DOCUMENT RESUME

ED 103 481	95	TM 004 329

AUTHOR	Bernard, Michael E.; Klausmeier, Herbert J.
TITLE	The Empirical Validation of the Model of Conceptual Learning and Development Using the Concept of Cutting Tool: Report from the Project on Children's Learning and Development. Technical Report No. 291.
INSTITUTION	Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
REPORT NO	WRDCCL-TR-291
PUB DATE	Dec 73
CONTRACT	NE-C-00-3-0065; OEC-5-10-154
NOTE	169p.; For related documents, see TM 004 330-333
EDRS PRICE	MF-$0.76 HC-$8.24 PLUS POSTAGE
DESCRIPTORS	*Age; Cognitive Development; Cognitive Measurement; Cognitive Processes; *Concept Formation; Conceptual Schemes; Discrimination Learning; Elementary Secondary Education; Evaluation Methods; *Hypothesis Testing; Learning Theories; Literature Reviews; *Models; *Organization; Prediction; Problem Solving; Tests of Significance; Validity
IDENTIFIERS	Cutting Tool Assessment Battery; *Model of Conceptual Learning and Development

ABSTRACT

The purpose of this study was to empirically test a set of predictions implied by the Model of Conceptual Learning and Development using the concept of cutting tool. Four subtests were developed to assess a subject's ability to perform at each of four successive levels of concept attainment (concrete, identity, classificatory and formal). In addition, three subtests were constructed to determine the extent to which a subject could use the concept cutting tool to cognize other concepts related to cutting tool as being supraordinate, coordinate or subordinate, to understand cause-and-effect and other relationships when cutting tool or its attributes were incorporated in a principle, and in problem-solving situations. The subtests were designed to elicit behaviors that reflected underlying cognitive operations that differentiated among the four levels and three uses. The subjects were kindergarten, third, sixth and ninth grade children. Each of the five major predictions specified by the Model of Conceptual Learning and Development were confirmed. The Cutting Tool Assessment Battery is included in the appendix. (Author/BJG)

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U.S. Office of Education Center No. C-03 Contract OE 5-10-154

Technical Report No. 291

THE EMPIRICAL VALIDATION OF THE MODEL OF CONCEPTUAL LEARNING AND DEVELOPMENT USING THE CONCEPT OF CUTTING TOOL

Report from the Project on Children's Learning and Development

by Michael Edwin Bernard

Herbert J. Klausmeier
Principal Investigator

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

December, 1973

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

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

STATEMENT OF FOCUS

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

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

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

ACKNOWLEDGEMENTS

This author would like to thank Dr. Herbert J. Klausmeier who served as major professor during the preparation and completion of this thesis. Not only did Dr. Klausmeier provide this author with support for this study, he also actively contributed to the generation of the assessment battery. His ideas have played an integral part both in the conceptualization of the type of questions used to assess the four attainment levels and three concept uses as well as in the writing of the items themselves.

Appreciation is also extended to Dr. Joel R. Levin who offered generous assistance in the measurement aspects of the thesis. Dr. Frank H. Hooper provided thoughtful criticism during the initial planning stages of the study. Dr. Levin and Dr. Hooper served on the examining committee.

The staff of the Wisconsin Research and Development Center for Cognitive Learning provided valuable assistance in the planning and running of the study. Special gratitude is extended to the following Center staff members: Con Katzenmeyer who assisted in test construction and data analysis; Pat Lane who provided competent guidance in the management and reduction of the data obtained from 800 subjects; Tom Sipple and Ann Maynard who helped administer the assessment battery; Vera Meyer who spent many long and thankless hours in preparing the assessment battery for publication; Ann Nelson who also aided in the preparation of the battery; Janis Van Brocklin who played an important role in the preparation of this manuscript; and Rick Marliave who provided insightful criticism of the assessment battery while it was being developed.

This author is indebted to Professor Roy A. Lindberg of the Department of Mechanical Engineering who identified information related to cutting tool that was used to generate the concept hierarchy and principles.

This author is also indebted to the personnel of the Watertown and Beloit schools in which the study was carried out. In Watertown, special thanks are due Mr. Charles Bruce, Principal of Douglas School; Mr. Joseph Chezota, Principal of Lincoln School; Mr. Wayne J. Simon, Principal of Schurz School; Mr. Martin Kerwin, Principal of Webster School; and Mr. Laurence Baker, Principal of Riverside Junior High School. In Beloit, recognition is due Mr. Arthur Engel, Principal of Merrill School; Ms. Virginia Carlson, Principal of Royce School; Mr. Ralph Crowe, Principal of Waterman School; Mr. Peter Peterson, Principal of McNeil School; and Mr. Ralph Terry, Principal of Adrich Junior High School.

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ABSTRACT

The purpose of this study was to empirically test a set of predictions implied by the Model of Conceptual Learning and Development using the concept of cutting tool.

Four subtests were developed to assess a subject's ability to perform at each of four successive levels of concept attainment (concrete, identity, classificatory and formal). In addition, three subtests were constructed to determine the extent to which a subject could use the concept cutting tool to cognize other concepts related to cutting tool as being supraordinate, coordinate or subordinate, to understand cause-and-effect and other relationships when cutting tool or its attributes were incorporated in a principle, and in problem-solving situations. The subtests were designed to elicit behaviors that reflected underlying cognitive operations that differentiated among the four levels and three uses. The subjects were kindergarten, third, sixth and ninth grade children.

Each of the five major predictions specified by the Model of Conceptual Learning and Development were confirmed. The essential findings of the study were:

(1) The proportion of subjects who passed each successive attainment level increased as a function of age.

(2) Subjects who passed any one of the four attainment levels passed all of the preceding lower levels.

(3) Subjects who attained the concept of cutting tool at the formal level used the concept more effectively in cognizing supraordinate-subordinate relationships, in

understanding principles and in problem-solving situations than subjects who only attained the concept of <u>cutting tool</u> at the classificatory level.

(4) Subjects who knew the label and the defining attributes of <u>cutting tool</u> as well as the definition performed better on the three concept uses than subjects who did not.

(5) A higher percentage of each successive grade group passed each of the concept uses.

Chapter I

INTRODUCTION

The study of concept learning has played an important part in revealing how human thought develops over the life span. During the past several decades, a great deal of experimentation relating to the nature of concept learning has been conducted. Both learning and developmental psychologists have been equally concerned with attempting to elaborate psychological theories of concept learning. In addition, educational psychologists have recognized concept attainment as an important form of school-related learning.

A great majority of the studies that deal with the nature of concept learning have been conducted in the experimental laboratory. While these studies have contributed both to the building and validation of theory and to the development of a scientific method of investigation, such studies have, however, significant limitations. These limitations have reduced the contribution these studies have made to both theory and practice.

Laboratory experimentation has generally dealt with aspects of the process of concept learning that have only a limited and indeterminate relationship to the process by which concepts are learned in the natural environment. Additionally, such studies have examined the acquisition of concepts that have little practical significance for the educator concerned with the process of teaching concepts related to various subject-matter fields. Clarke (1970) has indicated that it has only been within the last decade that the principles of concept learning derived from the laboratory have begun to be implemented in the classroom.

The instructional variables used in teaching concepts in the laboratory as well as the various ways the attainment of concepts have been inferred further restrict the value of many of these studies. It has been observed that only a few of many potentially powerful instructional variables have been experimentally manipulated (Frayer, 1970). Generally, the sequence in which examples and non-examples of the concept are presented is the sole independent variable. Such studies have also limited the assessment of concept learning to the measurement of reaction times, trials or number of errors made in the classification of concept examples and non-examples. It appears that a larger sample of instructional variables and evaluative measures could be employed in an effort to determine the optimal manner in which to teach concepts as well as to evaluate the degree to which particular concepts have been mastered.

The limited usefullness of laboratory studies is also due to a neglect of external validity considerations (Campell & Stanley, 1963). In these studies, college-age students usually constitute the sampling pool. Clearly, cognitive variables that are determined to be crucial for the mastering of concepts by college sophomores may be irrelevant to the nature of concept learning of third grade students. A wider age range of subjects needs to be employed especially if one's concern is with the application of knowledge gained from the laboratory study to the classroom.

Researchers at the Wisconsin Research and Development Center for Cognitive Learning have been engaged in the study of concept learning during the past 12 years. The substantial amount of work completed at the Center has been concerned with two basic types of research. One type of research has pertained to the external and internal conditions of concept learning. Research dealing with external conditions of concept learning has involved the identification of instructional variables such as the number of examples and non-examples, the ratio of examples to non-examples, relevant attribute emphasis, and the presence or absence of a definition, that affect the manner in which a concept is presented to the learner (Kalish, 1966; Lynch, 1966; Smuckler, 1966; Blount, Klausmeier, Johnson, Fredrick & Ramsay, 1967; Miller & Davis, 1968; Frayer, 1970; Nelson, 1972; Feldman, 1972; Swanson, 1972). The internal conditions of concept learning refer to characteristics of the learner such as age, level of conceptual ability and development, and socio-economic status that have been shown to determine the level at which a concept is obtained (Fredrick, 1965, 1968; Lemke, Klausmeier & Harris, 1967; Jones, 1968; Klausmeier, Harris, Davis, Schwenn & Frayer, 1968; Nelson, 1971; Nelson, in press).

The second line of research involves the analysis of concepts taught in the classroom. Such analyses involve the specification of the concept definition, of the defining and irrelevant attributes of the concept, and of concept examples and non-examples (Harris & Golub, 1971; Harris & Romberg, 1971; Golub, Fredrick, Nelson & Frayer, 1971; Tabachnick, Weible & Frayer, 1971; Voelker, Sorenson & Frayer, 1971).

At the Center, as a result of the extensive research program that has dealt with the variables and processes of concept learning, a model that relates the cognitive operations involved in concept learning to the mastery level of specific concepts of varying levels of inclusiveness and abstractness has been formulated (Klausmeier, Ghatala, & Frayer, in press.) The Model of Conceptual Learning and Development (CLD model) relates hypothesized cognitive operations involved in the learning of concepts to four hierarchically distinct and successive levels of concept attainment. In addition, the CLD model indicates that attainment of a concept at one of the four levels of concept attainment determines whether a concept can be used to cognize supraordinate-subordinate relationships, to understand principles, to identify examples and non-examples of the concept and to solve problems (concept uses).

The CLD model can be seen to serve two primary research functions. First, the CLD model provides a conceptual framework for the organization and integration of concept learning research conducted at the Center and elsewhere. The internal and external conditions of concept learning previously described affect the level at which a concept is attained. In addition, those concept variables that are examined in the analysis of concepts are crucial in the design of behavioral measures from which mastery of the four attainment levels is inferred.

The CLD model has also been utilized to formulate theoretical guidelines in the conducting of research that deals with the assessment of the normative pattern of conceptual development of school-age children. Several of these studies (Klausmeier, Ingison, Sipple &

Katzenmeyer, in press; Klausmeier, Ingison & Sipple, in press) that have been conducted at the Center have dealt with some of the problems that have limited the usefulness of previous concept learning experimentation. This ongoing research effort has included the selection of a wide range of concepts used in the assessment of the conceptual development of children. Careful attention has been directed towards the specification of the essential characteristics of the concept (Frayer, 1970). A set of clearly operationalized and differentiated response measures has been developed to assess the level at which a concept is attained. In addition, a wide range of subjects of different ages have been compared on the same measures of concept attainment.

Currently, several studies are being conducted at the Center to validate a set of predictions concerning the normative pattern of conceptual development of school-age children that are specified by the CLD model. This study is a part of the ongoing research program.

Purposes and Hypotheses of the Study

The purpose of the present study was to empirically test predictions specified by the CLD model using the concept of cutting tool. The specific predictions were:

(1) The proportion of subjects passing the successive attainment levels will increase as a function of grade group.

(2) Subjects who pass any one of the four attainment levels will also have passed all of the preceding lower levels.

(3) Subjects who attain a concept at the formal level will use the concept more effectively in cogniz.ng supraordinate-

subordinate relationships in understanding principles and in problem-solving than subjects who have only attained the concept at the classificatory level.

(4) Subjects who know the label of the concept and its defining attributes as well as the concept definition will perform better on each of three concept uses than subjects who do not.

(5) A higher percentage of each successive grade group will pass each of three concept uses.

In addition, two questions that do not derive from the predictions specified by the CLD model were posed:

(6) Is there a developmental difference between males and females as to when each group passes the four levels of concept attainment.

(7) Are items that use a smooth-edged cutting tool as a target at the concrete and identity levels more difficult than those items that use a tooth-edged cutting tool as a target.

Method

Seven subtests (Bernard, Klausmeier & Katzenmeyer, in press) were developed to assess a subject's performance at each of the four attainment levels and on three concept uses (supraordinate-subordinate, principles and problem-solving). The subtests were designed to elicit behaviors that reflected underlying cognitive operations that differentiated among the four levels and three uses. These subtests were incorporated within an assessment battery.

Four hundred subjects that were selected from the public school system in Beloit, Wisconsin were administered the assessment battery.

Fifty males and 50 females were selected at each of the kindergarten, third, sixth and ninth grades.

Kindergarten subjects were administered the battery in groups of six to ten. These subjects were removed from their classroom and given the battery in an empty school room. The third, sixth and ninth grade subjects were tested in intact classrooms.

All subjects received the subtest in the same order of presentation. The test examiners read aloud all instructions and each test question. Subjects wrote their answers directly in the assessment booklets.

Significance of the Study

The validation of the set of predictions that are specified by the CLD model would add both to the theoretical robustness and practical significance of the CLD model. The development of an inclusive methodology that assesses an individual's knowledge of concepts drawn from different school-related subject domains would provide educators with a means to evaluate the conceptual strengths and weaknesses of individual students. Specifications of what a student knows and does not know is an obvious pre-requisite for the provision of individualized learning experiences.

The kind of behavioral analysis of concepts employed in this study can also be used by teachers to break down the formidable task of teaching concepts. The delineation of instructional variables that contribute to the learning and understanding of concepts may assist teachers in the preparation of behavioral objectives as well as instructional materials.

When the results of the present study are compared with those obtained from other similar cross-sectional studies being conducted at the

Center that deal with a variety of school-related concepts, a clearer understanding of the general pattern of conceptual learning and development of school-age children will surely emerge.

This study will also provide the researcher who is concerned with individual differences in the cognitive make-up of children with a plethora of descriptive data. Data from this study should reveal the ages at which there is the greatest amount of within-group variation both at a given level of concept attainment as well as across all levels.

Chapter II

REVIEW OF RELATED LITERATURE

The primary purpose of this chapter is to describe the characteristics of the CLD model. The first section will examine the nature of concepts. In the second section, limitations of previous concept learning research will be discussed. The theoretical background of the CLD model will be presented in the third section. The properties of the levels of concept attainment and the four primary ways in which concepts can be used will be elaborated upon in the fourth section. Finally, the results of two previous studies which attempted to validate the CLD model will be discussed.

The Nature of Concepts

A basic assumption central to many different theories of cognitive development is that concept formation is a critical process in the ontogenesis of human thinking (Werner, 1948; Inhelder & Piaget, 1958; Ausubel, 1968; Gagné, 1970; Klausmeier & Ripple, 1971). Beginning with the formation of the perceptual invariants of the first year of life, concepts permit the young child to organize a bewildering variety of objects, sensations, sounds and feelings (Carroll, 1964). It is through the internalized representations of classes of experience that the infant begins to simplify his or her own surrounding environment. Concepts permit the child to recognize the same objects and events encountered over time as being of the same kind, and are the mediating mechanisms that help the child order and guide his or her own activity patterns (Bruner, Goodnow, & Austin, 1956).

The cataloging and storage of learned experiences creates for the individual an informational or cognitive structure from which subsequent learning occurs (Ausubel, 1968). Concepts can be seen to function across the life-span to further permit a higher and more abstract level of organization and reorganization of learned experiences.

The internal cognitive reality represented by concepts held by the individual has been generally acknowledged by scholars in the field. Ausubel (1968) states well the overwhelming significance of concepts as internal representational constructs of reality:

> Anyone who pauses long enough to give the problem some thought cannot escape the conclusion that man lives in a world of concepts, rather than in a world of objects, events and situations. The reality he experiences psychologically is related only indirectly both to the physical properties of his environment and to their sensory correlates. Reality, figuratively speaking, is experienced through a conceptual or categorical filter (p. 505).

Klausmeier et al., (in press) propose eight defining attributes of public concepts; that is, of concepts that are represented by words and have widely agreed upon meanings: (a) Learnability refers to the notion that some concepts are more readily learned than others by individuals who share similar cultural experiences and language, (b) Usability is the degree to which the attainment of a concept enables the individual to generalize to new instances and to discriminate noninstances of the concept, to recognize other concepts in a taxonomy as supraordinate, coordinate and subordinate, to understand cause and effect, correlational, probability and axiomatic relationships among concepts, and to solve problems involving the concept, (c) Validity is the level of societal and scientific agreement as to the definition of a concept, (d) Generality refers to the number of supraordinate, coordinate or subordinate concepts that exist within any given concept taxonomy, (e) Power pertains to the idea that certain concepts once acquired are essential to facilitate the attainment of other concepts, (f) Structure is the specific relationship that the defining attributes of a concept have to each other, (g) Instance Perceptibility refers to the various ways different concepts can be sensed, and (h) Instance Numerousness describes the number of times an individual within a given society, environment or culture encounters examples of a particular concept (pp. 6-14).

One of the major sources of individual differences both within a given age group and across ages is the level of concept attainment achieved by individuals within the many different concept domains. Such differences have been hypothesized to result from diverse learning histories that occur in different cultures and environments, and also as a function of different conceptual abilities manifested by individuals (Klausmeier, et al., in press).

As a basis for examining the level of concept attainment of individuals, Klausmeier et al., (in press) define a concept as follows:

> . . . We define a concept as ordered information about the properties of one or more things--objects, events or processes--that enables any particular thing, or class or things to be differentiated from, and also related to, other things or classes of things (p. 4).

According to Klausmeier, et al., concepts can be considered as the meanings of societally defined words that represent groups or classes of things (objects, events, ideas, etc.) and also as internal construct entities or mental constructs, that are the primary vehicles of the though processes of the individual. The definitions of societally accepted concepts, i.e., meanings of words, can be found in unabridged dictionaries or encyclopedias.

Limitations of Previous Concept Learning Research

Attempts to examine the variables and processes related to concept learning have been inadequate. In addition, studies designed to assess the normative pattern of concept attainment of different age groups have not been successful. A review of the concept formation and utilization literature (Bourne, Ekstrand & Dominowski, 1971; Bernard, 1973) suggest three major reasons for such failures. First, the milieu for much of the empirical work pertaining to concept learning has been the experimental laboratory rather than the classroom. Because the number of instructional variables that are examined is small and because the dependent measures used to assess concept mastery are typically non-differentiated, the conclusions of such studies have not been used by educators concerned with the planning of an instructional program. Second, the size of many of the experimental samples prohibits the results from being generalized to a larger population. Although idiographic or small sample studies may provide important data as to varieties and commonalities in concept learning abilities and knowledge, little can be extrapolated from such data to identify specific age-related learning patterns. And finally, since the operational definition of what a concept is varies so greatly from experiment to experiment, the relating of both the theoretical insights and empirical findings from different experimental studies has become an impossible task. Operational definitions of what a concept is has drrived, in too many instances, from particularized experimental settings rather than from fundamental differences in theoretical world views (e.g., witness the work of Bourne & Guy, 1968 in contrast with that of Gagné, 1972, or Engleman, 1969).

Theoretical Background of the Model of Conceptual Learning and Development

The Model of Conceptual Learning and Development outlines the cognitive operations involved in the attainment of concepts at specifiable levels of mastery by individuals whose abilities change in predictable ways with age (Klausmeier, Ghatala & Frayer, in press). The model is a novel approach to conceptual assessment in that it specifies a normative learning pattern and levels of mastery of concepts attained by children at various age levels. Its emphasis on qualitatively different levels in the learning of a particular concept and its focus on the continuity of the learning process across time is in contrast with the more short-term, discrete learning approaches and studies carried out by many American learning psychologists.

The scope of the CLD model is with the processes and products of learning that are necessary for the attainment of concepts, rather than with the processes of biological maturation. While Klausmeier, et al., (in press) recognize the role of biological-genetic and structural factors in the acquisition of the cognitive operations that underly the learning of concepts, the authors of the model state:

> . . . The higher levels of concept attainment and the related operations are presumed to be more intimately related to directed experiences, or guided learning, than are some other abilities such as prehensile grasping, upright walking and speech (p. 3).

