triangle, cutting tool, noun, and tree. Each battery included one subtest for each of the four levels of concept attainment and one for each of three uses of an attained concept. Thus, a total of 28 tests was developed, 7 for each of the four concepts.

Children at each of four grade groups--first, fourth, seventh, and tenth--participated in the study. Total number of children tested with each assessment battery was as follows: equilateral triangle, 351; cutting tool, 349; noun, 362; tree, 354. Children in the two lower grades were enrolled in 12 different elementary schools. Seventh graders were enrolled in 2 different junior high schools. The tenth-grade students were enrolled in a single 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 groups of about 30, except that the youngest children received the tests in smaller groups of about 5 to 10. On each subtest a child's responses were scored as passing or failing according to specific criteria established for each. Data were quantified by computing frequencies and proportions of subjects within each grade group who attained each concept level and each use. Preliminary analyses were conducted to determine existence of sex differences. Post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. Descriptive data and statistical tests were used to evaluate each of eight specific predictions derived from the CLD model. The predicted relationship between vocabulary and performance was evaluated by correlation coefficients.

CONCLUSIONS

Results of the four 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. The general absence of strong or systematic sex differences in performance on the four concept batteries contributes to whatever degree of generality is warranted by the following compilation of results. Each prediction is stated, and the evidence based on all four 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 well supported by results obtained for the four concepts assessed in the present study. Table 69 summarizes pertinent information for all concepts. Inspection shows that of the total subject population, 97 percent conformed to the predicted pass/fail patterns for equilateral triangle, 97 percent conformed for cutting tool, 100 percent conformed for noun, and 98 percent for tree.

Table 70 presents for each concept the frequencies of deviation from the predicted patterns in the total subject population. Three

TABLE 69

Proportion of Total Subject Population Conforming to Predicted Pass-Fail Patterns of Attainment: Comparing the Four Concepts

Pass-Fail Sequence	Concept			
	Equilateral Triangle (N=351)	Cutting Tool (N=349)	Noun (N=362)	Tree (N=354)
FFFF	.01	.00	.07	.00
PFFF	.01	.00	.12	.01
PPFF	.14	.06	.41	.15
PPPF	.56	.34	.32	.44
PPPP	.25	.57	.08	.37
Total	.97	.97	1.00	.98

percent of the total 351 children (10 subjects) did not conform to the predicted sequence in the assessment of equilateral triangle. Three percent (11 children) of the total 349 children did not conform in the assessment of cutting tool. No children deviated from the predicted sequence of attainment on the noun assessment and two percent (8 children) of the 354 children administered the tree battery deviated from the predicted invariant sequence of attainment. Looking across concept batteries, Table 70 shows that the largest number of nonconforming children was in the PPFP pattern; that is, the classificatory subtest was not attained, but formal was mastered. The next largest number of children appeared in the FPPF pattern of exception--5 children failed concrete, but went on to attain higher levels, contrary to prediction. The 5 remaining cases of deviation were spread over three patterns: FFPF, FPFF, and PFPF. No instances of deviation were observed in 6 of the 11 possible nonconforming patterns.

In two of the patterns of exception, PPFP and FPPF, there exists the possibility that the same children deviated from battery to battery. Further examination of protocols from the 19 children in the PPFP pattern and the 5 children in the FPPF pattern revealed that no subject followed either of the unacceptable patterns in

TABLE 70

Frequencies of Total Subject Population Showing Pass-Fail Patterns of Exception: Comparing the Four Concepts

Pass-Fail Sequence	Equilateral Triangle (N=351)	Cutting Tool (N=349)	Noun (N=362)	Tree (N=354)	Total
FFFP					0
FFPF		1			1
FFPP					0
FPFF				2	2
FPFP					0
FPPF	3	1		1	5
FPPP					0
PFFP					0
PFPF				2	2
PFPP					0
PPFP	7	9		3	19
Total	10	11	0	8	29
Proportion of Total Population	.03	.03	.00	.02	

more than one concept assessment. That is, there was no overlap in nonconformity to the predicted patterns among the assessment batteries. It was also possible that the same child may have deviated on more than one battery, but in <u>different</u> patterns of exception. Only two of the youngest children followed unacceptable patterns on more than one assessment battery (one first-grade girl showed the FFPF pattern on <u>cutting tool</u> and the PFPF pattern on <u>tree</u>; one fourth-grade boy showed the FPPF pattern on <u>equilateral triangle</u> and FPFF on <u>tree</u>).

This index of independence among the four concept batteries justifies interpreting exceptions to the predicted patterns as the result of errors of measurement or problems associated with the criteria established for concept level attainment, and not as the result of true exceptions in terms of sequential development. Had a large number of the deviating children been identical across assessment batteries the unavoidable conclusion would be that these children were truly not conforming to the hypothesized invariant sequence of conceptual development.

