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AUTHOR Merrill, M. David
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ABSTRACT

Five assumptions underlie task analysis procedures in instructional development in higher education. These are: 1) content and instructional strategy are independent; 2) most courses involve two types of content--concepts and operations; 3) two levels of abstraction are involved--generalities and instances; 4) four levels of behavior are most common--discriminated recall, classification, rule using, and rule finding; and 5) instructional strategies should focus upon rule using and rule finding, based on mastery models derived from needs and goals. Task analysis consists of content analysis and instructional analysis. Content analysis requires that the analyst: 1) identify and define the concepts in an area; 2) determine and specify the change operations used to relate them; 3) symbolically represent each role; and 4) identify instances for concepts and rules. Instructional analysis should recognize that higher education stresses cognitive transfer behavior and should order content to achieve such behaviors. Four steps are needed: 1) the identification of needs and goals; 2) the specification of a mastery model; 3) the specification of rule using and rule finding situations; and 4) the sequencing of required concepts and operations from the content network. (PB)

IRD

Department of Instructional Research and Development
Division of Instructional Services – Brigham Young University

INSTRUCTIONAL RESEARCH AND DEVELOPMENT

CONTENT AND INSTRUCTIONAL ANALYSIS FOR COGNITIVE TRANSFER TASKS

M. David Merrill

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Division of Instructional Services
Brigham Young University
Provo, Utah

CONTENT AND INSTRUCTIONAL ANALYSIS FOR COGNITIVE TRANSFER TASKS

M. David Merrill
Brigham Young University
September 24, 1972

The task analysis procedures described in this paper are based on the following assumptions: (1) Content and instructional strategy are independent phenomena. (2) Most courses, particularly at the secondary or higher education levels, involve only two types of content - concepts and operations. (3) Concepts and operations can be represented at two levels of abstraction - generalities and instances. (4) Most courses, particularly at the secondary or higher education levels, involve only four levels of behavior - discriminated recall, classification, rule using, and rule finding.[1] (5) Instructional strategies should revolve around rule using or rule finding tasks based on mastery models derived from needs and goals.

It has been found that these assumptions significantly simplify task analysis procedures. The content specialist with the assistance of an instructional psychologist does not spend time writing behavioral objectives but instead performs two separate and somewhat independent tasks - content analysis and instructional analysis.

The Problem With Objectives

A fundamental axiom states that objectives must be stated in terms of student behavior before one can proceed with other phases of instructional development. Many ID projects start and end (usually in frustration) with this critical step. WHY? Because specifying objectives is difficult, time consuming, and frequently unsatisfactory. Our previous ID efforts began by having a content specialist [illegible] his behavioral objectives. We were careful to train him in appropriate techniques, but the result was almost always the same. After weeks of agonizing effort we would receive a long list of memory level objectives. It was usually unnecessary to say "YUK!" The subject matter expert was already unhappy with his objectives and disillusioned with the whole ID process. It was finally concluded that while behavioral objectives may be necessary for instructional development, it is neither necessary nor desirable for the subject matter expert to write them.

Content Analysis

A fundamental assumption underlying the task analysis procedures to be described is that content structure and instructional procedure are completely independent. Content exists and has a structure whether or not it is organized or sequenced for instruction and regardless of how a student is asked to respond or interact with this content. Content analysis is a procedure for identifying this independent content network in a given area.

In the analysis of higher education courses it has been found that most subject matter content consists of a network of concepts related by a set of operations. A concept is any set of symbols, objects, or events which can be referenced by a single name or symbol. Most of the words we use are concept words which refer to classes or categories rather than to specific events, objects or symbols. It is usually necessary to use modifiers to make a word refer to one referent. When a word does refer to a unique symbol, object or event; or when all of the elements of a given set are essentially identical, then the word is an identity, which is the limiting case of a concept where the set, for practical purposes, has only a single member.

The concept building blocks which comprise a given content network are related by means of operations. An operation consists of the ways concepts can be described, compared with related concepts, or combined and changed to produce other concepts. The concept, or set of concepts, to which the operation is applied is called the domain. The concept, or set of concepts, which results from applying the operation is called the range. A given domain, operation, and range is called a rule. (See Scandura, 1970)

Perhaps a limited illustration will clarify these ideas. Consider the content of mental measurement. Some of the concepts involved are standard deviation (SD), raw score (X), mean ($\overline{X}$), and standard scores (Z). In a portion of the measurement content network these concepts are related by an operation for producing standard scores from the raw score, mean, and standard deviation. The relationship is illustrated in Figure 1. The mean ($\overline{X}$), raw score (X), and standard deviation (SD) are the domain, the operation

Insert Figure 1 about here

is the formula for computing standard scores, the domain is a standard score. Together this entire relationship constitutes a rule.