The CLD model is in some ways similar to two more general models of human development. The information-processing model (Hunt, 1962; Woodruff, 1967) conceives the mind of the human organism as an information-processing system that: (a) receives and selectively attends to environmental input, (b) internally manipulates environmentally produced and internally generated information, and (c) outputs a response that is a function of the previously manipulated information. Such a model, derived from American experimental and cybernetic psychology, proposes that it is through both the development of information processing abilities (operations) and the acquisition of information products (concepts), that the human organism gradually develops self-regulation over its own behavior.

The second theoretical orienation traditionally utilized in the elucidation of cognitive theory and theories of association is referred to as the stimulus-organism-response model (S-O-R). The study of the organism component of the S-O-R model has included both the manner in which stimuli are encoded, stored and decoded, and also the kind and timing of a response that is emitted as a function of sensory or environmental stimulation. Such internal construct variables as cognitive units, processes or concepts (Kagan & Kogan, 1968; Bourne, Ekstrand and Dominowski, 1971) are viewed as primary mediating agents in the development of human conceptual behavior.

In accord with these two orientations, Klausmeier, et al., (in press) propose that: (a) Concepts play a central role in purposeful, self-guided thinking of individuals of all ages, (b) Concepts are learned, and (c) Individuals learn concepts by attending to environmental phenomena, representing and processing the information gained through attending, and organizing the information through the formation of concepts at the four levels of attainment as specified by the CLD model.

It is important to recognize that the CLD model distinguishes the cognitive operations that are involved in the learning of all concepts, from the level at which specific concepts are attained. For example, consider the concepts of 'subway' and 'alfalfa'. The acquisition of both concepts are clearly tied to the experiential background of the individual. The child who is brought up in an urban setting knows more about the concept of 'subway' than he does about the concept of 'alfalfa'. The cognitive operations that the child uses to acquire both concepts are the same. Yet, because the child who grows up in a city is more likely to have encountered examples of 'subways' than of 'alfalfa', the levels of mastery of each concept are clearly going to be different. The functions of positive and also negative examples in the learning of concepts has been theoretically considered and experimentally verified by several investigators in the field of concept learning research (Markle & Tiemann, 1969; Tennyson, Wooley & Merrill, 1971; Feldman, 1972; and Swanson, 1972).

The Formal Structure of the Model of Conceptual Learning and Development

The CLD model indicates four successively higher levels of attainment of the same concept (see Figure 1). According to the model, the attainment of any one level of concept mastery is preceded by the attainment of all previous levels. As was alluded to earlier, the level at which a concept is mastered is determined by those operations that an individual can perform with regard to the specific concept itself. Additionally, at the fourth or highest level of concept attainment, an individual must have the labels of both the concept and its defining attributes as well as be able to state the definition of the concept. As is illustrated in Figure 1, the acquisition of the label of the concept as well as its defining attributes can occur at any one of the first three concept attainment levels.

The hierarchical ordering of levels of concept attainment relates to those concepts which have perceptible positive instances and which, generally, the young child has a high probability of encountering. This is in contrast to concepts which are either formally learned or which do not have perceptible instances. Klausmeier et al., (in press) indicate that although the four levels of concept attainment reflect a normative pattern of concept acquisition:

> 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 (p. 20).

The CLD model also indicates that once a concept is acquired at the classificatory level, it may be used in identifying examples and non-examples of the concept, in understanding supraordinate-subordinate

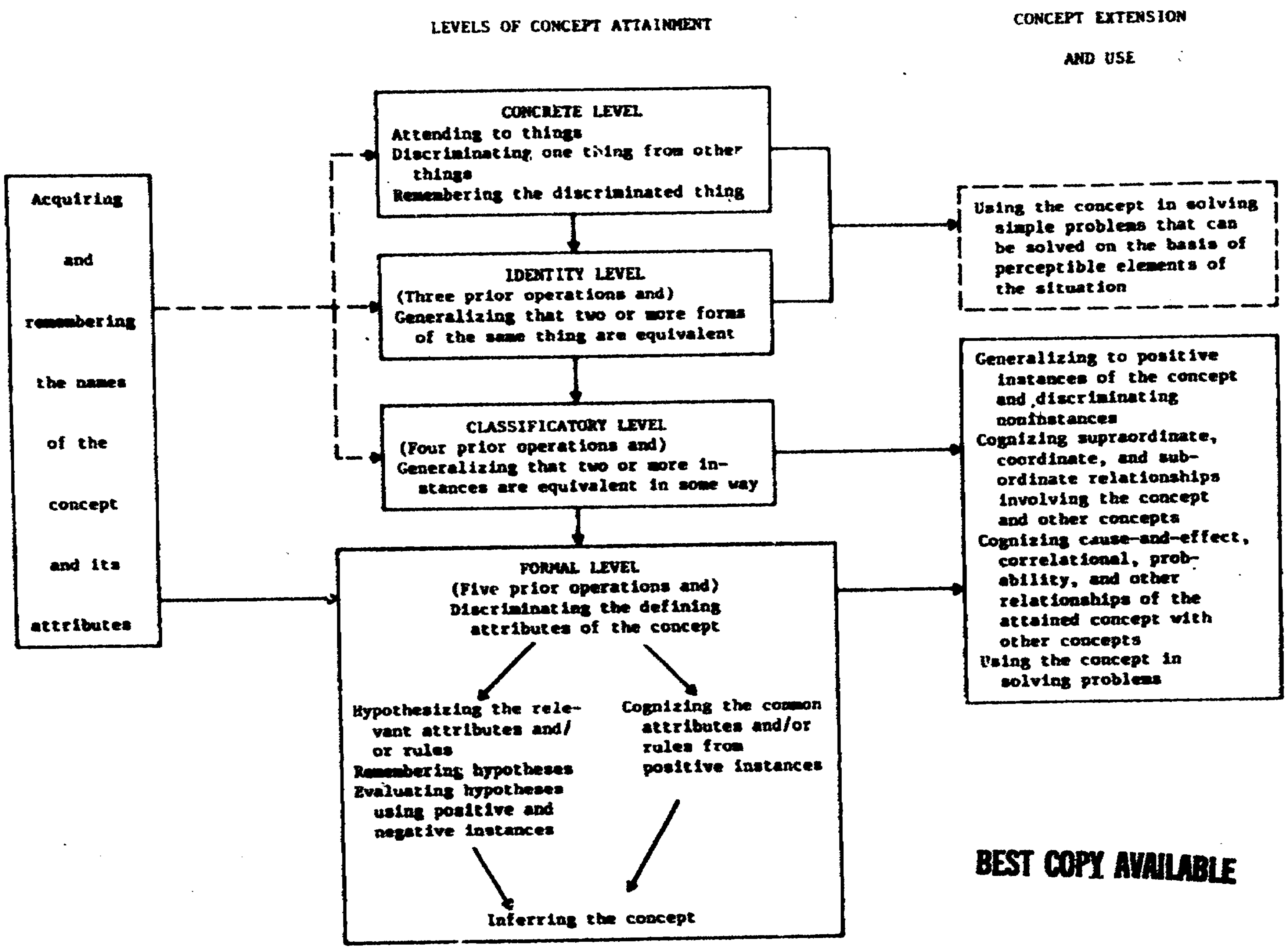

Figure 1. The Model of Conceptual Learning and Development

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relations relating to the taxonomy of the specific concept, in understanding principles based on the concept, and in problem-solving.

Levels of Concept Attainment

The first or concrete level of concept attainment is hypothesized to have been acquired when an individual is able to attend to, discriminate and remember a previously encountered instance of a concept. At this level the young child begins to distinguish the surrounding environment on the basis of some salient global feature or attribute.

The identity level is marked by the emergence of a new operation. At this level, the individual is able to cognize that two forms of the same thing are equivalent in some way. This new generalizing operation is what makes the identity level qualitatively and developmentally more advanced than the concrete level. Klausmeier et al., (in press) propose that this new operation permits the individual to know that an object is still the same object when viewed from different spatio-tempered perspectives, or when perceived in different sensory modalities.

At the classificatory level, an individual must not only have the operations that define the two earlier levels, he or she must also be able to generalize that two or more instances of the concept are equivalent in some way.

The attainment of a concept at the formal level is inferred when an individual: (a) Has acquired the labels of the concept class, (b) can discriminate and name its defining attributes, (c) can determine whether a particular exemplar is or is not a member of the concept class as well as being able to state the reason why it is or is not, and (d) can state the definition of the concept.

Uses of Attained Concepts

Klausmeier et al., (in press) propose that an individual who has attained a concept at the classificatory or formal level is able to use the concept in four primary ways. Firstly, the concept may be used in identifying both examples and non-examples of the concept. Secondly, the concept can be used to cognize supraordinate-subordinate relations such as knowing that some but not all members of a supraordinate class belong to a given subclass, that the sum of subclasses equal the sum of the supraordinate class, that all members of instances of a particular subclass belong to a higher more inclusive coordinate class. Thirdly, concepts may also be used to cognize other cause-and-effect, and correlational relationships. And finally, concepts can be used in the solving of problems. The CLD Model also indicates that concepts acquired at the concrete or identity levels can be used in solving simple problems that can be solved on the basis of perceptible elements of the situation.

Validation of the Model of Conceptual Learning and Development

At the Wisconsin Research and Development Center for Cognitive Learning, a test battery was designed to assess the attainment by individuals of the concept equilateral triangle (Frayer, Klausmeier & & Nelson, 1972). Contained in the battery was a test which was developed to assess mastery of each of the four attainment levels and three concept uses. The battery was individually administered to groups of 40 students drawn from each of the following seven grade groups: preschool, kindergarten, second, fourth, sixth, eighth and tenth.

The results of the study were in accord with a set of predictions that are implied by the CLD model. First, the proportion of students who passed a given attainment level increased as a function of grade group. Second, at any given grade level, the proportion of students who mastered successive attainment levels decreased. Third, almost 90 percent of all students manifested one of the following patterns of attainment of the four levels: fail-fail-fail-fail, pass-fail-fail-fail, pass-pass-fail-fail, pass-pass-pass-fail, or pass-pass-pass-pass. This result indicated the cumulative and hierarchical nature of the four levels of attainment. Fourthly, a higher proportion of subjects who attained the formal level, in comparison with subjects who attained only the classificatory level, passed the three concept uses. And finally, an increasing proportion of each successive grade group were able to use their attained concept in cognizing supraordinate-subordinate relationships, in understanding principles, and in problem-solving.

Because of limitations encountered in this study, both the test materials and test format were revised (Klausmeier, Ingison, Sipple & Katzenmeyer, in press). A new group-administered version of the _equilateral triangle_ battery that provided for multiple-choice response alternatives was administered to 100 students selected from the following grades: kindergarten, third, sixth and ninth.

The results of this study strongly validated the set of predictions just presented. One additional finding was that having the labels for the concept and its attributes was positively correlated with attainment of the attainment levels and mastery of the three concept uses.

In summary, the CLD model seems to provide an appropriate framework for both characterizing the cognitive operations that underly the learning of concepts and for assessing the mastery of concepts. Two experimental studies have validated predictions implied by the CLD model regarding the normative course of conceptual development. In the present study, this set of predictions was examined using the concept of <u>cutting tool</u>. This study was a part of a larger research effort carried out by Klausmeier at the Wisconsin Research and Development Center for Cognitive Learning, the purpose of which is to cross-validate the CLD model on a variety of concepts.

Chapter III

CONSTRUCTION OF ASSESSMENT BATTERY

This chapter describes the manner in which the Cutting Tool Assessment Battery was developed. The first section deals with the accumulation of information pertaining to the concept of cutting tool that provided the substantive basis for the construction of the assessment battery. In the second section, the rationale for and description of each of the items in the assessment battery is provided. The process by which the assessment battery was refined into a final form is detailed in the third and fourth sections. The reason for describing in great detail the process by which the assessment battery was developed and evaluated is that considerable time was spent in insuring that the assessment battery adequately measured the cognitive operations that underly the learning of concepts. It was strongly felt that before the assessment battery could be used to validate predictions derived from the CLD model, the battery as a measurement instrument needed to be validated.

The concept cutting tool was selected as one conducive to the development of an assessment battery. It was felt that cutting tool is a concept that has actual perceptible instances that most children have ample opportunity to encounter from an early age. The non-school related nature of the concept appeared to be a good one for the determination of the validity of the predictions of the CLD model.

The construction of an assessment battery based on the concept of <u>cutting tool</u> involved the identification of the following basic pieces of information that would later serve as the basis for the development of the assessment battery: (a) concept definition, (b) defining and irrelevant attributes of the concept, (c) concept hierarchy, (d) principles related to the concept, and (e) concept examples and non-examples.

A wide range of authorities were consulted in the process of securing information relevant to the concept of <u>cutting tool</u>. The initial phase of investigation, which involved consulting several encyclopedias and unabridged dictionaries, resulted in a first-draft formulation of the definition of <u>cutting tool</u>, the identification of the concept's defining and irrelevant attributes, and the placement of the concept in its appropriate taxonomic system.

The second phase of inquiry involved the consultations and recommendations of several professors on the faculty of the departments of Mechanical and Metallurgical Engineering at the University of Wisconsin-Madison. Their efforts resulted in a further refinement of the concept definition, concept attributes, and concept hierarchy. Additionally, several professors provided the substantive background that enabled this author to identify principles related to the concept <u>cutting tool</u>.

The final stage of information gathering and refinement occurred at several meetings with staff members at the Wisconsin Research and Development Center for Cognitive Learning. As a result of these meetings, the first four pieces of information were refined into a final form as presented in Table 1, Table 2, and Figure 2.

Once agreement was achieved concerning the defining and irrelevant attributes of <u>cutting tool</u>, it was possible to select both the examples

Table 1

Concept Definition
Defining and Irrelevant Attributes

definition of cutting tool:	Any tool that has a sharp edge that is used to shape or penetrate.

defining attributes
<u>of cutting tool</u>

1. used in carrying out work of a mechanical or manual kind

2. used to shape or penetrate

3. sharp edge

4. hard edge

5. tough edge

irrelevant attributes
<u>of cutting tool</u>

1. size

2. shading of handle

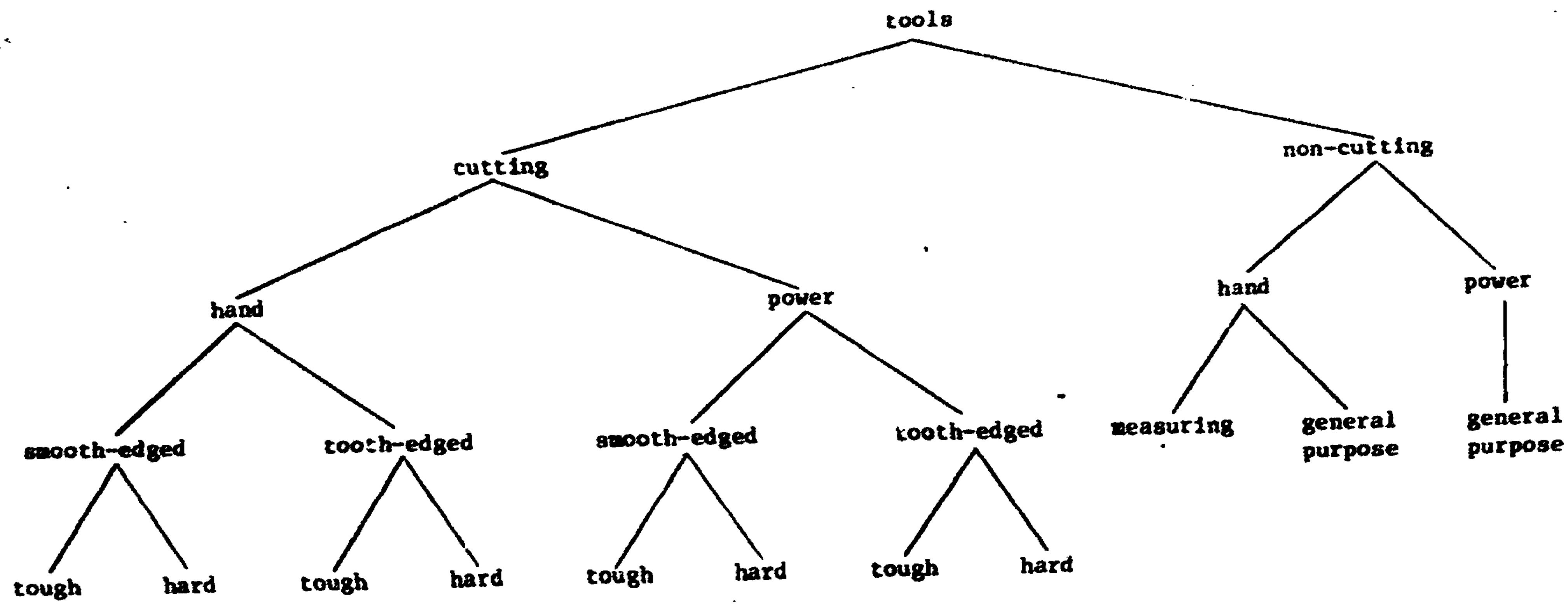
Table 2

Principles Related to Concept

1.	A large kind of cutting tool accomplishes a greater amount of cutting than a small cutting tool of the same kind.
2.	A sharp cutting tool blade cuts more quickly than a dull cutting tool blade.
3.	A cutting tool blade when heated to a low tempering temperature remains sharper over a longer period of use than a cutting tool blade heated to a high tempering temperature.
4.	A cutting tool blade heated to a high tempering temperature will be less likely to break than will a cutting tool blade heated to a low tempering temperature.
5.	A sharp cutting tool blade that has a high degree of hardness remains sharper over a longer period of use than a sharp cutting tool blade that has a low degree of hardness.
6.	A cutting tool blade that can withstand a large amount of impact is less likely to break than a cutting tool blade that cannot withstand a large amount of impact.

Figure 2

Concept Hierarchy



and non-examples of the concept that were subsequently used as stimulus representations in the assessment battery.

The examples and non-examples were selected from the class categories that define the concept hierarchy (see Table 3). No power tools were used in assessing any of the first three levels of concept attainment. The difficulty in representing many power tools was the primary reason for their omission. Three power cutting tools were, however, used at the formal level to assess a subject's ability to discriminate between power and hand tools. A wide representative sample of hand-operated smooth- and tooth-edged cutting tools were selected to assess mastery at the first three concept levels. The array of hand operated non-cutting tools that were selected differed from cutting tools on the basis of one defining attribute (utilized to shape or penetrate). All tools were chosen such that school age children had from a high (hammer, scissors) to medium (paring knife, compass) probability of encountering them in their daily activities. In addition, only cutting tools that had metal edges were selected. Because of this, the relevant attribute of edge was replaced by the label "blade" in the assessment battery.

Once these five areas of information pertaining to cutting tool were established, the construction of the assessment items was initiated. The following will provide a brief rationale behind the construction of a subtest at each of the four levels of concept attainment as well as the three concept uses (supraordinate-subordinate, principles, and problem-solving). No subtest was developed to assess the use of the concept in identifying examples and non-examples because of the difficulty in devising a test that would be distinct from a test assessing classificatory mastery. Seven subtests were therefore developed.

Table 3

Concept Example and Non-Examples

Concept Examples
<u>hand-operated smooth-edged cutting tools</u>
kitchen scissors, axe, chisel, general purpose knife, butter knife, hunting knife, butcher's knife, paring knife, steak knife, pocket knife, rasp
<u>hand-operated tooth-edged cutting tools</u>
rip saw, back saw, coping saw, key whole saw, tree saw, bow saw, hack saw
<u>power-operated smooth-edged cutting tools</u>
electric hedge trimmer
<u>power-operated tooth-edged cutting tools</u>
power saw, electric saw

Concept Non-Examples
<u>hand-operated measuring tools</u>
compass, ruler
<u>hand-operated general purpose tools</u>
wrench, clamp, screwdriver, mallet, bamboo rake,, hammer, paint brush

Rationale and Description of Item Construction

This section will describe the test battery in its final form. Also, the two steps in test construction employed in a larger research project that preceded the final form are described at the end of this section. The final test battery used in this study is included in Appendix A.

Concept Mastery Subtests

The Concrete subtest required a subject to look at a representation of a cutting tool that appeared on one page (target) and, after a five second pause, select on the following page the same cutting tool when it was presented along with other representations of tools (nonexamples). The target was represented in the same orientation in the array of non-examples as it was when it was initially shown. In order to have correctly identified the target among the non-examples, it is inferred that a subject must have attended to the target, remembered it over the five second delay interval, and discriminated it from among the non-examples. These three operations characterize the concrete level of concept mastery.