2. The number and proportion of children within a single grade group who fully master each successive level of concept attainment will decrease. This prediction was clearly supported by data for each of the four grade groups when the four concepts were examined individually. The row entries of Table 71 permit cross-concept comparisons for the proportions of each grade group that fully mastered each level of attainment. There might have been 64 exceptions to this prediction, based on the total number of entries in the table. Only two very minor reversals occurred. In the equilateral triangle assessment, 98 percent of the fourth-grade group attained concrete and 99 percent attained identity. In the cutting tool assessment, 99 percent of the fourth-grade subjects passed the concrete level, and 100 percent passed the identity level. For all concepts, seventh and tenth graders were equally proficient at the concrete and identity levels.

3. The number and proportion of successively higher grade groups mastering each concept level will increase. The summary information in Table 71 is also relevant to a final evaluation of this prediction. Inspection of the columns of this table discloses only two minor exceptions to the prediction: 92 percent of the fourth-grade group attained the classificatory level of cutting tool, compared to 89 percent of the seventh-grade group. On the tree battery, 87 percent of the fourth graders attained the classificatory level compared to 86 percent of the seventh graders. In general, the increase in attainment of levels with increasing grade group was marked, particularly at the classificatory and formal levels. In conclusion, we find strong support for the prediction that at each concept level the number and proportion of children who master the concept will increase as grade group increases.

4. 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 problems. This prediction has clearly been supported by all four concept assessments. The first half of Table 72 summarizes the results. Only in the cutting tool battery were identity-level attainers able to master two of the uses to more than a negligible degree. This finding has been discussed previously in Chapter IV. Among those children whose highest level of attainment was concrete, no uses were mastered for any of the concepts.

5. 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 consistently upheld when each of the concepts was examined individually. The second half of Table 72 summarizes data for all concepts; examination shows that 12 possible exceptions might have occurred to the prediction that children who attain a concept at the formal level demonstrate performance on the concept uses superior to that of classificatory level attainers. Inspection reveals no exceptions to the prediction. Indeed, the differences

TABLE 71

Proportion of Each Grade Group that Fully Mastered
Each Level of Attainment: Comparing the Four Concepts

Grade Group	Concrete	Identity	Classificatory	Formal
1				
Equilateral Triangle (N=82)	.94	.94	.66	.00
Cutting Tool (N=80)	.99	.99	.89	.44
Noun (N=83)	.67	.19	.00	.00
Tree (N=83)	.93	.93	.58	.00
4				
Equilateral Triangle (N=92)	.98	.99	.84	.05
Cutting Tool (N=92)	.99	1.00	.92	.49
Noun (N=95)	1.00	.97	.17	.00
Tree (N=93)	.99	.99	.87	.14
7				
Equilateral Triangle (N=91)	1.00	1.00	.87	.38
Cutting Tool (N=91)	1.00	1.00	.89	.62
Noun (N=93)	1.00	1.00	.63	.03
Tree (N=91)	1.00	1.00	.86	.52
10				
Equilateral Triangle (N=86)	1.00	1.00	.92	.65
Cutting Tool (N=86)	1.00	1.00	.95	.83
Noun (N=91)	1.00	1.00	.75	.27
Tree (N=87)	1.00	1.00	.97	.85

in the actual percentage values are both consistent and strikingly large. For example, data for equilateral triangle indicate that a marked advantage in mastery of uses occurred for individuals attaining at the formal level: 47 percent passed the supraordinate-subordinate subtest, compared to 12 percent of classificatory attainers; 61 percent passed the principles subtest, compared to 7 percent of classificatory attainers; and 76 percent passed the problem-solving subtest, compared to 15 percent of classificatory attainers.

6. The number and proportion of children of successively higher grade groups who master each concept use will increase. Data assessing the four concepts supported this prediction. Table 73 summarizes data for all four assessment batteries. Inspection reveals two reversals to the predicted progression, both in the cutting tool battery. Chapter IV discussed possible reasons for these results. Aside from

TABLE 72

Relationship Between Full Mastery of Levels and Full Mastery of Uses:
Comparing Proportions of Total Subject Population Passing Uses for the Four Concepts

Concept	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	2			49			200			96		
N Passing Use	0	0	0	3	1	2	23	13	30	45	59	73
Equilateral Triangle	.00	.00	.00	.06	.02	.04	.12	.07	.15	.47	.61	.76
N Passing Level	0			21			121			207		
N Passing Use	0	0	0	8	1	8	68	6	41	160	84	151
Cutting Tool	.00	.00	.00	.38	.05	.38	.56	.05	.34	.77	.41	.73
N Passing Level	43			149			115			28		
N Passing Use	0	0	0	4	2	9	8	9	16	15	13	17
Noun	.00	.00	.00	.03	.01	.06	.07	.08	.14	.54	.46	.61
N Passing Level	4			55			160			134		
N Passing Use	0	0	0	0	0	0	13	0	0	66	61	24
Tree	.00	.00	.00	.00	.00	.00	.08	.00	.00	.49	.46	.18