Concepts and operations can be represented at two levels of abstraction. A generality is the statement of the rule using concept labels. An instance is a member of a particular concept class. In the illustration from measurement theory, Figure 1, the rule is stated as a generality. Figure 2 represents a particular instance of this rule.

Insert Figure 2 about here

Content analysis involves the following steps. (1) Identify by label all of the concepts in a given content area. (2) Determine the change operations used to relate each of these concepts and plot a content network. (3) Specify each change operation. (4) Define each concept by identifying descriptive or relational operations. (5) Symbolically represent each rule. (6) Identify one or more instances for each concept and each rule.

Step 1. The content specialist lists one by one all of the concepts that he can identify in the content area. It is not serious if some omissions occur during this first attempt, but the list should be as comprehensive as possible. Holes in the initial list will become apparent during later steps in the content analysis and during instructional analysis. Figure 4a is an incomplete list of concepts from the area of mental measurement.

Step 2. Once all of the concepts have been listed, the next step is to determine the change operations which relate these concepts. It has been found that a limited number of operations will completely describe most content areas (Donio, 1972). These operations can be divided into three broad classes. Change operations are those which combine, decompose, or transform the domain concepts into new or different range concepts. Scientific procedures, formulas, and natural laws are some examples of these change operations. Descriptive operations are those which identify characteristics or component parts of a given concept. Relational operations are those which relate one concept with similar or complementary concepts. Figure 3 presents a set of the most frequently occuring operations divided into the three categories just described. While this list is not exhaustive, the content of most areas can adequately be described with this set of operations. Taking each concept in turn, the content specialist should indicate if it is combined, transformed, or decomposed to produce other concepts in the list.

Insert Figure 3 about here

For each operation listed in Figure 3, a symbolic representation is indicated. These symbols make possible the construction of a content network diagram as the change operations are identified. Figure 4b illustrates an incomplete network for mental measurement content. Note that each symbol represents a concept from the list generated in Step 1 while the diagram indicates how each of the concepts are combined to produce other concepts in the content area.

Insert Figure 4 about here

Step 3. To complete Step 2 it was only necessary to identify what kind of a change operation relates sets of concepts, it was not necessary to completely specify each operation. A check on the content network is provided when each change operation that was identified during Step 3 is completely specified. In the process of this specification, it is likely that other concepts will be identified which were not included in the original list. These should be added to the list and included on the network diagram. A list of operation generalities should be completed and appended to the network diagram and the concept list. Figure 4 contains the operation generalities for the network illustrated in Figure 4b.

Step 4. A complete generality has not yet been specified for each concept in the list. For most concepts it is possible to provide a definition. A definition is one of the descriptive operations relating attribute concepts or component concepts to the primary concept. In the process of defining each concept in the list, new concepts, which are attributes or components of those listed, will be identified. It is usually unnecessary to include all attribute concepts as part of the content network diagram. Occasionally an attribute concept will need further definition. The descriptive operations should again be applied until all of the concepts thus identified are unambiguous and likely to have already been acquired by the potential students.[2]

The other types of operations needed to describe a content network are those which relate concepts to other concepts. Some of these relational operations will have already been identified during Steps 2 and 3, and the first part of Step 4. Each concept in the list should be carefully examined to determine the relational operations in which it is involved.

Some concepts in the list will not lend themselves to descriptive or relational operations. These are concepts which are defined by change operations. Gagné (1970) referred to such concepts as "defined" concepts as opposed to concepts which exist in time and space. Most "defined" concepts will already have been defined by their inclusion in the content network. Most often, however, even these "defined" concepts also have descriptive attributes that are independent of the change operations used to define them. These attributes should be identified as described in the previous paragraph. Figure 4d indicates the descriptive and relational rules for each of the concepts in Figure 4a.

Step 5. The formulation of concepts and operations is stated in set function language from mathematics, consequently it is possible to represent each rule in set roster form. The first elements represent the domain concepts, the second the range concepts and the third the operation. Consequently, the roster (1, 5, 6: 7, 8: P) indicates a rule which combines concepts 1, 5, and 6 to produce concepts 7 and 8. Figure 4e indicates the roster representation of each rule for the measurement network.

Step 6. A final check on the content analysis consists of specifying one or more instances for each generality in the network. This means that for each concept an instance illustrating all of the descriptive attributes or component concepts should be identified and specified. A solved problem should be identified for each of the change operations in the network.

Instructional Analysis

It has been found that the goals of most higher education courses emphasize primarily cognitive transfer behavior.[3] Cognitive transfer means that capabilities acquired in one situation can be demonstrated in a new situation which differs in some nontrivial way from the first. In other words, it is hoped that students will learn to solve problems not only of the type presented in a given course, but in a wide variety of situations. By requiring the student to interact in an appropriate way with the concepts and operations previously identified he should acquire such cognitive transfer behavior.