The Concrete level subtest consisted of four items which used a smooth-bladed cutting tool as a target and four which had a tooth-bladed cutting tool as target. Within each of the two sets of four items, each item became more difficult in terms of the number of relevant and irrelevant attributes the non-examples had in common with the target. For instance, the easiest two items were ones which had a target sharing no common relevant attributes with the non-examples (except that all are tools) and having the irrelevant attributes of shading and size randomly assigned to the three different non-examples and the target. The most difficult item had the target sharing all relevant and irrelevant attributes with the non-examples except for the irrelevant attribute of shape. (The number of non-examples in the array from which the target was selected--three or six--was an additional source of difficulty across all eight subtest items). A more complete description of the eight concrete level items is presented in Table 4. Two sample items were also included to insure that a subject understood what was required.

The Identity subtest consisted of the same eight items that appeared in the Concrete subtest. The only difference between the first two subtests of concept level mastery was a change in non-example and target orientations of the Identity items. If a subject selected the target from among the non-examples even after its orientation had changed, it was inferred that the subject had generalized that the two or more forms of the same thing were equivalent in some way. The use of the identical cutting tool representations in both the Concrete and Identity subtests insured that any differences in subject performance would reflect differences in the developmental emergence of the cognitive operation that is hypothesized to differentiate the first two levels of concept attainment.

The Classificatory subtest consisted of eight items that ranged widely in difficulty. The first two items used the exact same target examples and non-examples as were used in the two easiest items in the Concrete and Identity subtests. This was done so as not to make the Classificatory subtest artificially more difficult than the two previous levels through the manipulation of the stimulus materials. The first two items required a subject to select from a group of four tools ... tool which is used to do the same kind of work as

Table 4

Concrete and Identity Item Characteristics

Item	Subtest	Number of Non-examples	Number of Defining Attributes that Target Shares with Non-examples	Number of Irrelevant Attributes that Target Shares with Non-examples
1	concrete	3	2	1
2	identity	3	2	1
3	identity	3	5	1
4	concrete	3	5	1
5	identity	6	5	0, 1 or 2
6	concrete	6	5	0, 1 or 2
7	concrete	6	5	2
8	identity	6	5	2
9	concrete	3	2	1
10	identity	3	2	1
11	identity	3	5	1
12	concrete	3	5	1
13	identity	6	5	0, 1 or 2
14	concrete	6	5	0, 1 or 2
15	concrete	6	5	2
16	identity	6	5	2

a cutting tool that appeared to the left of the group of four tools. The first item determined whether a subject could classify two knives together while the second question determined if a subject could group two saws together. If a subject correctly responded to these items, it was felt that the subject could generalize that two instances of a cutting tool are equivalent in some way. The emergence of this operation distinguishes the classificatory from the identity level.

Of the remaining six items, three required a subject to classify two concept examples together when they were presented with three non-examples. These items became progressively more difficult in terms of a decrease in perceptual and functional similarity between the two examples. The other three items presented a subject with four examples and six non-examples which also had to be correctly classified according to whether they were cutting or non-cutting tools. The similarity among the examples on each of the three successive items became less obvious. An additional difficulty factor across these six items was the absence of a target or example to which a subject could refer when classifying. Two sample questions were also included to clarify the format of the Classificatory subtest. The item characteristics of the Classificatory subtest are presented in Table 5.

The Formal subtest contained three parts. The first part consisted of five items which determined whether a subject could discriminate one tool or object from three others on the basis of a defining attribute. For example, one item presented a subject with three different representations of a knife and one of a saw. A subject who could correctly identify the tool which was different from the other three was inferred to be able to discriminate the attributes of smooth and tooth blades. The second

Table 5

Classificatory Item Characteristics

Item	Example Present	Characteristics of Stimulus Array
*1	yes (general purpose knife)	one correct example (hunting knife) and three non-examples
**2	yes (rip saw)	one correct example (back saw) and three non-examples
3	no	two correct examples (keywhole saw, butcher's knife) and three non-examples
4	no	four correct examples (butcher's knife, hack saw, keywhole saw, butter knife) and six non-examples
5	no	two correct examples (axe, rasp) and three non-examples
6	no	four correct examples (hack saw, hunting knife, scissors, axe) and six non-examples
7	no	two correct examples (rip saw, chisel) and three non-examples
8	no	four correct examples (coping saw, chisel, rasp, pen knife) and six non-examples

*Parallel with item 1 and item 10 in concrete and identity level subtests
**Parallel with item 2 and item 9 in concrete and identity level subtests

part consisted of nine multiple-choice vocabulary items that dealt with important attributes of cutting tool, as well as the definition of a term that was needed in order for a subject to understand several of the principles (tempering). The third part contained one item which required a subject to select the correct definition of cutting tool from three possible alternatives. Table 6 presents a full description of each of the Formal subtest items.

Concept Uses

The Supraordinate-Subordinate subtest contained 10 multiple-choice items which were designed to determine whether subjects could understand the following relaionships:

I. Some but not all members of a supraordinate class belong to a given subclass.

II. The sum of the members of the subclasses equal the sum of the members of the supraordinate class.

III. All members of a subclass belong to a higher class.

IV. The members of one coordinate class are not members of another coordinate class.

Contained in each of these items was an array of six tools and/or objects that illustrated each of the four above relationships. As Table 7 shows, two of the relationships are assessed by two similar items while the other two are assessed using three.

The Principles subtest consisted of two parts, each part containing six multiple-choice items. The two sets of six items which were based on the principles described in Table 2, ranged from easy, concrete and non-technically worded items, to more abstract and technically worded ones. The six items that required a subject to cognize the principle in a context elicited information that revealed whether a subject was aware

Table 6

Formal Item Characteristics

I. Discriminating the Attributes

Item		Stimulus Examples and Non-examples
1	hand tool vs power tool	1 hand tool - 3 power tools
2	cutting tool vs non-cutting tool	1 cutting tool - 3 non-cutting tools
3	tooth-edged vs smooth-edged	1 tooth-edged cutting tool - 3 smooth-edged cutting tools
4	smooth-edged vs tooth-edged	1 smooth-edged cutting tool - 3 tooth-edged cutting tools
5	tool vs non-tool	3 tools - 1 non-tool

II. Vocabulary

Item	Label
6	tool
7	blade
8	cutting tool
9	toothed blade
10	hand tool
11	smooth blade
12	tempering (definition)
14	toughness
15	hardness

III. Concept Definition

Item	
13	

Table 7

Supraordinate-Subordinate Item Characteristics

I. Some but not all members of a supraordinate class belong to a given subclass (9, 11, 12)*

1. Some but not all cutting tools have a blade that is smooth
2. Some but not all cutting tools have a blade that has teeth.
3. Some but not all tools are cutting tools.

II. The sum of the members of the subclasses equals the sum of the members of the supraordinate class (14, 18)*

1. All the smooth-bladed cutting tools and all the tooth-bladed cutting tools equal all the cutting tools.
2. All the cutting tools and all the non-cutting tools equal all the tools.

III. All members of a subclass belong to a higher class (10, 15, 16)*

1. All of the smooth-bladed cutting tools are cutting tools.
2. All of the tooth-bladed cutting tools are cutting tools.
3. All of the cutting tools are tools.

IV. The members of one coordinate class are not members of another coordinate class (13, 17)*

1. Some large tools are not smooth-bladed cutting tools.
2. Some tools that have black handles are not tooth-bladed cutting tools.

*The numbers that follow each of the four statements of the supraordinate-subordinate relationship correspond to the item numbers as they appear in the assessment battery.

of the relationship defined by the principle when concrete instances of the relationship were provided. The second six items were constructed to determine whether a subject could cognize the verbally stated relationship without the help of a concrete referent.

Each of the six Problem Solving multiple-choice items was derived from one of the six principles. Each of the six questions which were presumed to be answered more readily if a subject understood one or more of the six principles required a subject to internally manipulate concrete information in attaining problem solution. The six items contained either a novel situation, an application of several concepts and principles, or knowledge of the more technical applications and implications of one of the six principles. The characteristics of the Problem-Solving and Principles items are provided in Table 8.

Initial Evaluation of Assessment Battery

Once the construction of the assessment battery was completed, the battery was administered to a small group of school age children. Three questions were posed previous to the administration of the battery. The first was to determine whether the test format and general testing procedure were appropriate for the particular population that was to be used in the study. Of particular concern was: (a) Would the paper-and-pencil nature of the battery be comprehensible by the youngest subjects, (b) Would subjects understand the wording of both instructions and questions, and (c) Would the two-dimensional representations of tools be recognized. The second was to see whether the Concrete and Identity subtests could be shortened by eliminating items of equivalent difficulty levels. The third was to determine whether the test battery could be

Table 8

Principle and Problem-Solving Item Characteristics

Item	Subtest	Characteristic
1	problem-solving	related to principle 6
2	problem-solving	related to principle 1
3	problem-solving	related to principle 5
4	problem-solving	related to principle 4
5	problem-solving	related to principle 2
6	problem-solving	related to principle 3
7	principle	cognize principle 6 in a context
8	principle	cognize principle 1 in a context
9	principle	cognize principle 3 in a context
10	principle	cognize principle 4 in a context
11	principle	cognize principle 2 in a context
12	principle	cognize principle 5 in a context
13	principle	statement of principle 6 without context
14	principle	statement of principle 3 without context
15	principle	statement of principle 2 without context
16	principle	statement of principle 1 without context
17	principle	statement of principle 4 without context
18	principle	statement of principle 5 without context

completely administered in one testing session without creating subject discomfort and inattentiveness.

The battery was administered to a total of 24 subjects. One male and one female of high, medium and low achievement were drawn from each of the kindergarten, third, sixth and ninth grades. One low ability kindergarten male who became ill during the administration of the battery was able only to complete the Concrete and Identity subtests. The subjects were selected from classrooms at one elementary and one junior highschool in Beloit, Wisconsin. The seven subtests that were described in a previous section were presented in five test booklets. All subjects marked their answers directly in the test booklets. The 24 subjects received an invariant order of subtest administration. All questions and response alternatives were read aloud by the test administrator to all subjects. After the test was administered, each subject was interviewed to secure information concerning possible confusions and ambiguities of test items or general procedure. The complete test was administered to six subjects at a time. Subjects were removed from their regular classrooms and were tested in an unoccupied classroom or in the library.

As a result of feedback provided by the 24 subjects, it was determined that those items which had a multiple-choice format could be understood by kindergarteners, provided that the instructions were clear and simple. The test manual was, therefore, modified for kindergarten and third grade subjects to a 'primary test manual' which contained less complex language. Visual aids in the form of letters printed on four by six index cards proved to be valuable in assisting the younger subjects in locating answers in their test booklets. The sixth and ninth grade subjects had few problems with the test manual format ('adult test manual') though several answers and questions, particularly at the problem solving level, had to be reworded.

Tables 9 through 15 indicate the performance of the 24 subjects on the items contained in each subtest. The data from Tables 10 and 11 reveal that almost all the items contained in the Concrete and Identity subtests were answered correctly by the 24 subjects. It was decided that items five through eight from the Concrete and Identity subtests could be dropped. Since those Concrete and Identity items that underwent stimulus changes appeared to be more difficult than when they were originally administered, two more difficult items were added to the Classificatory subtest. This was done to insure that the difficulty level of these subtests remained comparable. It was apparent in scoring the performance of the 24 subjects that several subjects had difficulty in recognizing some of the two-dimensional representations of tools. These non-verbal stimuli were modified or eliminated. No other significant changes were made as a result of the initial evaluation of the assessment battery.

Final Evaluation of Assessment Battery

The purpose of the final evaluation was fourfold. The first was to evaluate tne items changes made as a result of the first evaluation. The second was to see whether on a larger scale the difficulty levels of the four attainment subtests were too easy for kindergarten subjects. It was felt that if the kindergarten subjects were correctly answering most of the attainment items, then younger subjects would have to be used or more difficult items would have to be introduced. The third purpose was

Table 9

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Concrete Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	1.00	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00
3	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00
9	.83	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00
15	1.00	.83	1.00	1.00
16	1.00	1.00	1.00	1.00

Table 10

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Identity Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	1.00	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00
3	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00
13	.83	1.00	1.00	1.00
14	.83	1.00	1.00	1.00
15	.83	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00

Table 11

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Classificatory Item

	Grade Group			
Item	Kindergarten*	Third	Sixth	Ninth
1	.80	.83	1.00	1.00
2	1.00	1.00	1.00	1.00
3	1.00	1.00	1.00	1.00
4	1.00	.83	1.00	1.00
5	.80	1.00	1.00	.83
6	.60	.83	1.00	.67
7	.80	1.00	1.00	1.00
8	.80	.67	1.00	1.00

*One low ability kindergarten male absent

Table 12

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Discriminating the Attributes Item

	Grade Group			
Item	Kindergarten*	Third	Sixth	Ninth
1	.20	.67	.67	1.00
2	.40	.83	.83	1.00
3	.60	.83	1.00	1.00
4	.40	1.00	.83	1.00

*One low ability male student absent

Table 13

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Vocabulary and the Concept Definition Item

	Grade Group			
Item	Kindergarten*	Third	Sixth	Ninth
1	.60	1.00	1.00	1.00
2	.20	.83	1.00	1.00
3	.20	.67	.83	1.00
4	.20	1.00	1.00	1.00
5	.80	1.00	1.00	1.00
6	.20	1.00	1.00	1.00
7	NA***	.50	.67	.83
8	NA	.67	.67	.83
9	NA	.17	.50	.83
10**	NA	.33	.50	.67

*one low ability male student absent
**concept definition item
***not administered

Table 14

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Supraordinate-Subordinate Item

	Grade Group			
Item	Kindergarten*	Third	Sixth	Ninth
1	.60	1.00	.83	1.00
2	.20	.83	.83	.67
3	.00	1.00	1.00	1.00
4	.40	1.00	1.00	1.00
5	.20	1.00	1.00	1.00
6	.20	.50	1.00	.83
7	.20	.83	.83	1.00
8	.00	.17	.83	.17
9	.00	1.00	1.00	1.00
10	.00	.50	.50	.50

*One low ability kindergarten male absent

Table 15

Initial Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Principle and Problem Solving Item

		Grade Group			
	Item	Kindergarten*	Third	Sixth	Ninth
Problem Solving	1	NA*	.00	.33	.00
	2	1.00	.67	.67	.33
	3	NA	.50	.50	.67
	4	1.00	.50	.83	.83
	5	NA	.33	.00	.00
	6	NA	.00	.33	.33
Principle	7	NA	.17	.67	1.00
	8	.40	.33	.67	.67
	9	NA	.00	.00	.17
	10	NA	.33	.50	.17
	11	.00	.67	.67	1.00
	12	NA	.17	.50	.67
	13	NA	.33	.67	1.00
	14	NA	.33	.33	.33
	15	.20	.83	.67	1.00
	16	.00	.50	.83	.67
	17	NA	.33	.00	.67
	18	NA	.00	.67	.50

*one low ability kindergarten male absent
**not administered

to determine whether either manual needed further revision before the test battery could be used to validate the predictions of the CLD model. The final purpose was to determine whether some of the test items could be eliminated at certain grades so as to reduce the time of administration. The first evaluation of the battery demonstrated that older subjects passed almost all of the easiest items, while the younger subjects failed many of the most difficult items. The rationale for deciding which items or subtests would not be administered was one which stated that kindergarten subjects would not receive certain items that most third grade subjects had answered incorrectly. Ninth and sixth grade subjects would not be administered those subtests that contained items that a large proportion of third grade subjects answered correctly. It was felt that if the test could be shortened, time, money, and both subject and test administrator energy could be conserved.

A sample of approximately 400 subjects were administered the assessment battery. Approximately 50 males and 50 females from kindergarten, third, sixth and ninth grades were selected at four elementary schools and one junior high school in Watertown, Wisconsin.

The subjects selected were the same ones that participated in a previous concept assessment study reported by Klausmeier, Ingison, Sipple, and Katzenmeyer, (in press). The kindergarten, third and sixth grade subjects who participated in that study were chosen on the following bases: (a) subjects were drawn from intact classrooms, (b) the classrooms that were administered the assessment battery were taught by teachers whom the principal of the particular elementary school considered 'cooperative',

(c) only one kindergarten, third, and sixth grade classroom from each elementary shcool participated in the study, and (d) each participating classroom contained approximately equal numbers of high, medium and low ability students. The ninth grade subjects were selected on the following bases: (a) subjects were tested in intact classrooms, (b) three levels of math achievement were represented across the four classrooms (one high ability, 2 medium ability and 1 low ability classrooms), and (c) four classes met consecutively during the morning school hours. This was done to decrease the amount of communication between classes.

A revised test battery consisting of five parts was administered to all subjects. Included in the five parts were the seven subtests previously described.

The test battery was administered to intact classrooms of subjects. As was done in the initial pilot, each intact classroom of subjects received the test in the same order (IIA, IIB, IIC, IID, and IIE). Each subject marked his or her own response directly in the test booklets. The instructions, questions, and response alternatives (where appropriate) were read aloud to all subjects. For the kindergarten subjects, the test administrator provided assistance on multiple-choice questions in the form of large printed letters that corresponded to each of the response alternatives. After the administrator read a question and first response alternative, she would hold up the letter 'A' and say "if you think the answer I just read is the correct one, mark the letter in your booklet that looks like the one I'm holding up." This procedure was done for each of the response alternatives. On the basis of the results obtained from the first pilot study, it was decided that several different questions from the formal level, principle and problem solving subtests would not be administered to kindergarten subjects.

The following subtest changes were made as a result of the data presented in Tables 16 through 22.

As Tables 16 and 17 indicate, most of the Concrete and Identity items were answered correctly by the kindergarten subjects. As a result, a decision was made that rather than carrying out the study with children younger than kindergarten age, some of the items on the Concrete and Identity subtests were made more difficult. The specific changes were the following. Items 3 through 8 on both subtests were completely eliminated. It was decided to leave the first two items in the battery since these items, as explained earlier, had a parallel form on the Classificatory subtest. One stimulus change was made on item 2 on the Concrete and Identity subtests. A broom was substituted for a wrench. This was done because it was observed that on Classificatory item number 2, subjects classified the screwdriver and wrench together. Two items which required a finer perceptual discrimination were also added to the first two subtests. It was felt that these two items would make the difficulty level of the Concrete subtest more appropriate for kindergarten subjects. Additionally, the Concrete and Identity items were counterbalanced to avoid the possible development of a practice set or effect that could possibly bias test performance. The Classificatory and Formal items were not counterbalanced because these subtests required completely different response behaviors than did the Concrete and Identity items. It was felt that because the younger students have limited repetoires of test-taking behaviors rapid changes

Table 16

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Concrete Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	.92	1.00	1.00	1.00
2	.92	1.00	1.00	1.00
3	.92	.99	1.00	1.00
4	.96	1.00	1.00	1.00
5	.97	1.00	1.00	1.00
6	.94	1.00	1.00	.98
7	.88	1.00	1.00	.99
8	.93	1.00	1.00	1.00
9	.93	.99	1.00	1.00
10	.84	.99	1.00	1.00
11	.81	.98	.99	.99
12	.94	.99	1.00	.99

Table 17

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Identity Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	.99	1.00	1.00	1.00
2	.99	.99	1.00	1.00
3	.96	.99	1.00	1.00
4	.97	.98	1.00	1.00
5	.99	.99	1.00	1.00
6	.97	.99	1.00	1.00
7	.86	.95	1.00	.99
8	.97	1.00	1.00	1.00
9	.94	1.00	1.00	1.00
10	.90	.97	.99	1.00
11	.92	.99	1.00	.99
12	.92	.97	1.00	.99

Table 18

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Classificatory Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	.95	.98	1.00	1.00
2	.95	1.00	1.00	1.00
3	.92	.90	.99	.97
4	.97	.99	1.00	1.00
5	.79	.86	.82	.88
6	.54	.57	.73	.85
7	.37	.27	.42	.34
8	.03	.06	.02	.04
9	.03	.25	.34	.36
10	.00	.11	.04	.13

Table 19

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Disciminating the Attribute Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	.67	.80	.86	.91
2	.67	.97	.99	.97
3	.63	.86	.94	.97
4	.85	.99	.98	.99
5	.97	.97	.92	.97

Table 20

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Vocabulary and the Concept Definition Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	.81	.88	.88	.99
2	.89	.89	.95	.99
3	.85	.82	.86	.98
4	.74	.95	.99	1.00
5	.58	.92	.93	.99
*6	.68	.81	.96	1.00
7	NA**	.45	.62	.95
8	NA	.52	.75	.91
9	NA	.35	.32	.51
10	NA	.13	.17	.34

*concept definition item
**not administered

Table 21

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Supraordinate-Subordinate Item

	Grade Group			
Item	Kindergarten	Third	Sixth	Ninth
1	.44	.86	.92	1.00
2	.66	.79	.81	.87
3	.62	.96	.96	1.00
4	.63	.98	.97	1.00
5	.62	.91	.94	.98
6	.29	.62	.66	.85
7	.55	.73	.89	.96
8	.19	.37	.59	.73
9	.59	.95	.96	.98
10	.23	.39	.50	.71

Table 22

Final Evaluation of Assessment Battery. Proportion of Each Grade Group Correctly Responding to Each Principle and Problem Solving Item

	Item	Kindergarten	Third	Sixth	Ninth
		Grade Group			
Principle	1	NA*	.60	.71	.95
	2	.86	.88	.81	.84
	3	.33	.50	.61	.84
	4	NA	.53	.52	.76
	5	.59	.70	.82	.95
	6	NA	.53	.51	.71
Problem Solving	7	NA	.34	.60	.86
	8	.84	.73	.69	.82
	9	NA	.47	.39	.66
	10	NA	.33	.47	.74
	11	.62	.71	.77	.95
	12	.15	.46	.52	.82
	13	NA	.47	.60	.92
	14	NA	.30	.35	.65
	15	.49	.79	.83	.98
	16	.19	.53	.65	.77
	17	NA	.19	.28	.59
	18	.32	.39	.50	.83

* ot administered

in response modes would confuse these subjects thereby possibly depressing their performance. It was decided that sixth and ninth grade subjects would not receive the Concrete and Identity subtests because they were found to be too easy.