TABLE 73

Proportion of Each Grade Group that Fully Mastered Each of the Three Concept Uses: Comparing the Four Concepts

Grade Group	Supraordinate-Subordinate	Principle	Problem Solving
1			
Equilateral Triangle (N=82)	.00	.00	.00
Cutting Tool (N=80)	.45	.03	.43
Noun (N=83)	.00	.00	.00
Tree (N=83)	.00	.00	.00
4			
Equilateral Triangle (N=92)	.15	.01	.14
Cutting Tool (N=92)	.72	.14	.66
Noun (N=95)	.00	.00	.01
Tree (N=93)	.10	.02	.00
7			
Equilateral Triangle (N=91)	.15	.24	.37
Cutting Tool (N=91)	.66	.29	.51
Noun (N=93)	.06	.08	.15
Tree (N=91)	.24	.13	.07
10			
Equilateral Triangle (N=86)	.50	.58	.67
Cutting Tool (N=86)	.86	.58	.69
Noun (N=91)	.23	.19	.30
Tree (N=87)	.55	.54	.21

these two reversals in a single battery, improvement in mastery of the uses markedly increased with increasing grade group. For example, for the problem-solving subtest of equilateral triangle the increment in percentage of attainment was as follows: first grade, 0 percent; fourth grade, 14 percent; seventh grade, 37 percent; tenth grade, 67 percent.

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 upheld by data for all concepts assessed in the present study. Table 74 summarizes the 48 correlations obtained between vocabulary scores and scores on levels, uses, and combined levels and uses at each grade group. In general, magnitude of correlations was

TABLE 74

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 the Four Concepts

Grade Group	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
1			
Equilateral Triangle (N=82)	.17	.00	.17
Cutting Tool (N=80)	.43**	.00	.27*
Noun (N=83)	.04	.00	.04
Tree (N=83)	.31**	.00	.31**
4			
Equilateral Triangle (N=92)	.09	.23*	.21
Cutting Tool (N=92)	.49**	.32**	.47**
Noun (N=95)	.00	.07	.02
Tree (N=93)	.36**	.18	.37**
7			
Equilateral Triangle (N=91)	.57**	.45**	.60**
Cutting Tool (N=91)	.57**	.45**	.55**
Noun (N=93)	.36**	.39**	.47**
Tree (N=91)	.71**	.37**	.63**
10			
Equilateral Triangle (N=86)	.66**	.59**	.68**
Cutting Tool (N=86)	.46**	.20	.33**
Noun (N=91)	.63**	.65**	.75**
Tree (N=87)	.59**	.57**	.67**

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

greatest for the two highest grade groups, smallest for grade groups one and four. In the equilateral triangle and noun assessments correlations were uniformly low and nonsignificant for the first graders; correlations obtained for noun in the fourth-grade group were also low and nonsignificant. Among first graders, none of the concept assessments obtained a relationship between vocabulary scores and scaled scores on concept uses. In all of these cases, the zero or low order correlations reflected very limited ranges of performance on vocabulary and the various task measures among the youngest children.

Although a few zero order correlations were found, no negative correlations were observed; the prediction of a positive relationship between vocabulary proficiency and attainment of concept levels and uses was verified by these data. Moreover, the size of the correlations within the various grade groups, in general, was considerably higher than anticipated. Thirty-three of the 48 correlations were statistically significant from zero at or beyond the .05 level; actual values ranged from .23 to .75.

8. Vocabulary scores and scores based on the attainment of the four levels and the three uses will be positively and highly correlated across combined grade groups. Evidence to uphold this prediction was found in all four concept assessments, as summarized in Table 75. Magnitude of the correlations was smallest for cutting tool, largest for noun and tree. Correlations across grade groups were, in general, highest for vocabulary scores and combined levels and uses scores. The 12 correlations entered in this table were generally larger in magnitude than those obtained within grade groups and, without exception, were statistically significant from zero at or beyond the .01 level.

TABLE 75

Pearson Product-Moment Correlations for Total Subject Population Between Mean Vocabulary Scores and Mean Scores on Levels, Uses, and Combined Levels and Uses: Comparing the Four Concepts

Concept	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
Equilateral Triangle (N=351)	.58*	.60*	.67*
Cutting Tool (N=349)	.51*	.33*	.46*
Noun (N=362)	.70*	.60*	.77*
Tree (N=354)	.72*	.56*	.73*

*p < .01

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