Rather than containing an infinite number of behaviors, it has been found that the goals of most higher education courses can be represented by four levels of behavior: discriminated recall, classification, rule using, and rule finding. These behavioral levels can be applied to the types of content, concepts and operations previously identified to produce a two way classification of student learning outcomes (Merrill & Boutwell, 1973).

Discriminated recall occurs when a student recalls or recognizes a specific object, event or symbol. This behavior does not involve cognitive transfer but is included here because of its prominent role in most higher education courses as they are now taught. The discriminated recall of concept content can take two forms: recall of the generality or definition and recall of a particular instance or example. In our experience there is an over emphasis of this behavior content combination in most courses. When the content involves identity concepts, then discriminated recall is the necessary and desired behavior. However, discriminated recall is frequently applied to concepts which are not identities. Whenever a test consists of multiple choice questions where the stem is a concept label and the alternatives are various definitions, the student is demonstrating generality recall (memorization). Too often, even when examples are used in presentation, these same examples show up on evaluation instruments reducing what could be classification behavior to instance recall. While recall of generalities and specific instances may be a desirable step in instruction, it is an error to expect that practice at a discriminated recall level will produce cognitive transfer.

In like manner discriminated recall is frequently the behavior applied to operations. Remembering or recognizing a rule statement or specific problem may be desirable but when this behavior is the sole basis for inferring cognitive transfer, a valid inference is extremely unlikely.

Classification occurs when a student is able to correctly identify the class membership of a previously unencountered object, event, or symbol. When applied to an identity concept it is not possible to infer classification since by definition all instances of the class are essentially identical and therefore once presented cannot be unencountered. When applied to multi-instance concepts, however, it is possible to infer classification whenever the student correctly includes or excludes a new (to him) instance or non-instance of a given class. Obviously, the validity of the inference depends on several factors including the degree to which the instances classified are representative of the class and the number of instances a student correctly identifies.

Classification can also occur in relationship to operations a student is classifying when he is given a previously unencountered problem either solved or to be solved and asked to indicate if a given operation is appropriate to produce the solution (i.e., to produce the corresponding instance or instances of the range). While discriminated recall of generalities is overused and abused, classification of operations is frequently neglected or forgotten. Students learn to use operations to solve problems when told the operation which is appropriate but they never learn to identify (classify) which kind of problem requires a given rule.

Rule using occurs when given previously unencountered instances of the domain concepts and a specific operation the student is able to produce or identify the corresponding instance of the range concept(s). A less common form of rule using occurs when given the instance(s) of the range and a specific operation the student is asked to identify instances of the domain concepts. For some operations this type of problem is not possible. In some areas of the curriculum, particularly mathematics and science areas, rule using is frequently employed both in instruction and evaluation. In other areas, such as the humanities and social sciences, rule using is often completely neglected and discriminated recall used almost exclusively. Rule using as described here applies particularly when the rules involve change operations. Technically, however, classification behavior involves descriptive and relational operations and is properly called rule using as well.

Rule finding occurs when given previously unencountered instances of the domain concepts the student is asked to discover or invent a new operation which will result in instances of the range concept. Numerous variations are possible. If only instances of the domain are given the behavior combines rule finding and rule using. The class of rules which are appropriate may be identified or not. When the class of possible operations is not identified, the problem becomes a divergent creative task where evaluation becomes a matter of expert judgment. Similarly, the range concepts can be identified or not. Here again when the student is allowed to identify not only instances but the class itself, he is in a creative mode which in some sense is no longer in the realm of instruction but more in the realm of creative effort. Perhaps the ultimate goal of education is to promote this type of creative rule finding while in training situations we are primarily concerned with appropriate rule using.

Hierarchy analysis. Gagné (1968) originated the idea of hierarchical analysis suggesting that starting with the terminal objective, one should ask the question "What does the student need to be able to do given only directions to be able to engage in the terminal behavior?" This process is repeated for each resulting behavior until those behaviors identified are prerequisite abilities or capabilities which can be reasonably assumed of the student. Unfortunately the procedure described does not make a distinction between horizontal and vertical hierarchies. A horizontal hierarchy represents a typical or preferred sequence for presenting a series of content segments all requiring the same level of behavior. Hence the hierarchy might consist of a series of concepts or a series of principles. On the other hand, a vertical hierarchy consists of an ordered sequence of different levels of behavior. A vertical hierarchy might start with paired associate content which is prerequisite for a given concept, concepts which are attributes of more general concepts, range and domain concepts which are prerequisite components of rules, and rules which are component operations of rule finding. The sequence in a horizontal hierarchy may be arbitrary while the sequence in a vertical hierarchy, when correctly identified, is never arbitrary. While it can be inferred from his statements, Gagné never made an explicit distinction between a horizontal hierarchy and a vertical hierarchy. Consequently, the resulting hierarchies are sometimes a combination, but often only horizontal. All of the research on task hierarchies (see Glaser and Resnick, 1972) has explicitly investigated horizontal rather than vertical hierarchies.