Since almost all subjects responded correctly to the first four Classificatory items, items 3 and 4 were eliminated from the Classificatory subtest (see Table 18). It was discovered that on Classificatory items 2, 6, 7, 8, and 10, subjects could correctly follow the instructions and yet incorrectly classify two non-cutting tools (i.e., wrench and screwdriver) as cutting tools. The instructions were to put an X on the things that "are used to do the same kind of work." Therefore, changes in these stimuli were made to eliminate this problem.

An ambiguous representation of a tool (scissors) that appeared in the Supraordinate-Subordinate subtest was replaced with a more easily recognizable one.

The wording of several questions and answers in the Principle and Problem Solving subtests was further refined and clarified.

And finally, having applied the previous criteria dealing with difficulty, it was decided that kindergarten subjects would not receive three of the most difficult Vocabulary items, four of the six Problem Solving items and eight of the twelve Principle items.

Chapter IV

METHOD

The purpose of this study is to test a set of five predictions implied by the CLD model.

The five hypotheses tested in this study were the following: (a) the proportion of subjects passing each attainment level--concrete, identity, classificatory and formal--will increase as a function of grade group,(b) subjects who pass any one of the four concept levels will also have passed the preceding lower levels,(c) subjects who attain a concept at the formal level will use the concept more effectively in cognizing supraordinate-subordinate relationships, in understanding principles, and in problem solving than subjects who have only attained the concept at the classificatory level,(d) subjects who know the labels of the concept and its defining attributes and also the concept definition will perform better on the three concept uses than subjects who do not, and (e) a higher percentage of each successive grade group will pass each of the three concept uses. Two additional questions were asked: (f) is there a difference in chronological age between males and females when each group passes the four levels of concept attainment and the three concept uses?, and (g) are items that use a smooth-edged cutting tool as a target at the concrete and identity levels more difficult than those items that use a tooth-edged cutting tool?

Subjects

The subjects who participated in the study were drawn from four elementary schools and one junior high school in Beloit, Wisconsin. Beloit, which has a population of almost 36,000, is both a manufacturing and farming community. Seven percent of Beloit's residents are black with less than one percent of the remaining 93% representing other non-white populations. The average income of $9,460 is slightly above average for a midwest industrialized community. The Beloit public school system has 14 elementary schools, three junior high schools, and one senior high school. In addition, Beloit contains five parochial grade schools and one parochial high school. The five public schools from which subjects were selected ranged in characteristics from one that had an all white, middle- to upper-class stable population to one that had a 50 percent non-stable black population that generally came from a lower socioeconomic class in the community. The scope of academic achievement also ranged from high to low. These schools were selected by the Beloit school superintendent as ones that were representative of the racial and socioeconomic characteristics of the Beloit community and would be cooperative in the study.

A total of 400 kindergarten, third, sixth and ninth grade subjects were administered the assessment battery. One hundred subjects, 50 males and 50 females, were tested at each of the four grade levels.

The selected subjects were the same ones that participated in a previous concept assessment study conducted under the supervision of Professor Herbert J. Klausmeier. The kindergarten, third and sixth grade subjects who participated in that study were selected on the following basis: (a) subjects were drawn from intact classrooms, (b) the classrooms that were administered the assessment battery were taught by teachers whom the principal of the particular elementary school considered 'cooperative,' (c) only one kindergarten, third, and sixth grade intact classroom from each elementary school participated in the study, and (d) each participating classroom contained approximately equal numbers of high, medium and low ability students. The ninth grade subjects were chosen on the following basis: (a) subjects were tested in intact classrooms, and (b) three levels of math achievement were represented across the four classrooms (one high ability, two medium ability and one low ability classrooms), and (c) the four classes met consecutively during the morning hours. This was done to decrease the amount of communication between classes.

Kindergarten subjects were administered the battery in groups of six to ten. These subjects left their classroom and were assessed either in the school library or in empty classrooms. The third, sixth and ninth grade subjects were tested in intact classrooms. Whereas the assessment of kindergarten subjects generally lasted for one and a half classroom periods, third, sixth and ninth grade subjects were administered the complete battery within one class period. Because of the difficulty of obtaining exactly 50 males and 50 females at the third, sixth and ninth grades, one or two small groups of subjects at each of these grade levels left their classroom and were administered the battery in the school library. The number of males and females, the mean age and age range at each grade level of the subjects is presented in Table 23.

Table 23

Number of Males and Females,
Mean Age, and Age Range at Each Grade Level

Grade	Males	Females	Mean Age (years - months)	Age Range (years - months)
K	50	50	6-0	5-5 to 6-6
3rd	50	50	9-1	8-5 to 9-10
6th	50	50	12-0	11-4 to 12-10
9th	50	50	14-11	14-4 to 15-9

Materials

The four subtests of concept level mastery and the three subtests of the concept uses described in Chapter III were organized into four assessment booklets (IIA-IID). Booklet IIA contained the eight Concrete and eight Identity subtest items. These items were presented in a counterbalanced order. In addition, two sample items appeared at the beginning of the booklet. Booklet IIB included both the eight Classificatory subtest items--which were presented first--and the 10 Supraordinate-Subordinate concept use items. Booklet IIC contained the six Problem Solving items and the 12 Principle subtest items. The order of presentation of these items was presented in Table 8 of Chapter II. Booklet IID included first the five Discriminating Attributes followed by the nine Vocabulary items. The item dealing with the definition of the concept was presented after the seventh Vocabulary item. The assessment battery was printed in black ink on a light blue opaque paper.

An administrator's manual for children of primary age and another for older students were used by the two testers when they administered the assessment battery. The primary administrator's manual, used when the test was administered to kindergarten and third grade subjects, contained a detailed and explicit description of the behavior required of subjects as well as verbal descriptions that were much simpler than those used in the adult test manual.

Procedure

The assessment battery was administered by one white male and one white female both of whom were in their middle twenties. At the beginning of each assessment session, all of the assessment booklets were distributed to subjects. The sixth and ninth grade subjects did not receive the Concrete and Identity subtests (Booklet IIA). The kindergarten subjects received an abbreviated version of the Principle and Problem Solving subtests [IIC(K)]. Booklet IIC(K) contained items 2 and 5 from the Problem Solving subtest and items 8, 11, 15 and 16 from the Principles subtest. Kindergarten subjects also did not receive Vocabulary items 12, 14, and 15.

All subjects received the booklets in the same order of presentation (IIA-IID). The test examiners read aloud all instructions. The examiners also read aloud each of the questions as well as each of the possible response alternatives where appropriate. When the response alternatives to multiple-choice questions were read aloud to the kindergarten subjects, the examiner held up 4 by 6 index cards each of which contained a large lower case letter ('a', 'b', 'c', 'd', and 'e'). This procedure assisted kindergarteners in locating their response preferences. Pencils were provided for those who needed them. A new pencil was given to each subject after the completion of the assessment battery.

The following demographic data which was obtained from each subject before the battery was administered was recorded on the first page of Battery IIA: Name ______________________________, Birthdate ________
Last First Middle Month

______________________, School ______________________, Grade ______, Today's
Day Year

Date __________________, Sex F M, and Adm. No. (Administration Number) __________________.

Design of Study

This cross-sectional study was conducted to test the set of predictions implied by the CLD model. Students of four grade levels (kindergarten, third, sixth and ninth) of both sexes (male and female) participated. The seven assessment battery subtests served as dependent repeated-measures. The design of the study is presented in Table 24.

Table 24

Design of Study

		Attainment Level				Concept Use		
		Concrete	Identity	Classificatory	Formal	Supraordinate-Subordinate	Principles	Problem Solving
Kindergarten	Male	------------------>						
	Female	------------------>						
Third	Male	------------------>						
	Female	------------------>						
Sixth	Male	------------------>						
	Female	------------------>						
Ninth	Male	------------------>						
	Female	------------------>						

Chapter V

RESULTS

Criteria for Determining Mastery of the Four Attainment and Three Concept Uses Subtests

A mastery level score was computed for each subject for each of the seven subtests. The initial mastery scores were determined at one more than the number of items subjects could answer correctly on a chance basis. The full mastery scores were determined arbitrarily. Generally, a subject attained a full mastery score if no more than one incorrect response was made. A subject received either a no mastery, initial mastery, or full mastery score for each of the subtests depending on the total number of items answered correctly. Subjects who failed to correctly answer sufficient items to receive an initial mastery score received a no mastery score. Subjects who failed to correctly respond to enough items to receive a full mastery score yet who exceeded the initial mastery criteria received an initial mastery score. Subjects who exceeded the full mastery criteria received a full mastery score. These mastery level scores were used in statistically evaluating predictions implied by the CLD model. In performing the statistical tests the no mastery and initial mastery scores were combined to form one group. The primary reason for combining the no mastery and initial mastery scores was that none of the predictions derived from the CLD model dealt with the no mastery and initial mastery distinction. An additional reason was that at most of the grade levels on most of the subtests very little information was lost by combining groups. A summary of the criteria for subtest mastery is provided in Table 25.

Table 25

Criteria for Mastery of the
Four Attainment and Three Concept Uses Subtests

Subtest	No Mastery	Initial Mastery	Full Mastery
concrete	0 or 1 of 8	2 of 8	7 of 8
identity	0 or 1 of 8	2 of 8	7 of 8
classificatory	0 or 1 of 5	2 of 5	4 of 5
formal			
discriminating the attributes	0 or 1 of 5	2 of 5	4 of 5
vocabulary	0, 1 or 2 of 9	3 of 9	7 of 9
definition	No	Yes	Yes
supraordinate-subordinate	0 of 4	1 of 4	3 of 4
principle	0 of 5	1 of 5	4 of 5
problem-solving	0 or 1 of 5	2 of 5	4 of 5

The criterion for initial mastery of both the Concrete and Identity subtests was that a subject needed to have correctly responded to two of the 'eight' items. To receive a full mastery score, seven of the eight items had to be answered correctly.

Prior to data analysis, three items from the Classificatory subtest were dropped (7, 9 and 10). In addition, one of the Problem Solving items (6) and one pair of Principle items (12 and 18) were eliminated from the assessment battery. The reason these Classificatory items were not dropped before the final battery was developed was that there was a lag in the analysis of the Classificatory item characteristics. It was felt that these items required subjects to classify cutting tools that young children had low probabilities of encountering in their daily activities (i.e., chisel). These items also contained visually ambiguous representations of cutting tool (i.e., rasp). For these two reasons, it was determined that these items should not be scored. The reason for not scoring the three uses items was that the overall difficulty levels of the items in the Principle and Problem Solving subtest was too high.

The criterion for full mastery at the classificatory level was responding correctly to four of the five items. Initial mastery required a subject to correctly respond to two of the five items.

A subject had to receive a full mastery score on three separate parts of the Formal subtest to obtain a full mastery score at the formal level. A subject needed to have correctly responded to four of the five items which required a subject to discriminate the attributes of the concept, seven of the nine vocabulary items and the item relating to the concept definition. To attain initial mastery at the formal level, a subject must have correctly answered two of the five discriminating attributes items, three of the nine vocabulary items and the concept definition item.

To attain full mastery of the Supraordinate-Subordinate subtest, a subject must have correctly responded to three of the four pairs or triads of items that were related to one of the four basic supraordinate-subordinate relationships. Initial mastery was set at answering one of the four pairs of triads of items.

Full mastery of the Problem Solving subtest required a subject to correctly respond to four of thé five items. Initial mastery was determined at two of five.

For a subject to attain full mastery of the Principle subtest, four of five pairs of principle items needed to have been answered correctly. Initial mastery was set at one of five.

Analysis

The results are presented in accordance with the five predictions implied by the CLD model and the questions that were presented in Chapter IV.

The first and fifth hypotheses were examined using a chi-square test of homogeneity. If significant differences were obtained, a chi-square analog to Scheffeś theorem was employed in a post-hoc examination of all pair-wise contrasts. In addition, hypothesis 1 was examined using a trend analysis that was conducted at each of the four attainment levels. In the examination of hypothesis 2, the percentage of subjects who attained the successive levels of attainment according to the five allowable patterns implied by the CLD model was compared with the percentage of subjects who were exceptions to these patterns. A chi-square test of independence was employed in the testing of hypothesis 3 and hypothesis 4. If significant differences were found, a strength of relationship measure (phi-coefficient) was computed between the two independent variables of concern. In examining question 6, a two-sample Z-test was performed on the percentage of males and females who achieved full mastery at a particular level. A test of correlated proportions (McNemar's Test of Change) was employed in the examination of question 7.

The results of these five hypotheses and two questions are now presented. 'Passing' refers to the attainment of full mastery at either an attainment level or concept use.

Hypothesis 1

The results of the chi-square test of homogeneity showed significant differences in full mastery among the four grade groups on each of the four concept subtests (Concrete, $\chi^2_3 = 77.25$; Identity, $\chi^2_3 = 130.49$: Classificatory, $\chi^2_3 = 51.93$; Formal, $\chi^2_3 = 140.05$; $p < .05$). The mastery level performance of each grade group on each of the four attainment subtests is presented in Table 26.

When all pair-wise comparisons were examined using Scheffé's procedure, a significant difference was found between kindergarten subjects and third grade subjects, sixth grade subjects and ninth grade subjects on the Concrete and Identity subtests ($p < .05$). On the Classificatory subtest, a significant difference was obtained between kindergarten subjects and third, sixth and ninth grade subjects and between third and ninth grade subjects ($p < .05$). A significant difference was also obtained between each of the grades groups on the Formal subtest (kindergarten < third < sixth < ninth, $p < .05$).

Table 25

Performance of Each Grade
Group on Each of the Four Attainment Subtests

Grade	Score	Concrete	Identity	Classificatory	Formal
		Subtest			
		Percent Passing Mastery Levels			
Kindergarten	no mastery	.01	.01	.12	.92
	initial mastery	.28	.45	.35	.08
	full mastery	.71	.54	.53	.00
Third	no mastery	.00	.00	.04	.59
	initial mastery	.04	.06	.19	.25
	full mastery	.96	.94	.77	.16
Sixth	no mastery	.00	.00	.00	.26
	initial mastery	.00	.00	.14	.28
	full mastery	1.00	1.00	.86	.46
Ninth	no mastery	.00	.00	.00	.10
	initial mastery	.00	.00	.07	.17
	full mastery	1.00	1.00	.93	.73

The post-hoc trend analysis conducted on the data obtained from each attainment subtest demonstrated the following. On the Concrete and Identity subtests, the linear trend component was found to be significant between kindergarten and third grades ($p < .05$). Because sixth and ninth grade subjects obtained 100 percent scores, no analysis was conducted on these data. The linear trend component was the only significant component when the performance of all grades at the Classificatory and Formal levels was compared ($p < .05$).

Hypothesis 2

Table 27 presents the number and proportion of each grade group that conformed to the five patterns of concept attainment that are consistent with the CLD model. Table 28 contains the number and proportion of each grade group that were exceptions to the five patterns.

Eighty-eight percent of the 400 subjects performed according to the five predicted patterns. Of the 50 subjects who did not conform to the predicted patterns, 58 percent were kindergarten subjects. At least 90 percent of the third, sixth and ninth grade groups conformed to the predicted patterns.

Hypothesis 3

Table 29 contains two sets of data. First, the number and proportion of subjects who passed the classificatory level but not the formal level and who also passed each of the three concept uses. Second, the number and proportion of subjects who passed the classificatory level but failed the formal level as well as having passed each of the three concept uses is given. A significant chi-square statistic was obtained when the performance of these two groups were compared on each of the three uses

Table 27

Number and Proportion of Each Grade Group that
Conformed to the Five Allowable Patterns of Concept Attainment*

Attainment Pattern	Subjects Conforming				
	Kindergarten	Third	Sixth	Ninth	All Grades
FFFF	14 .14	1 .01	0 .00	0 .00	15 .04
PFFF	11 .11	1 .01	0 .00	0 .00	12 .03
PPFF	20 .20	18 .18	9 .09	1 .01	48 .12
PPPF	26 .26	58 .58	45 .45	26 .26	155 .39
PPPP	0 .00	12 .12	41 .41	67 .67	120 .30
Total Conforming	71 .71	90 .90	95 .95	94 .94	350 .88

Table 28

Number and Proportion of Each Grade Group that were Exceptions to the Five Allowable Patterns of Concept Attainment

Attainment Pattern	Subjects Not Conforming				
	Kindergarten	Third	Sixth	Ninth	All Grades
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	7 .07	0 .00	0 .00	0 .00	7 .02
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	2 .02	0 .00	0 .00	0 .00	2 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	6 .06	2 .02	0 .00	0 .00	8 .02
FPPP	0 .00	1 .01	0 .00	0 .00	1 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	14 .14	4 .04	0 .00	0 .00	18 .04
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	3 .03	5 .05	6 .06	14 .04
Total Not Conforming	29 .29	10 .10	5 .05	6 .06	50 .12

Table 29

The Relationship of Attaining Full Mastery of the Classificatory and Formal Levels to Mastery of the Three Concept Uses

Grade	Classificatory But Not Formal			Formal		
	Supraordinate-Subordinate	Principle	Problem Solving	Supraordinate-Subordinate	Principle	Problem Solving
Kindergarten						
N Passing Level	53			0		
N Passing Use	1	0	0	0	0	0
Proportion	.02	.0	.00	.00	.00	.00
Third						
N Passing Level	64			16		
N Passing Use	33	0	14	6	1	7
Proportion	.52	.00	.22	.37	.06	.44
Sixth						
N Passing Level	45			46		
N Passing Use	22	6	17	29	8	35
Proportion	.49	.13	.38	.63	.17	.76
Ninth						
N Passing Level	26			73		
N Passing Use	21	3	15	60	19	58
Proportion	.80	.11	.58	.82	.26	.79
All Grades						
N Passing Level	188			135		
N Passing Use	77	9	46	95	28	100
Proportion	.41	.05	.22	.70	.21	.74

subtests (Supraordinate-Subordinate, $\chi^2_1 = 51.45$; Principle, $\chi^2_1 = 14.93$; and Problem Solving, $\chi^2_1 = 77.26$; $p < .05$).

The relationship between classificatory and formal level mastery and performance on the concept uses was greatest for the Problem Solving subtest ($\phi = .49$) and smallest for the Principles subtest ($\phi = .21$). The strength of the relationship proved to be an intermediate one for the Supraordinate-Subordinate subtest ($\phi = .40$).

Hypothesis 4

The prediction that knowing the label for the concept, the labels for its attributes, and the concept definition (Vocabulary) will be related to the mastery of the three concept uses was also confirmed. As Table 30 indicates, while 70 percent who passed the Vocabulary passed the Supraordinate-Subordinate subtest, only twenty-seven percent who failed Vocabulary passed the Supraordinate-Subordinate subtest. This difference was found to be significant ($\chi^2_1 = 72.06$; $p < 05$). The relationship of passing Vocabulary to passing the Supraordinate-Subordinate subtest proved to be a moderate one ($\phi = .42$).

Of those who passed Vocabulary, nineteen percent also passed the Principles subtest; whereas, of those who failed Vocabulary only 3 percent passed the Principles subtest. This difference proved to be significant ($\chi^2_1 = 72.06$; $p < .05$). The strength of association between passing Vocabulary and passing the Principles subtest was found to be weaker ($\phi = .31$) than it was for the Supraordinate-Subordinate subtest.

A significant difference was also obtained when the proportion of subjects who passed Vocabulary and who also passed the Problem Solving subtest was compared with the proportion of subjects who failed Vocabulary

Table 30

The Relationship of Vocabulary Performance to Mastery of the Three Concept Uses Subtests

Grade	No Vocabulary Mastery			Vocabulary Mastery		
	Supraordinate–Subordinate	Principle	Problem Solving	Supraordinate–Subordinate	Principle	Problem Solving
Kindergarten						
N Passing Level	100			0		
N Passing Use	2	0	0	0	0	0
Proportion	.02	.00	.00	.00	.00	.00
Third						
N Passing Level	73			27		
N Passing Use	32	0	13	12	1	13
Proportion	.43	.00	.17	.44	.03	.48
Sixth						
N Passing Level	36			64		
N Passing Use	15	3	11	43	11	46
Proportion	.41	.08	.30	.67	.17	.71
Ninth						
N Passing Level	14			86		
N Passing Use	12	0	9	69	22	65
Proportion	.85	.00	.64	.80	.25	.75
All Grades						
N Passing Level	233			177		
N Passing Use	61	3	33	124	34	124
Proportion	.27	.01	.14	.70	.19	.70

and who passed the Problem-Solving subtest ($\chi^2_1 = 126.37$; $p < .05$). The relationship between passing Vocabulary and passing the Problem Solving subtest proved to a fairly strong one ($\phi = .56$).

<u>Hypothesis 5</u>

Table 31 presents the performance of each grade group on each of the three concept uses subtests. The prediction that performance on each concept use would increase as a function of grade was confirmed (Supraordinate-Subordinate, $\chi^2_3 = 131.82$; Principles, $\chi^2_3 = 40.35$; and Problem-Solving, $\chi^2_3 = 134.68$; $p < .05$).

An examination of all pair-wise comparisons revealed an ordering of the grade groups in the predicted direction. The ordering of the grade groups on the Supraordinate-Subordinate subtest was as follows: kindergarten < third < sixth < ninth ($p < .05$). The ordering of the grades groups on the Principles subtest was: kindergarten = third < sixth = ninth ($p < .05$). On the Problem-Solving subtest, each grade group performed in relation to one another as follows: kindergarten < third < sixth = ninth ($p < .05$).

<u>Question 6</u>

Table 32 presents the performance of males and females on each of the four attainment and three concept uses subtests. No significant differences were obtained when the performances of males and females on the Concrete and Identity subtests were compared. On the Classificatory subtest males significantly outperformed females at the third and ninth grades ($\chi^2_1 = 4.57$ and $\chi^2_1 = 3.84$; $p < .05$). Ninth grade males also performed better than ninth grade females on the Formal subtest ($\chi^2 = 4.11$; $p < .05$).

Table 31

Performance of Each Grade Group
on Each of the Three Concept Uses Subtests

Grade	Score	Concept Use: Supraordinate-Subordinate	Concept Use: Principle	Concept Use: Problem Solving
		Percent Passing Mastery Levels		
Kindergarten	no mastery	.62	.74	.91
	initial mastery	.36	.26	.09
	full mastery	.02	.00	.00
Third	no mastery	.05	.52	.15
	initial mastery	.51	.47	.59
	full mastery	.44	.01	.26
Sixth	no mastery	.04	.18	.12
	initial mastery	.39	.68	.32
	full mastery	.57	.14	.56
Ninth	no mastery	.00	.09	.03
	initial mastery	.19	.69	.23
	full mastery	.81	.22	.74

Table 32

Performance of Males and Females on Each of the Four Attainment and Three Concept Uses Subtests*

Grade			Attainment Level: Concrete	Attainment Level: Identity	Attainment Level: Classificatory	Attainment Level: Formal	Concept Use: Supraordinate-Subordinate	Concept Use: Principles	Concept Use: Problem Solving
			Percent Passing Mastery Levels						
Kindergarten	M	no mastery	.02	.02	.12	.90	.58	.74	.94
		initial mastery	.28	.44	.28	.10	.40	.26	.06
		full mastery	.70	.54	.60	.00	.02	.00	.00
	F	no mastery	.00	.00	.12	.94	.66	.74	.88
		initial mastery	.28	.28	.42	.06	.32	.26	.12
		full mastery	.72	.72	.46	.00	.02	.00	.00
Third	M	no mastery	.C0	.00	.04	.56	.00	.40	.12
		initial mastery	.02	.04	.10	.24	.42	.58	.50
		full mastery	.98	.96	.86	.20	.58	.02	.38
	F	no mastery	.00	.00	.04	.62	.10	.64	.18
		initial mastery	.06	.08	.28	.26	.60	.36	.68
		full mastery	.94	.92	.68	.12	.30	.00	.14
Sixth	M	no mastery	.00	.00	.00	.20	.28	.24	.12
		initial mastery	.00	.00	.12	.34	.18	.58	.32
		full mastery	1.00	1.00	.88	.46	.54	.18	.56
	F	no mastery	.00	.00	.00	.32	.00	.10	.12
		initial mastery	.00	.00	.16	.22	.40	.78	.32
		full mastery	1.00	1.00	.84	.46	.60	.12	.56
Ninth	M	no mastery	.00	.00	.00	.06	.00	.10	.02
		initial mastery	.00	.00	.02	.12	.12	.64	.22
		full mastery	1.00	1.00	.98	.82	.88	.26	.76
	F	no mastery	.00	.00	.00	.14	.00	.08	.04
		initial mastery	.00	.00	.12	.22	.26	.74	.24
		full mastery	1.00	1.00	.38	.64	.74	.18	.72

*Fifty males and 50 females were assessed at each grade level

On the Supraordinate-Subordinate and Problem-Solving subtests, third grade males performed significantly better than third grade females (χ^2_1 = 7.95 and χ^2_1 = 7.46; $p < .05$). No other differences were found. In addition, no significant sex differences were obtained on the Principles subtest.

Question 7

Table 33 shows the proportion of kindergarten and third grade subjects who attained full mastery of the smooth-bladed and tooth-bladed items. The criterion for full mastery for both kinds of items was set at correctly responding to seven of eight. McNemar's Test indicated that there was a significantly higher probability of achieving mastery of the smooth-bladed items than attaining mastery of the tooth-bladed items (χ^2_1 = 8.40; $p < .05$). Table 27 indicates that ten percent more of the 200 kindergarten and third grade subjects who were administered the Concrete and Identity subtests attained mastery of the smooth-bladed items than they did for tooth-bladed items.

Table 33

Proportion of Kindergarten and Third Grade Subjects Attaining Full Mastery of Smooth-Bladed and Tooth-Bladed Items

		Smooth-Bladed		
		mastery	no mastery	total
Tooth-Bladed	mastery	.66	.06	.72
	no mastery	.16	.12	.28
	total	.82	.18	1.00

Chapter VI

DISCUSSION

The present study tested the validity of predictions specified by the CLD model concerning the normative pattern of conceptual development of school-age children. Knowledge of the concept of cutting tool was used as the performance variable in validating the predictions.

The CLD model implies that since each successively higher level of attainment involves the use of a new and more complex operation not required at the next lower level, the proportion of subjects passing successive levels will increase as a function of the grade group of the subjects. This hypothesis received strong support. The grade in which the students were enrolled was an important variable in determining performance of the subjects at each attainment level. Significant differences were found between the grade groups. It appears that the greatest increases in the mastery of the concrete, identity and classificatory levels occurred between the kindergarten and sixth grades. The differences in the percentage of kindergarten subjects who attained full mastery at the concrete (.71) and identity levels (.54) is of interest. Apparently the operation of generalizing that two or more forms of the same thing are equivalent emerges developmentally much later than do the operations of attention, discrimination and memory. Furthermore, the fact that only one hundredth of a percent point separates the percentage of kindergarten subjects who attained full mastery at identity and classificatory levels may suggest that the two kinds of generalizing operations that distinguish these two levels are qualitatively quite similar. This similarity in performance at the identity and classificatory levels which is mirrored to a lesser degree at the other grades may also be a function of task or measurement variables which somehow make the identity level artificially more difficult than the classificatory level. More will be said of this type of problem in a subsequent section.

The extreme linear nature of the data at the classificatory and formal levels seems to suggest that significant amounts of higher level learning occurs throughout the first nine grades. Data from another study that is quite similar to the present one revealed that much formal level learning occurs in the later elementary years (Klausmeier, Ingison, Sipple, and Katzemeyer, in press).

There are five possible patterns of concept attainment that are implied by the CLD model: FFFF, PFFF, PPFF, PPPF or PPPP. Eighty-eight percent of all subjects conformed to these patterns while 12 percent of the subjects did not. Almost 70 percent of subjects who conformed to the five allowable patterns fall into either the PPPF or PPPP patterns. It would seem that a concept that is not taught as part of the standard school curriculum and that has many perceptible instances that young children have a high probability of encountering is mastered at the classificatory level at a fairly young age. Further experimentation using concepts that are introduced in the later school years and that have few perceptible instances in the natural environment may indicate that such concepts are acquired at a later age.

There appears to be two primary reasons why 12 percent of the subjects did not conform to the five allowable patterns of concept attainment. One reason appears to have been that the difficulty levels of some items on the four attainment subtests were inappropriately high. That is, it is quite possible through the manipulation of stimulus materials to construct items to assess one of the lower levels of concept mastery that will be more difficult than items designed to measure a high level of attainment. The second factor that apparently influenced the performance of the non-conforming group was the criteria used to determine mastery levels both within and across attainment levels. Although the criteria were established as a result of pilot data and a previous concept development study (Klausmeier, Ingison, Sipple & Katzenmeyer, in press), the determination of each subtest criterion was, in fact, somewhat arbitrary. Most of the 12 percent of subjects who did not conform to the five allowable patterns were about equally distributed across the following four non-allowable attainment patterns: FFPF, PFPF, FPPF, and PPFP.

Table 34 presents the number of items correctly answered at the four attainment levels by subjects who demonstrated a FFPF pattern of concept attainment. Five of the seven subjects missed attaining full mastery at the concrete and identity levels by one item. It will be recalled that two difficult types of items were added to the assessment battery as a result of the second pilot study. One item which appeared both in the Concrete and Identity subtests required subjects to select a previously seen rip saw from among six other very similarly shaped rip saws. All rip saws shared the irrelevant attributes of size and

Table 34

Number of Items Correctly Answered at the Four Attainment Levels by Subjects Who Demonstrated a FFPF Pattern of Concept Attainment

Grade	Concrete	Identity	Classificatory	FORMAL: Discriminating the Attributes	FORMAL: Definition	FORMAL: Vocabulary
K	6	6	5	2	0	4
K	5	5	4	1	0	1
K	6	6	4	3	0	3
K	6	6	5	4	0	2
K	6	6	4	4	0	5
K	4	2	5	1	0	2
K	6	6	5	4	0	5

shading of handle. The other items which also appeared in the first two subtests, required a subject to select a pen knife from among six other pen knives which shared the exact same shape as the example pen knife. The pen knives differed on the basis of size and the shading of the handle. An examination of the individual raw scores of these five subjects revealed that each subject missed at least one of the new items. Three of the subjects missed all four items. It appears, then, that either the four difficult items should not have been included in the battery, or the criteria for concrete and identity level mastery should have been determined at six rather than seven of eight.

Table 35 shows that of the 18 subjects who demonstrated a PFPF non-conforming pattern of concept attainment, 15 failed to achieve full mastery of the identity level by one item. Each one of these subjects missed at least one of the two difficult Identity items that were introduced into the battery after the second pilot. The individual raw scores of these subjects indicated that more of the two parallel Concrete items were answered than the Identity items. Apparently, the additional cognitive operation required at the identity level, made the two most difficult Identity items qualitatively more difficult than the two parallel Concrete items. Thus, an analysis of the Concrete and Identity items reveals that almost all of the subjects who failed the identity level and passed the classificatory level did so possibly because of measurement errors.

Table 36 indicates that five of the eight subjects who failed the Concrete subtest and passed the Identity subtest missed one less Concrete than Identity item. It is quite possible that the observed difference

Table 35

Number of Items Correctly Answered at the Four Attainment Levels by Subjects Who Demonstrated a PFPF Pattern of Concept Attainment

Grade	Concrete	Identity	Classificatory	FORMAL		
				Discriminating the Attributes	Definition	Vocabulary
K	7	6	4	2	0	1
K	7	6	5	3	0	2
K	7	5	5	2	0	0
K	8	4	4	4	0	3
K	8	6	4	1	0	0
K	7	5	5	1	1	5
K	7	6	5	4	1	6
K	7	6	4	4	0	2
K	8	6	4	3	0	1
K	7	6	4	3	0	4
K	8	6	5	5	1	3
K	7	6	5	4	0	5
K	7	6	4	5	0	4
K	8	6	5	2	0	5
3	7	6	5	4	0	7
3	7	6	4	4	0	2
3	8	6	5	4	1	5
3	8	6	5	5	0	1

Table 36

Number of Items Correctly Answered at the Four Attainment Levels by Subjects Who Demonstrated a FPPF Pattern of Concept Attainment

Grade	Concrete	Identity	Classificatory	FORMAL		
				Discriminating the Attributes	Definition	Vocabulary
K	6	7	4	4	0	6
K	6	7	5	4	0	6
K	6	7	5	3	0	3
K	6	7	5	2	0	3
K	4	7	4	0	0	2
K	4	7	5	4	0	3
3	5	7	4	4	0	3
3	6	7	4	4	0	6

is a function of subject inattentiveness. Alternately, as was previously indicated, six of eight items may have been a more reasonable mastery criterion given the nature of the more difficult Concrete and Identity items.

Table 37 shows that fourteen of the non-conforming subjects who failed to achieve full mastery at the classificatory level, did so at the formal level. This finding suggests that it may be possible for some subjects to attain formal level mastery without being able to classify all the more difficult (less familiar) examples and non-examples of the concept. That is, it appears that several of the cutting tool stimuli which were required to be classified as examples or non-examples of the concept were totally unfamiliar to these subjects. The unfamiliar stimuli may have appeared on several of the most difficult classificatory items and in none of the formal level items. The issue raised may be worded in the form of a question. Did those Classificatory items that were failed by subjects who passed the formal level require behaviors that were too difficult and inappropriate for the assessment of classificatory level mastery? A close inspection of the classificatory subtest does indicate that some of the items required subject to be familiar with concept examples that have a low frequency of occurrence in the natural environment. That is, the 14 subjects who manifested a PPFP pattern of concept attainment could generalize that two or more cutting tool instances were quivalent in some way if they had previously encountered these instances. Identification of newly encountered examples of the concept is a test of one of the four primary uses of a concept and is not a test of classificatory mastery. It appears, then, that the

Table 37

Number of Items Correctly Answered at the Four Attainment Levels by Subjects Who Demonstrated a PPFP Pattern of Concept Attainment

Grade	Concrete	Identity	Classificatory	FORMAL: Discriminating the Attributes	FORMAL: Definition	FORMAL: Vocabulary
3	8	8	3	4	1	7
3	8	7	3	5	1	7
3	7	8	3	5	1	7
6	8	8	2	5	1	7
6	8	8	3	5	1	7
6	8	8	3	5	1	7
6	8	8	2	5	1	7
6	8	8	3	5	1	8
9	8	8	3	4	1	7
9	8	8	3	4	1	8
9	8	8	3	4	1	7
9	8	8	2	5	1	8
9	8	8	3	5	1	7
9	8	8	3	5	1	7

difficulty level of some of the more difficult classificatory items was determined both by the cognitive operations the item is inferred to by tapping as well as the measurement procedures and stimulus variables themselves.

A higher proportion of subjects who passed the formal level, in comparison with subjects who passed only the classificatory level, were found to pass each of the three uses. It appears that the relatively weak relationship between concept mastery and performance on the principles use is related to the high level of difficulty of the principle items. No kindergarten or third grade subjects passed the Principles subtest while only 13 and 11 percent of the sixth and ninth grade subjects passed. The strong relationship that was obtained between mastery of the levels and passing the problem-solving use can be further seen at the third, sixth and ninth grades. The difference between those who failed formal and passed classificatory and those who passed formal at these three grades was .22, .38 and .21 respectively. The strength of the relationship between concept level mastery and supraordinate-subordinate performance was found to be a moderate one. It should be noted that while 52 percent of third grade subjects who passed the classificatory level and failed the formal level passed the supraordinate-subordinate use, only 37 percent of those subjects who passed the formal level also passed the supraordinate-subordinate use.

The relationship between having the appropriate language and passing the concept uses was found to be significant on each of the three uses. The only finding that directly contradicted this pattern was found at the ninth grade on the Supraordinate-Subordinate subtest. The rest of the data is overwhelming in its confirmation of the hypothesis implied by the CLD model that those subjects who can name the concept, define it, and know the concept labels will perform better on the three uses than those who do not.

Performance on the three uses was found to increase as a function of grade. The mastery of the Supraordinate-Subordinate and Problem-Solving subtests increased in a linear fashion across the four grade levels. On the Supraordinate-Subordinate subtest, the largest gains in performance occurred between the kindergarten and third and between the sixth and ninth grades. The problem solving ability of children can be seen to increase at an equal rate of development across the four grades. Full mastery of the Principles subtest did not begin until the sixth grade. Kindergarten and third grade subjects failed to demonstrate full mastery of the Principles subtest. No differences in attainment were found between sixth and ninth grade subjects. It should be recognized that the CLD model does not at present specify the cognitive operations or strategies that underlie either problem-solving performance or that contribute to the understanding of principles.

No differences were found between males and females in attainment at the concrete and identity levels. This result is not surprising since the items at these two levels were perceptual ~~rather~~ than conceptual in nature. Even though male children may have a higher likelihood of encountering examples of cutting tools in their daily activities, such experiences apparently do not facilitate mastery of the first two concept levels. Significant between sex differences were, however, found at the classificatory level. The performance of third and ninth grade males differed significantly and the differences at the kindergarten and sixth grade--though not significant--were in favor of the males. Since the Classificatory subtest requires the generalization of instances of cutting tools, previous experience would appear to facilitate the generalizing process.

At the formal level, ninth grade males performed better than ninth grade females. This difference may also be a result of males having a higher probability of literally and conceptually using the concept outside the classroom. It is not unreasonable to assume that given our current cultural role expectations, young boys have a higher probability of encountering and using cutting tools in their natural environment that do young girls.

The fact that males have been more exposed to and involved with cutting tools than have females is reflected in a differential performance between the groups on the supraordinate-subordinate and problem-solving uses. Males and females did, however, perform equivalently on the Principles subtest. Apparently, as has been indicated, the specific principles used in the assessment battery were not taught either inside or outside the classroom.

The reason why more subjects attained mastery of smooth-bladed rather than tooth-bladed items may have been that one of the tooth-bladed Concrete and Identity items was an extremely difficult one. The data indicates that a smooth-bladed item which conceptually was believed at an equivalent difficulty level as the tooth-bladed item just described was, in fact, found to be an easier one. The reason for this observed difference in the difficulty of these two items might be that young children have had more opportunities to visually and tactually encounter smooth-bladed cutting tools such as knives than they have with tooth-bladed cutting tools as saws. Such experiences, then, would enable children to more easily attend to, discriminate, remember and generalize perceptually smooth-bladed cutting tools than tooth-bladed cutting tools. This explanation is consistent with the CLD model which implies that the age at which any particular level is attained is largely dependent upon the learner's experiences with concept instances.

Summary and Conclusions

This study has validated five predictions implied by the CLD model. First, the proportion of subjects who passed each successive attainment level increased as a function of grade group. Second, subjects who passed any one of the four attainemnt levels passed all of the preceding lower levels. Third, subjects who attained a concept at the formal level used the concept more effectively in cognizing supraordinate-subordinate relationships, in understanding principles and in problem solving than subjects who only attained the concept at the classificatory level. Fourth, subjects who knew the label and the defining attributes of <u>cutting tool</u> as well as the definition performed better on the three concept uses. And finally, a higher percentage of each successive grade group passed each of the concept uses.

Two additional questions that were not directed at validating the CLD model were answered. It was found that males performed significantly better than females at the classificatory and formal levels as well as on the supraordinate-subordinate and problem-solving uses. These differences, however, only occurred at some of the grade levels. Test items that used a smooth-bladed cutting tool as a target at the concrete and identity levels were determined to be more difficult than items that used a tooth-edged cutting tool as a target.

Several interesting issues were raised as a result of the data analysis that could lead to the formulation of interesting research questions. The performance of subjects on each of the four attainemnt subtests appeared to be a function of the kind of operation that a particular item was inferred to be measuring as well as the characteristics of the item itself. That is, the difficulty of a test item may have been unintentionally influenced by uncontrolled variations in the nonverbal stimuli used, the vocabulary in which the items were expressed, and the instructions given. The criteria for mastery at the various levels may also have been at fault. In addition the multiple-choice format that was used in each of the seven subtests may have been a source of difficulty and confusion for the younger subjects who have limited repetoires of test-taking behaviors. Such a format may also not have elicited the full underlying competences and knowledge of some of the subjects.

The verbal nature of the assessment battery and especially of the instructions may have unequally affected the performance of subjects across age groups and within the age groups. Braine (1959) has written:

> No theory which postulates levels of conceptual development can be regarded as definitely established when the supporting data are obtained through extensive verbal communication with Ss who differ in their ability to verbalize (p. 184).

While Braine's position is an admittedly extreme one, it does point to the need for scraping away data variance that is a product of one's measurement techniques. As was mentioned in Chapter II, the CLD model has been validated using an individually administered test assessment battery (Klausmeier, Ingison, Sipple & Katzenmeyer, in press). The format of the battery was a non-multiple choice one with less emphasis being placed on verbal comprehension skills.

Two limitations of the present study that relate to the construction of the assessment battery itself and to the type of causal inferences that can be drawn from the study need be mentioned. First, no probability analysis was conducted on the familiarity levels of the examples and non-examples of cutting tools included in the battery. Such an analysis would have permitted the selection of examples and non-examples of the concept of known levels of familiarity. This information would have facilitated a more systematic manipulation of the non-verbal stimuli. Second, the nature of cross-sectional research does not permit one to infer the developmental pattern of the cognitive operations that emerge across time within a given individual. Answers to such questions can only be provided from the longitudinal study of the conceptual development of individuals.

An important question that remains to be considered is whether children would respond to real examples and non-examples of <u>cutting tool</u> as they did to drawings of cutting tools. It is quite possible that children would pass both the items and attainment levels earlier but in the same sequence.

It is clear that the CLD model is a powerful heuristic and practical instrument in the study of both the internal and external conditions of concept learning, in the conducting of behavioral analyses of concepts that are taught in the classroom, as well as in the examination of the conceptual development of large groups of school-age children.

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APPENDIX A

CUTTING TOOL ASSESSMENT BATTERY

(The Cutting Tool Assessment Battery has been subsequently revised and is being used as part of an ongoing longitudinal study)

Name ______________________________ Birthdate ______________
Last First Middle Month Day Year

School ______________________ Grade ______ Today's Date __________

Sex F M Adm. No. __________

Concept Development IIA

Bernard, Michael E., Klausmeier, H.J., and Katzenmeyer, C. G.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

1

A.

Stop

2

A.

Stop

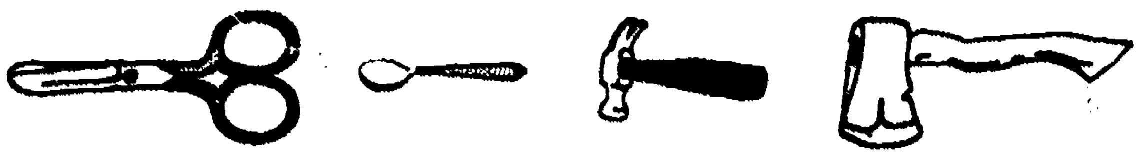
3

B.

Stop

4

B.



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2.a

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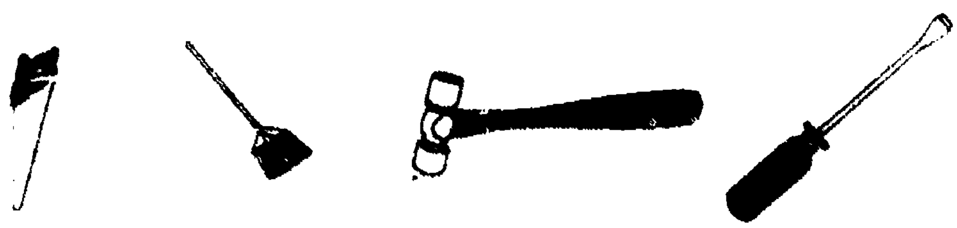
8

2.b



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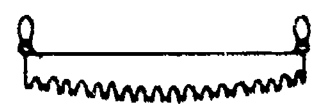

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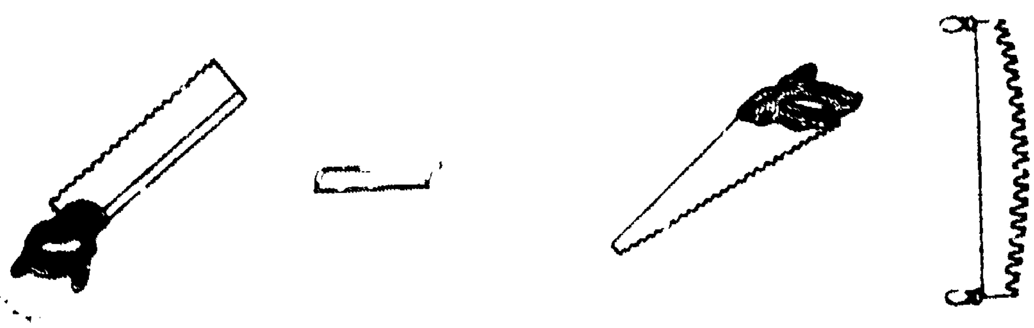

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4.a

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4.b

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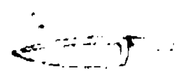
13

5.a



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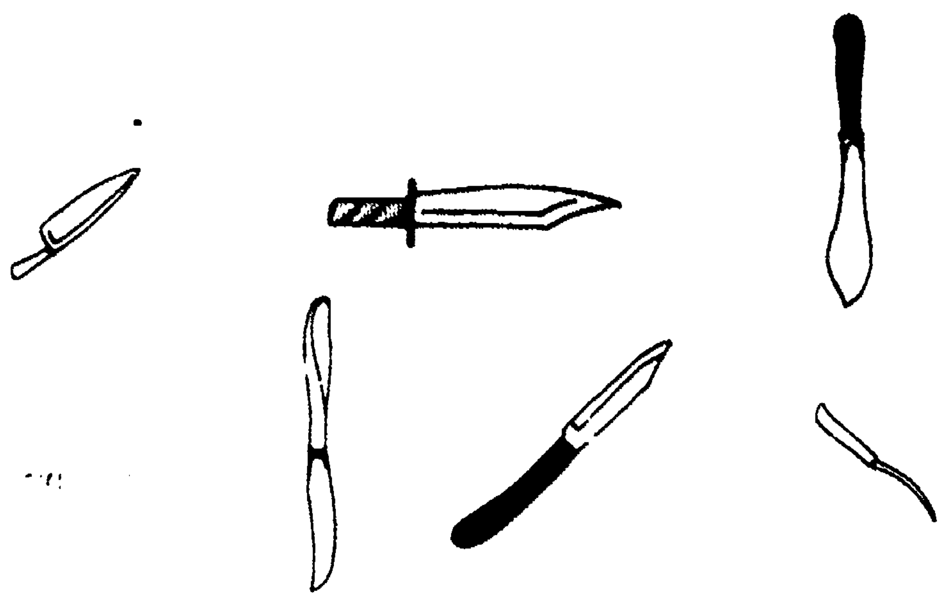

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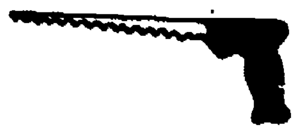

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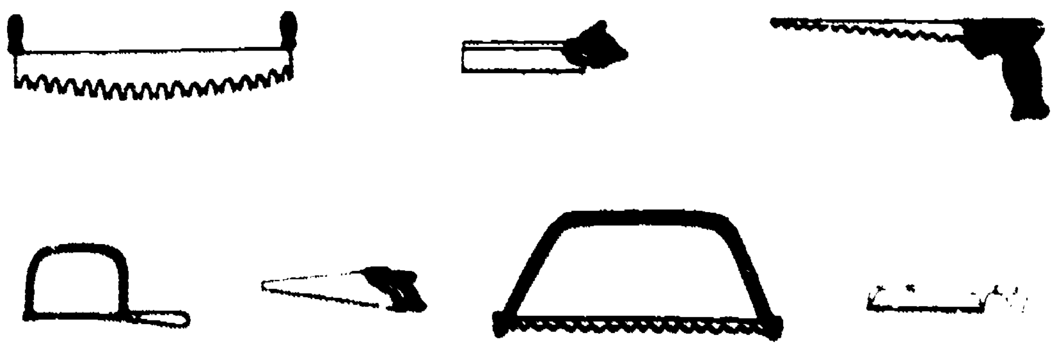

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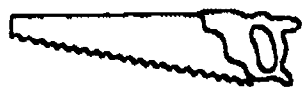

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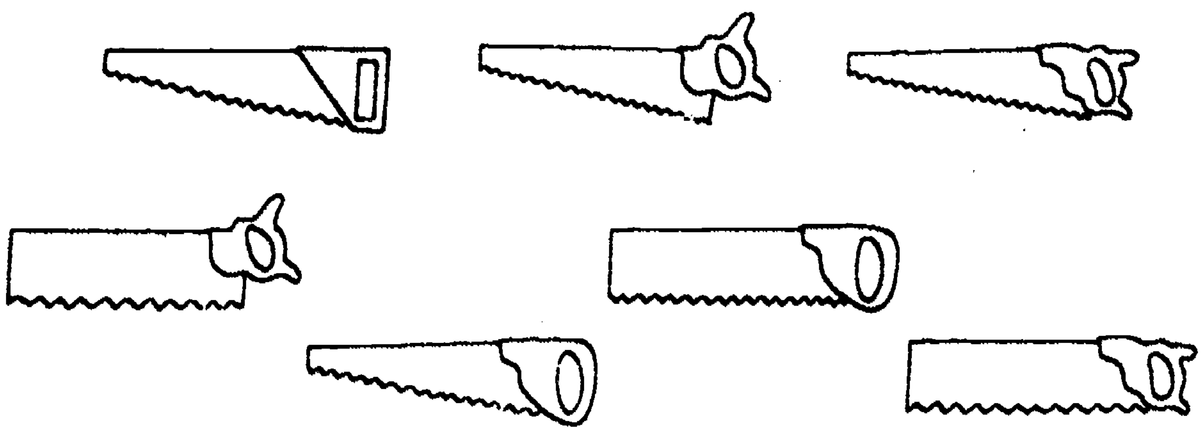

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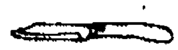

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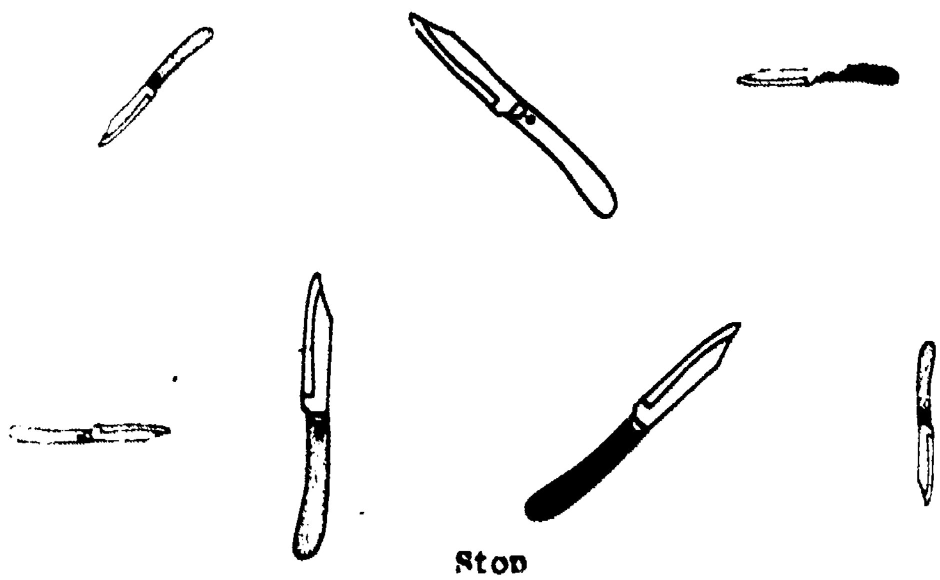

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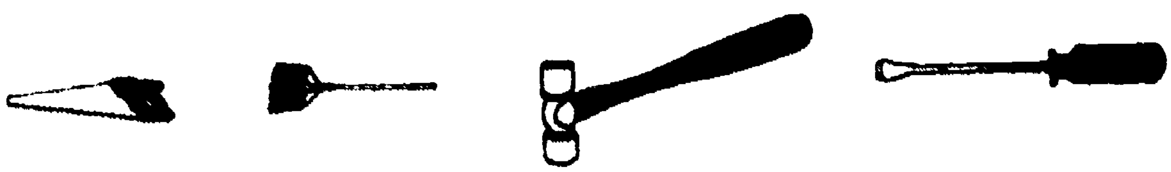
9.b



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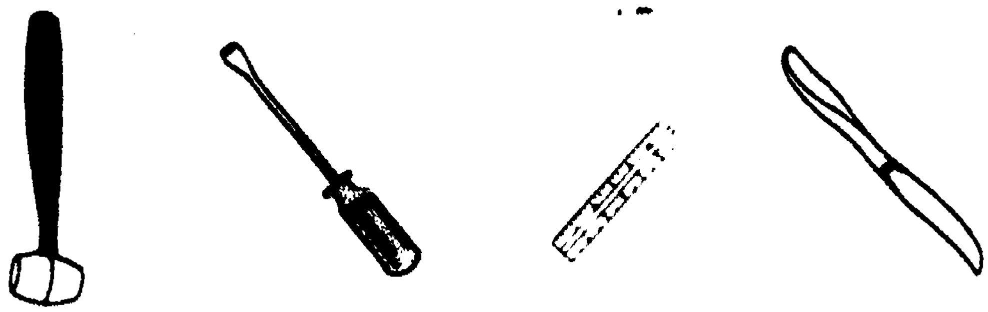
10.b



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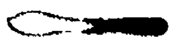

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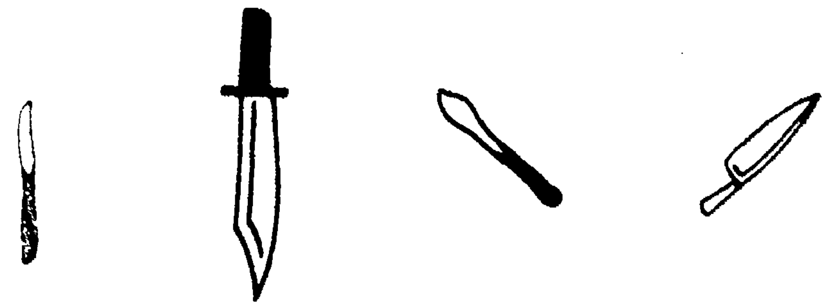

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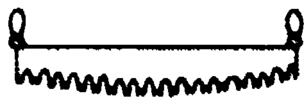

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12.b

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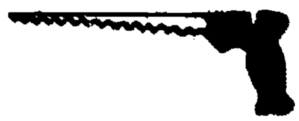
13.a



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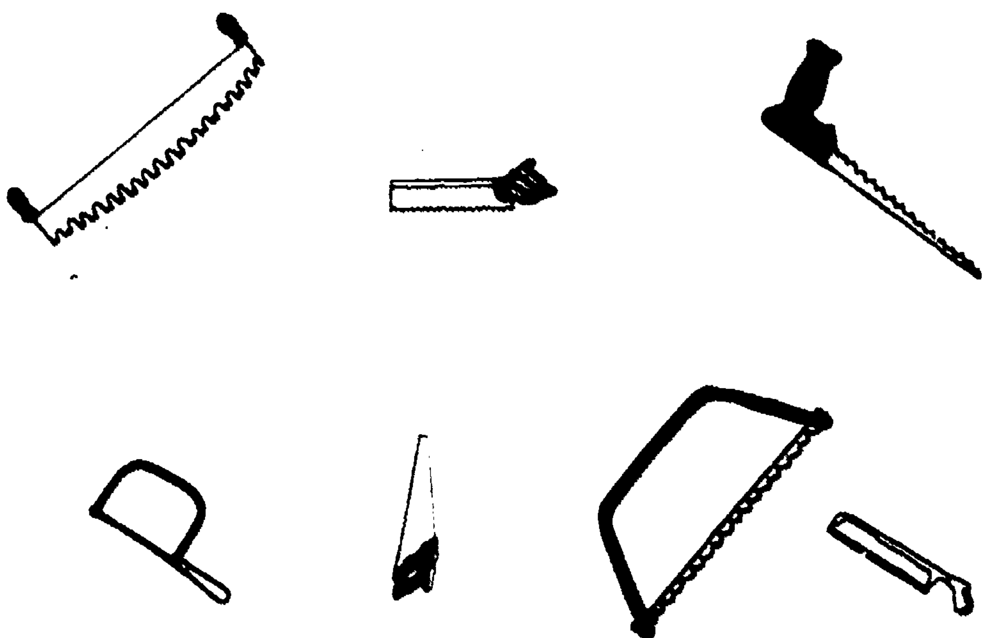

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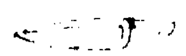

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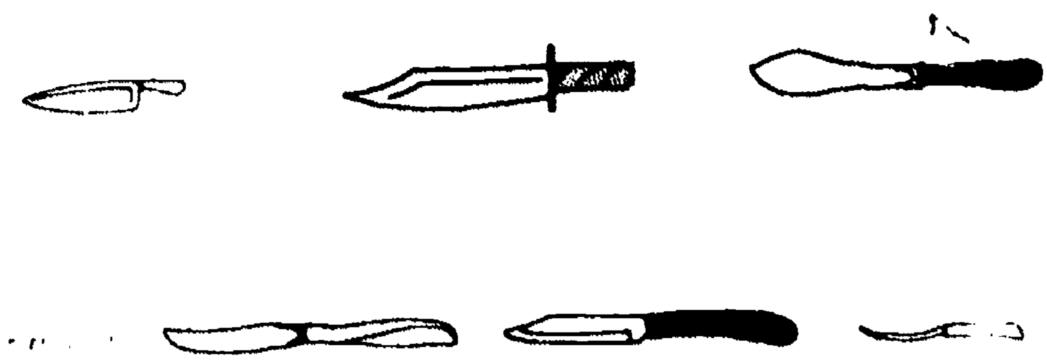

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15.a

Stop

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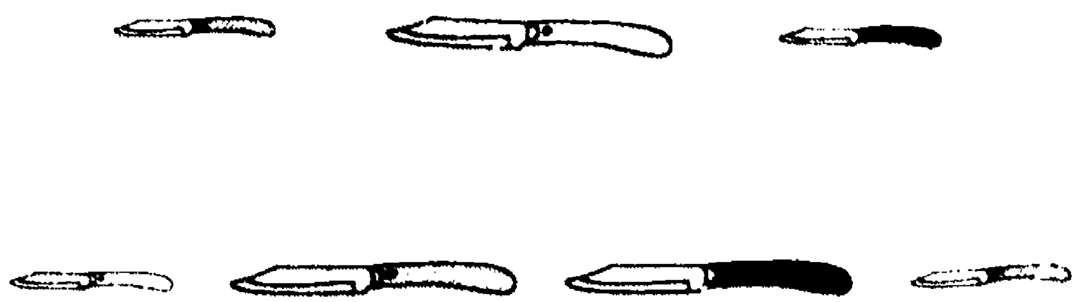
15.b



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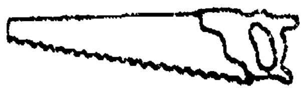

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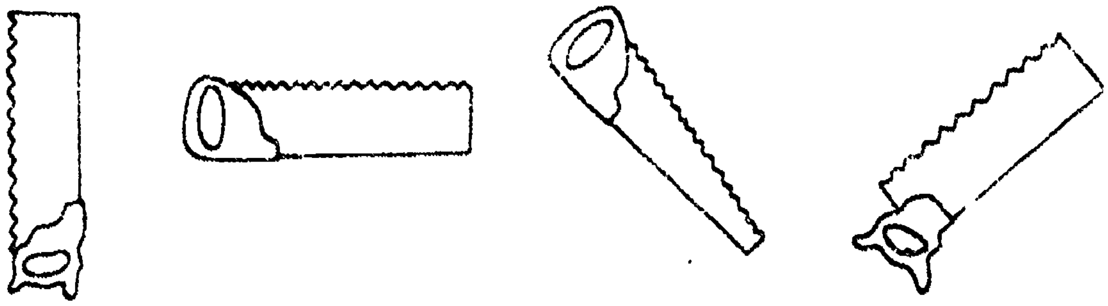

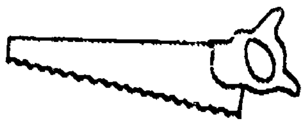

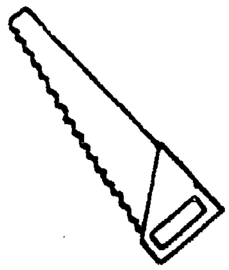

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NAME______________________________

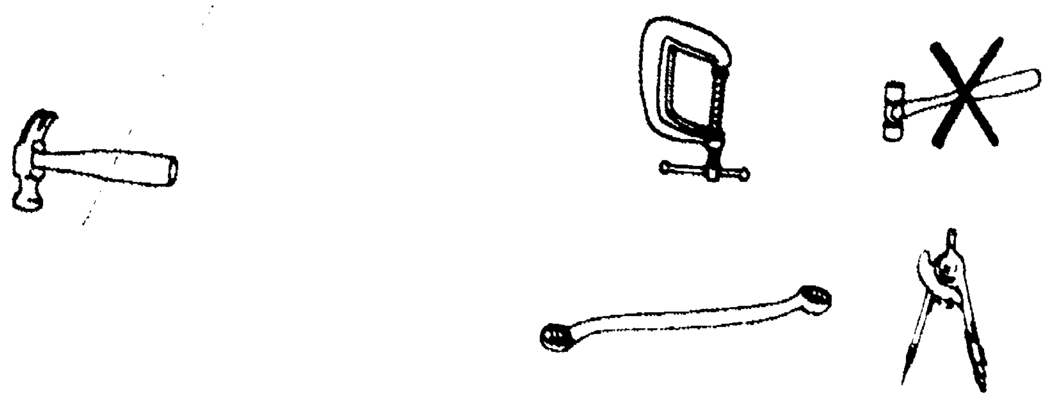
Concept Development IIB

Bernard, Michael E., Klausmeier, H. J., and Katzenmeyer, C. G.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

1

A. The thing on the left is used to do certain kinds of work. Put an X on the thing on the right that is used to do the same kind of work as the thing on the left.



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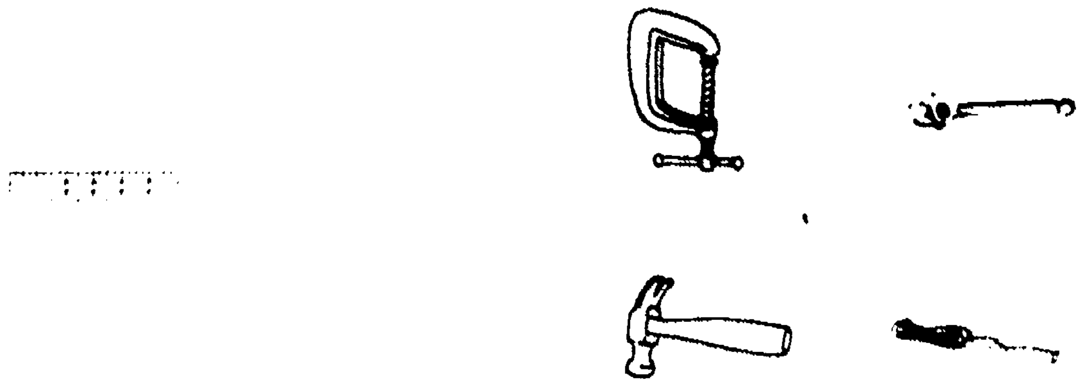
B. The thing on the left is used to do certain kinds of work. Put an X on the thing on the right that is used to do the same kind of work as the thing on the left.

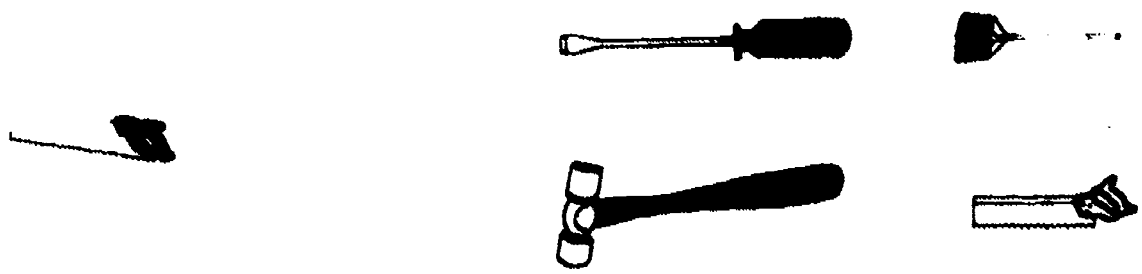


3

1. The thing on the left is used to do certain kinds of work. Put an X on the thing on the right that is used to do the same kind of work as the thing on the left.

4

2. The thing on the left is used to do certain kinds of work. Put an X on the thing on the right that is used to do the same kind of work as the thing on the left.



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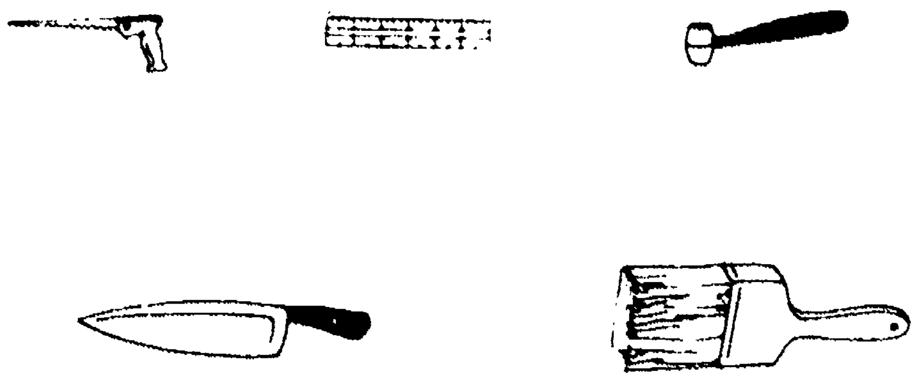
3 Put an X on the things below that are used to do the same kind of work.



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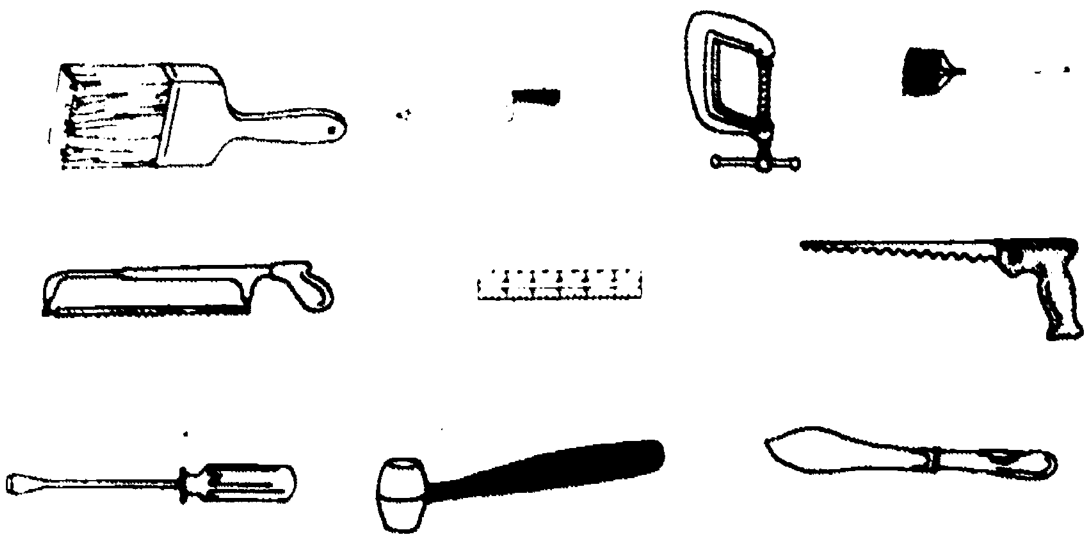
4. Put an X on the things below that are used to do the same kind of work.



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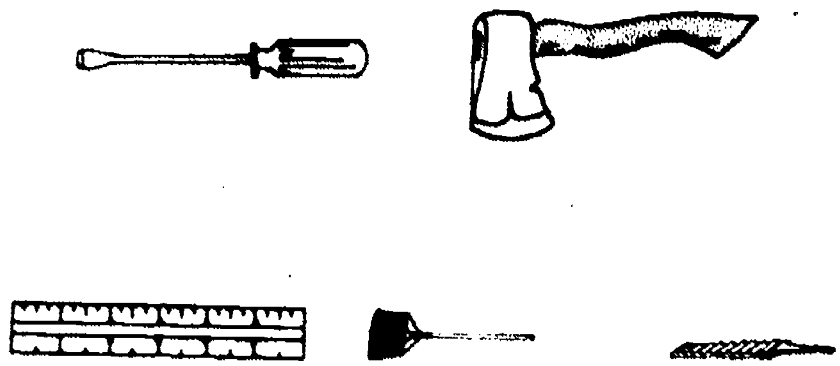
5. Put an X on the things below that are used to do the same kind of work.



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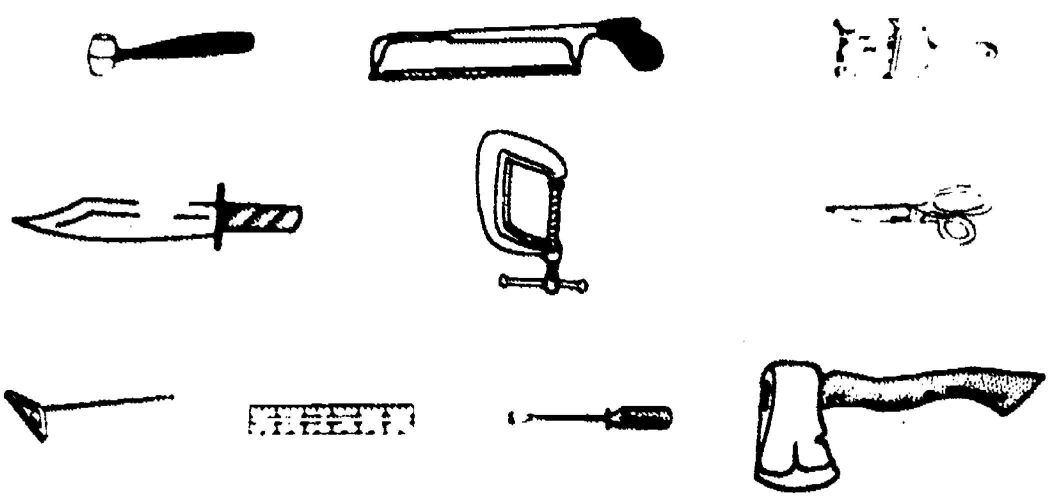
6. Put an X on the things below that are used to do the same kind of work.



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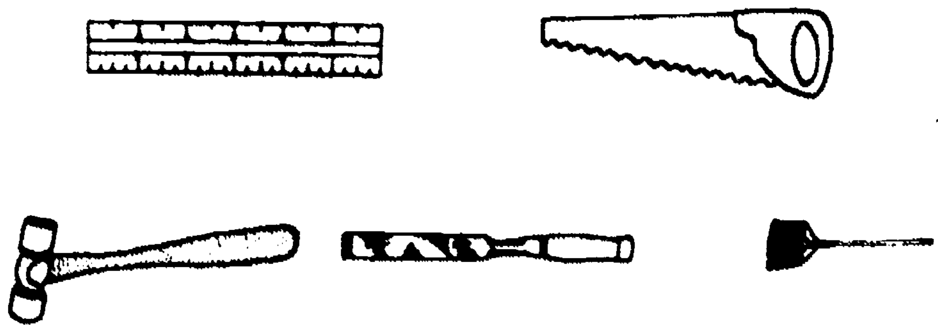
7. Put an X on the things below that are used to do the same kind of work.



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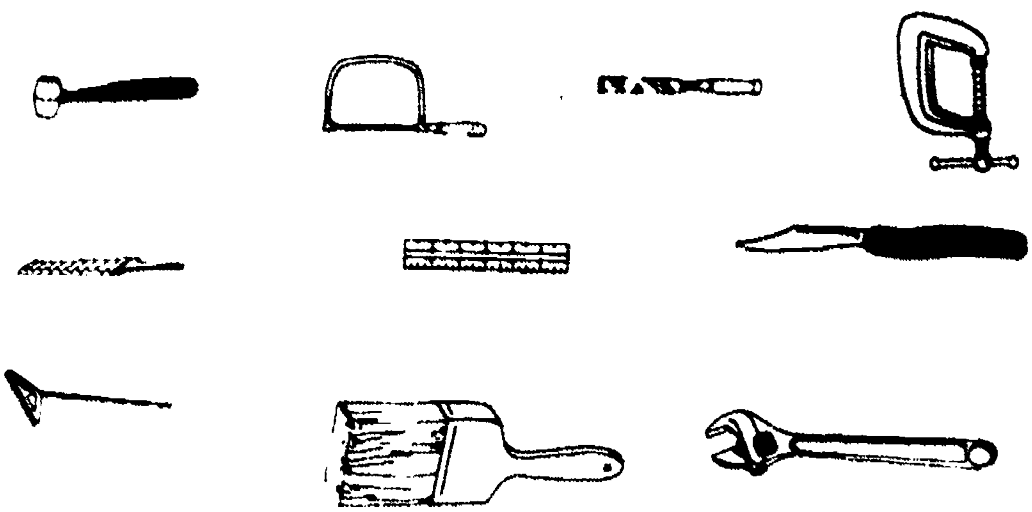
8. Put an X on the things below that are used to do the same kind of work.



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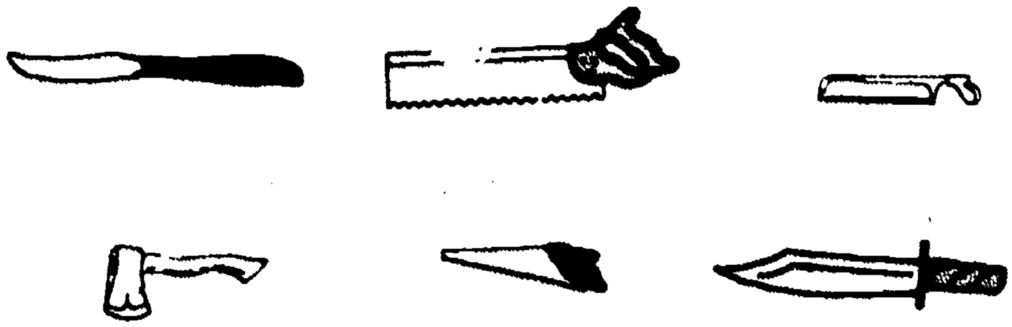


9. Look at the things above. Do they all have a blade that is smooth?

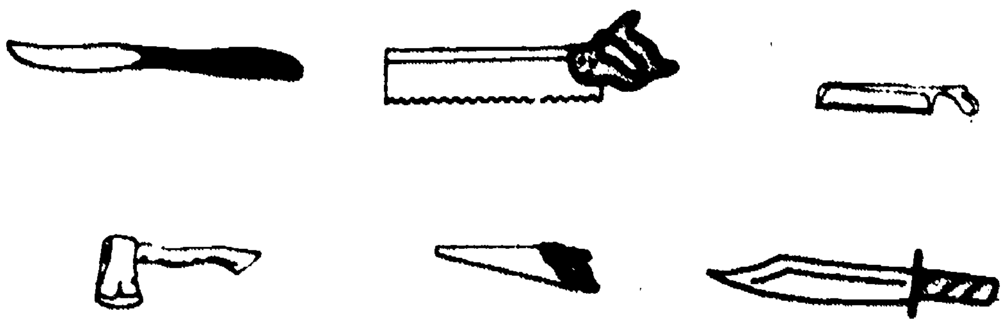
   a. Yes, all of them have a blade that is smooth.

   b. No, only some of them have a blade that is smooth.

   c. No, none of them have a blade that is smooth.

   d. I don't know.

12



10. Look at the things above that have a blade that is smooth. Are they all cutting tools?

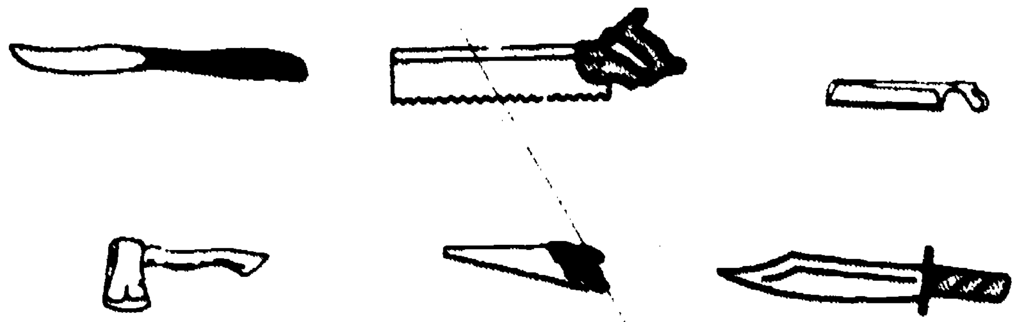
   a. Yes, all of them are cutting tools.

   b. No, only some of them are cutting tools.

   c. No, none of them are cutting tools.

   d. I don't know.

13



11. Look at the things above. Do they all have a blade that has teeth?

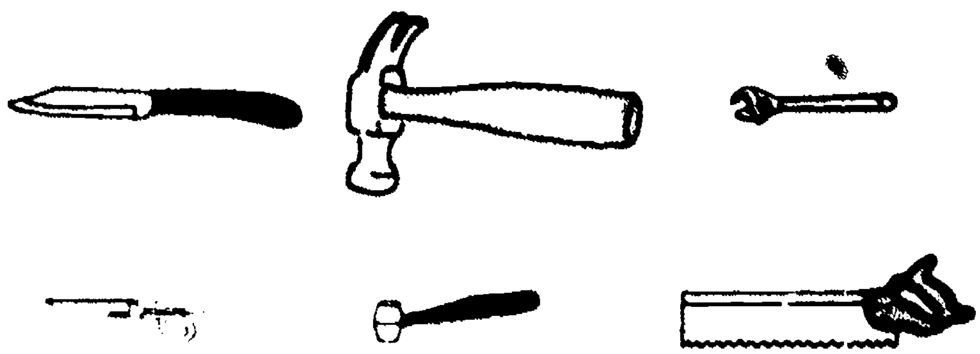
   a. Yes, all of them have a blade that has teeth.

   b. No, none of them have a blade that has teeth.

   c. No, only some of them have a blade that has teeth.

   d. I don't know.

14



12. Look at the things above. Are they all things that cut?

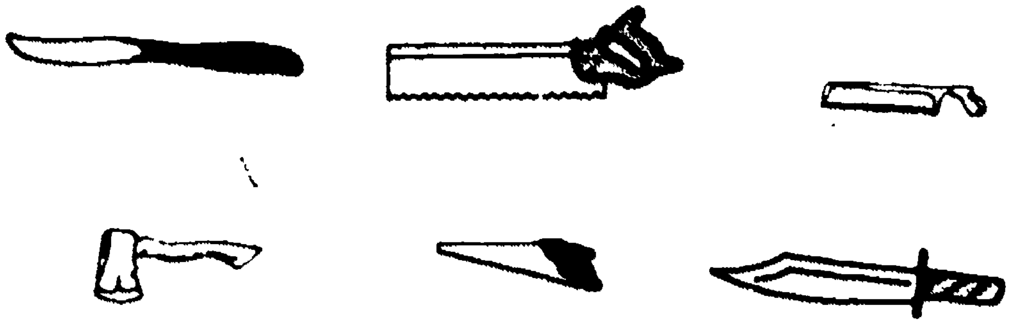
   a. No, only some of them cut.

   b. Yes, all of them cut.

   c. No, none of them cut.

   d. I don't know.

15



13. Look at the large things above. Do they all have a blade that is smooth?

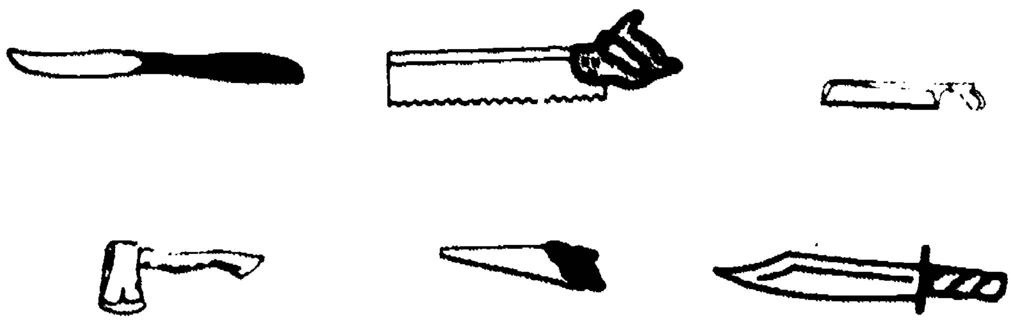
    a. Yes, all of them have a blade that is smooth.

    b. No, only some of them have a blade that is smooth.

    c. No, none of them have a blade that is smooth.

    d. I don't know.

16



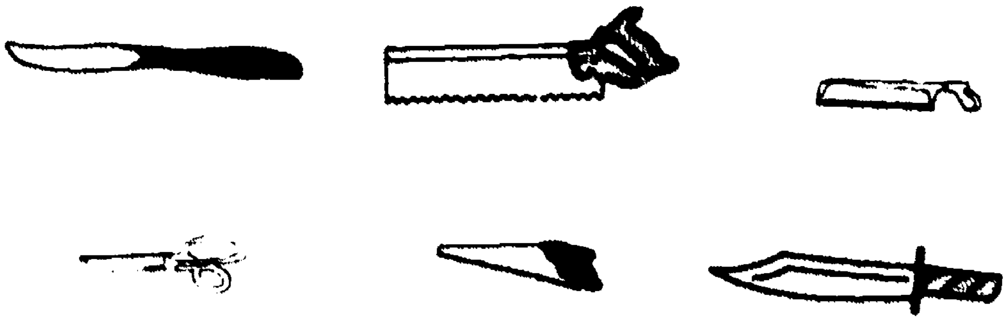
14. Look at all the things above that have a blade that is smooth and all the things that have a blade that has teeth. If you put them all in a group, there would be ____________ there are cutting tools.

    a. fewer of them than

    b. more of them than

    c. the same amount of them as

    d. I don't know.



17

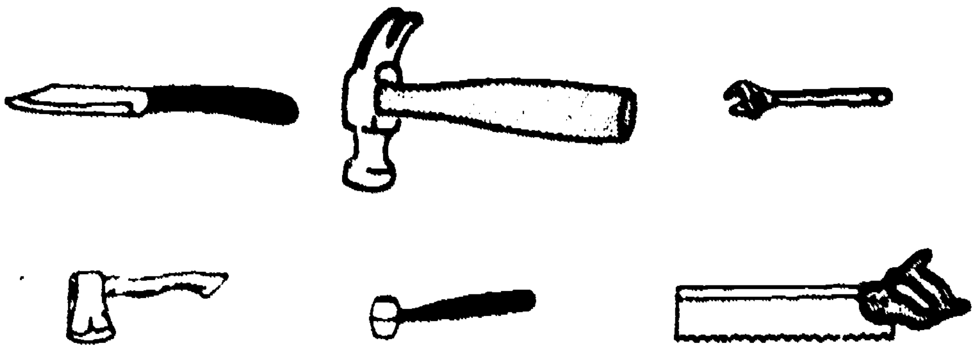
15. Look at the things above that have a blade that has teeth. Are they all cutting tools?

a. Yes, all of them are cutting tools.

b. No, only some of them are cutting tools.

c. No, none of them are cutting tools.

d. I don't know.



18

16. Look at the things above that cut. Are they all tools?

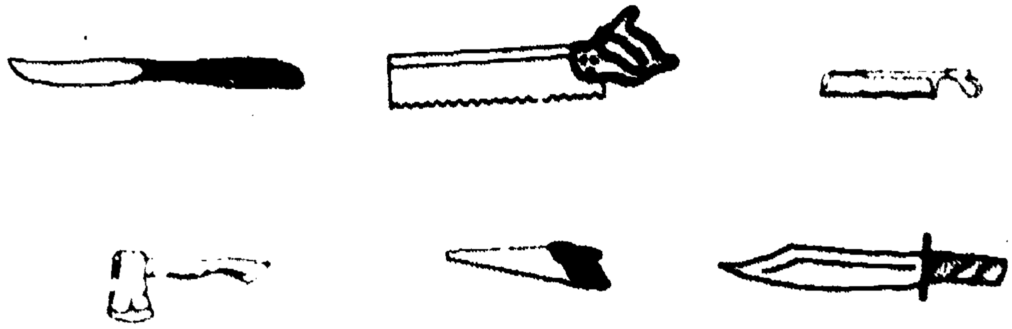
a. Yes, all of them are tools.

b. No, only some of them are tools.

c. No, none of them are tools.

d. I don't know.

19



17. Look at the things above that have a black handle. Do all of them have a blade that has teeth?

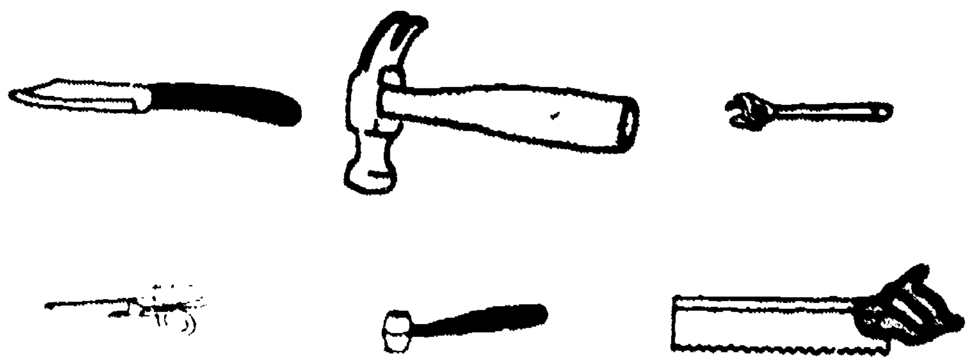
    a. Yes, all of them have a blade that has teeth.

    b. No, only some of them have a blade that has teeth.

    c. No, none of them have a blade that has teeth.

    d. I don't know.

20



18. Look at all of things above that cut and all of the things that do rot cut. If you put them all in a group, there would be ______________ there are tools.

    a. fewer of them than

    b. more of them than

    c. the same amount of them as

    d. I don't know.

Name ______________________________

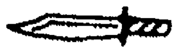
Concept Development IIC

Bernard, Michael E., Klausmeier, H. J., and Katzenmeyer, C. G.

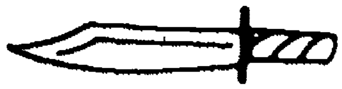
DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

1

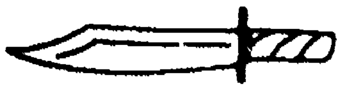
1.



Knife X = 3 inches



Knife Y = 6 inches



Knife Z = 6 inches

Knife X, Knife Y, and Knife Z have sharp blades. Imagine that Knife X is three inches long and can only withstand a small amount of impact. Imagine that Knife Y is six inches long and can withstand a large amount of impact. Imagine that Knife Z is six inches long and can withstand only a small amount of impact.

Which knife should be used to cut through a piece of hard wood if you want to use a knife that will not break?

a. Knife X

b. Knife Y

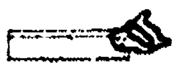
c. Knife Z

d. It is impossible to tell without trying them out.

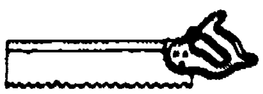
e. I don't know.

2

2.

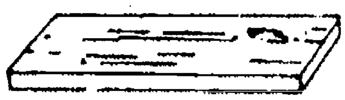


Saw X = 8 inches



Saw Y = 12 inches

Saw Z = 16 inches



Imagine that Saw X has a sharp blade and is eight inches long. Imagine that Saw Y has a sharp blade and is twelve inches long. Imagine that Saw Z has a sharp blade and is sixteen inches long.

Which saw should be used to cut through the large piece of wood most quickly?

a. Saw X

b. Saw Y

c. Saw Z

d. It is impossible to tell without trying them out.

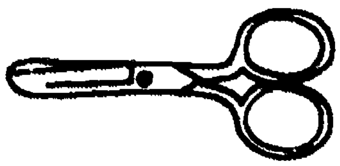
e. I don't know.

3

3.

Scissor X = 4 inches

Scissor Y = 5 inches



Scissor Z = 6 inches

Scissor X, Scissor Y, and Scissor Z have sharp blades. Imagine that Scissor X is four inches long and has a high degree of hardness. Imagine that Scissor Y is five inches long and has a low degree of hardness. Imagine that Scissor Z is six inches long and has a low degree of hardness.

Which scissor should be used if you want a scissor that will stay sharp when cutting many pieces of tough cloth or material?

a. Scissor X

b. Scissor Y

c. Scissor Z

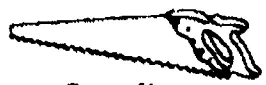
d. It is impossible to tell without trying them out.

e. I don't know.

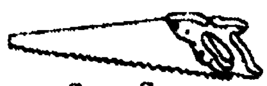
4

4.

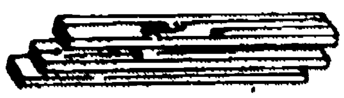
Saw X



Saw Y



Saw Z



Saw X, Saw Y, and Saw Z are exactly alike in size and sharpness. Saw X was tempered at 430 degrees, Saw Y at 520 degrees, and Saw Z at 610 degrees.

Which saw should be used if you want a saw that will not break when cutting through many pieces of hard wood?

a. Saw X

b. Saw Y

c. Saw Z

d. It is impossible to tell without trying them out.

e. I don't know.

5

5.

Knife X = 4 inches

Knife Y = 6 inches

Knife Z = 8 inches

Imagine that Knife X has a dull blade and is four inches long. Imagine that Knife Y has a sharp blade and is six inches long. Imagine that Knife Z has a dull blade and is eight inches long.

Which knife should be used to cut through the piece of meat most quickly?

a. Knife X

b. Knife Y

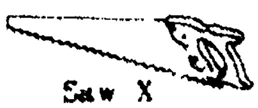
c. Knife Z

d. It is impossible to tell without trying them out.

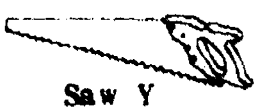
e. I don't know.

6

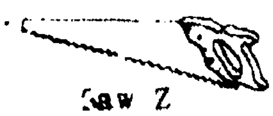
6.



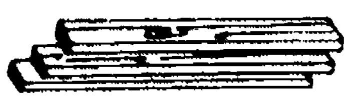
Saw X



Saw Y



Saw Z



Saw X, Saw Y, and Saw Z are exactly alike in size and sharpness. Saw X was tempered at 430 degrees, Saw Y at 520 degrees, and Saw Z at 610 degrees.

Which saw should be used if you want a saw that will remain sharp when cutting through many pieces of hard wood?

a. Saw X

b. Saw Y

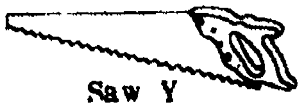
c. Saw Z

d. It is impossible to tell without trying them out.

e. I don't know.

7

7. 
Saw X


Saw Y

Saw X can withstand a larger amount of impact than can Saw Y. When cutting the hard piece of wood, Saw X will break ______ ______ Saw Y.

a. more quickly than

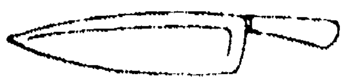
b. as quickly as

c. less quickly than

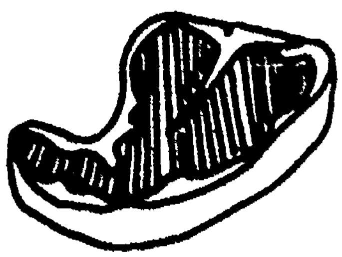
d. It is impossible to tell without trying them out.

e. I don't know.

8

8. 
Knife X

Knife Y



Knife X is larger than Knife Y. Knife X and Knife Y have equally sharp blades. Knife X will cut through a large piece of meat ______ ______Knife Y.

a. more quickly than

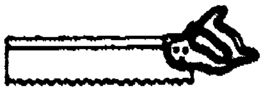
b. less quickly than

c. as quickly as

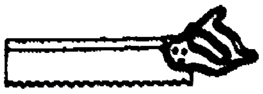
d. It is impossible to tell without trying them out.

e. I don't know.

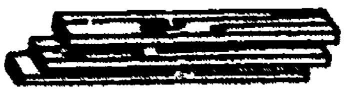
9

9. 

Saw X



Saw Y



Saw X and Saw Y are equally sharp. Saw X was heated to a lower tempering temperature than was Saw Y. When cutting several pieces of hard wood, Saw X will ________________ Saw Y.

a. become duller over a longer period of use than

b. remain as sharp over a long period of use as

c. remain sharper over a longer period of use than

d. It is impossible to tell without trying them out.

e. I don't know.

10

10. 

Knife X

Knife Y

Knife X and Knife Y are equally sharp. Knife X was heated to a higher tempering temperature than was Knife Y. When cutting the hard piece of wood, Knife X is ________________ Knife Y.

a. less likely to break than

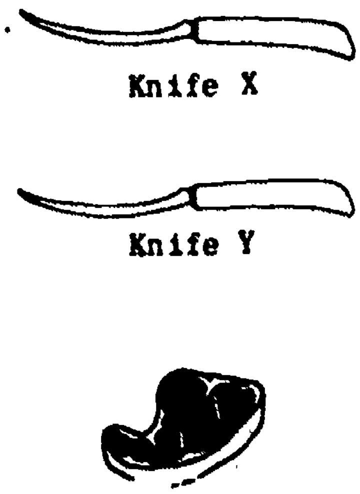
b. equally likely to break as

c. more likely to break than

d. It is impossible to tell without trying them out.

e. I don't know.

11

11\. 

The blade of Knife X is hard and sharp. The blade of Knife Y is hard and dull. Knife X will cut through a piece of meat __________ Knife Y.

a. as quickly as

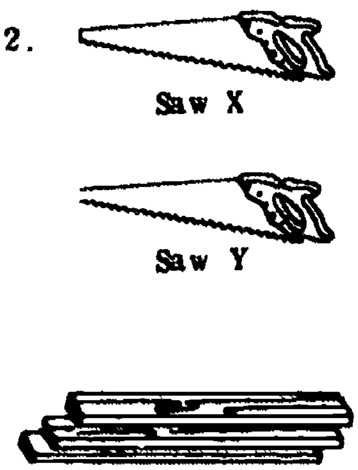
b. more quickly than

c. less quickly than

d. It is impossible to tell without trying them out.

e. I don't know.

12

12\. 

Both Saw X and Saw Y have sharp blades. The blade of Saw X is much harder than is the blade of Saw Y. When cutting through many pieces of hard wood, Saw X will ______________ Saw Y.

a. become duller over a longer period of use than

b. remain as sharp over a long period of use as

c. remain sharper over a longer period of use than

d. It is impossible to tell without trying them out.

e. I don't know.

13

13. A cutting tool blade that can withstand a large amount of impact is ___________ a cutting tool blade that cannot withstand a large amount of impact.

a. as likely to break as

b. less likely to break than

c. more likely to break than

d. It is impossible to tell without trying them out.

e. I don't know.

14

14. A cutting tool blade when heated to a low tempering temperature ___________.

a. remains quite sharp over a long period of use

b. becomes sharper if properly used over a long period of time

c. becomes quite dull over a long period of use

d. It is impossible to tell without trying them out.

e. I don't know.

15

15. A sharp cutting tool blade cuts __________ a dull cutting tool blade.

a. less quickly than

b. more quickly than

c. as quickly as

d. It is impossible to tell without trying them out.

e. I don't know.

16

16. A large kind of cutting tool accomplishes __________ a small cutting tool of the same kind.

a. a lesser amount of cutting than

b. the same amount of cutting as

c. a greater amount of cutting than

d. It is impossible to tell without trying them out.

e. I don't know..

17

17. A cutting tool blade when heated to a high tempering temperature will ______________.

a. be quite likely to break

b. have a sharp blade

c. be likely not to break

d. It is impossible to tell without trying it out.

e. I don't know.

18

18. A sharp cutting tool blade that has a high degree of hardness ______________.

a. becomes quite dull over a long period of use

b. remains sharp over a long period of use

c. becomes sharper if properly used over a long period of time

d. It is impossible to tell without trying it out.

e. I don't know.

Name ______________________________

Concept Development IID

Bernard, Michael E., Klausmeier, H. J., and Katzenmeyer, C. G.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

1

1. Below are four things. Put an X on the one that is different from the other three.

Stop

2

2. Below are four things. Put an X on the one that is different from the other three.

Stop

3

3. Below are four things. Put an X on the one that is different from the other three.

Stop

4

4. Below are four things. Put an X on the one that is different from the other three.

Stop

5. Below are four things. Put an X on the one that is different from the other three.

Stop

6. 

Group 1

Group 2

Which one name <u>best</u> fits all of the things in <u>Group</u> 1 but does not fit all of the things in Group 2?

a. batteries

b. furniture

c. tools

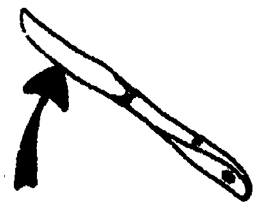
d. motors

e. I don't know

Stop

7

7.



What is the one word that best indicates what the arrow is pointing at?

a. blade

b. stick

c. slice

d. handle

e. I don't know

Stop

8

8.

Group 1

Group 2

Which one name best fits all of the things in Group 1 but does not fit all of the things in Group 2?

a. measuring tools

b. cutting tools

c. tightening tools

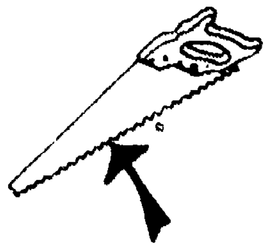
d. work tools

e. I don't know

Stop

9

9.



Which are the words that best indicate what the arrow is pointing at?

a. smooth blade

b. wooden handle

c. toothed blade

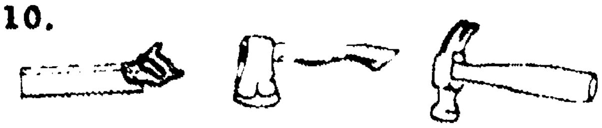
d. square handle

e. I don't know

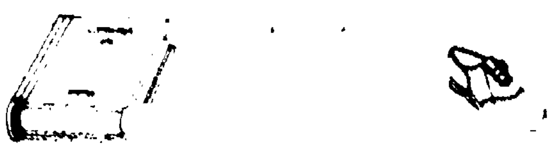
Stop

10

10.



Group 1



Group 2

Which one name best fits all of the things in Group 1 but does not fit all of the things in Group 2?

a. sanding tools

b. electric tools

c. power tools

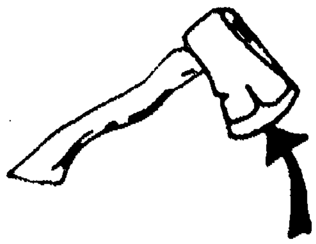
d. hand tools

e. I don't know

Stop

11

11.



Which are the words that best indicate what the arrow is pointing at?

a. plain handle

b. smooth blade

c. toothed blade

d. round handle

e. I don't know

?

Stop

12

12. Which of the following is the definition of "tempering"?

a. a filing process that sharpens a blade

b. a molding process that allows one to shape a blade to perform a particular task

c. a heating process which determines the toughness and hardness of a blade

d. a polishing process that prevents a blade from becoming rusty

e. I don't know

Stop

13

13. Which of the following is the definition of "cutting tool"?

a. any tool that is used to accomplish work

b. any tool that has a sharp edge that is used to shape or penetrate

c. any tool that is used to measure lengths or distances

d. any tool that has a solid metal head and a wooden handle

e. I don't know

Stop

14

14. Which of the following means the same thing as the toughness of a cutting tool's blade?

a. the amount of force the blade can withstand without breaking

b. the ability of the blade to cut with and against the grain of wood

c. the ability of the blade to remain sharp when it is used repeatedly to cut material

d. the size of the blade

e. I don't know

Stop

15. Which of the following means the same thing as the hardness of a cutting tool's blade?

    a. the size of the blade

    b. the amount of force the blade can withstand without breaking

    c. the ability of the blade to cut with and against the grain of wood

    d. the ability of the blade to remain sharp when it is used to cut material

    e. I don't know

Stop

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