All rule finding and rule using tasks are composed of such vertical hierarchies. The previously described content analysis makes these component parts explicit. Series of such vertical hierarchies can then be arranged into horizontal hierarchies. Too often task analysis procedures identify only the top level of each vertical hierarchy and students are inadequately instructed on the unidentified components. The purpose of instructional analysis is to enable us to arrange content in appropriate combinations of vertical and horizontal hierarchies.

Given the content analysis and the additional assumption that a given course involves only four levels of behavior and that as much as 80% of this behavior will involve classification or rule using, simplifies instructional analysis considerably. The following steps are involved. (1) Identify needs and goals as related to the course under consideration. (2) Specify a mastery model. (3) Specify instructional rule using or rule finding situations. (4) Select and sequence the required concepts and operations from the content network.

Step 1 - Needs and Goals.[4] Instructional analysis is usually more convincing especially to funding agencies or administrative officials both institutional and political if a case can be made for the needs served by a given course. Schools are filled with vestiges of past needs and many resources are frequently spent feeding species which border on extinction due to obsolescence. Prior to engaging in content analysis an extremely useful exercise for the content specialist is to do a needs assessment and prepare a brief report on his findings.

Needs can stem from two sources. The ultimate source is societal needs. What needs in society are filled by this course. Our experience indicates that only moderate effort should be spent specifying these needs since a great deal of controversy and opinion usually abounds in any area. Perhaps the major function of a societal need statement is to alert the content expert and the technology group to potential problems and controversy in this area. Occasionally such an analysis will result in an aborted or redirected project. It is much better to come to the realization of a given project's inappropriateness at this stage than after the expenditure of considerable time and resources.

Most courses are more directly related to institutional needs. The second part of the need statement should identify these institutional needs. These vary from prerequisites for other courses to specific training for institutional roles. For example, an educational psychology course may be necessary because it is required for teacher certification. College algebra may be necessary because students entering the institution do not have mathematical skills which are prerequisite for other math courses.

Often institutional needs are unrelated to student needs. The reason for engaging in systematic ID in a given course may stem from problems existing in the current system. Examples of such problems include insufficient professional staff to adequately handle the course in a conventional manner, lack of adequate facilities, lack of resources, need to cut costs without cutting offerings, a failure to adequately train students in skills needed for subsequent courses or expenses, curriculum reform, etc. Knowing just which of these institutional needs is the catalyst for change can have a profound influence on the specification of mastery models and problems as well as on subsequent system design.

Following from these needs should be a statement of institutional goals. The mastery models and problem statements represent goals for the students. The goals referred to in this paragraph are those hoped for system outcomes that may be only indirectly related to student objectives. For example, a goal may be to double the number of students enrolled in the course with no increase in staff, physical facilities, or cost. It may be to increase the percentage of students who are able to attain the terminal objectives (able to solve the problems specified for the course). It may be a goal to utilize some high cost media equipment such as cable tv or information retrieval, which has previously been under used. It may be a goal to demonstrate some new media such as teaching machines or CAI. While most educational technologists would argue that such decisions should be based on a careful analysis of student goals, in the real world the media decision is often made first and its effective use becomes the primary goal of the ID effort. Knowing these institutional goals provides an appropriate context for the development of mastery models and course problems.

Step 2 - Mastery Models. A mastery model is a description of a student doing those things in the real world which the course is intended to prepare him to do. It is parallel to what used to be called task analysis in training.[5] Task analysis consisted of a detailed description of a real world job in an attempt to determine the component skills required to execute a given task. It was most often applied in manual tasks or trade school like settings. This type of description is one form of mastery model. A distinction has been made between education and training indicating that education often prepares a person in a general way rather than with the capability to perform a specific task. A mastery model attempts to describe situations where this general training is being applied in real world settings.

Many courses are really based on multiple mastery models. If the student is expected to use the capabilities in a variety of different situations, examples of each type of situation should be described. On the other hand, the course might be designed for students pursuing different career or academic goals. In this case a separate mastery model needs to be described for each type of student for whom the course is intended. Multiple mastery models of the second type often have implications for alternative tracks within the course.

Step 3 - Rule Using or Rule Finding Problems. When a course involves primarily cognitive transfer content, discriminated recall and classification behavior are almost never terminal outcomes of the instruction but are enabling behaviors necessary for the student to acquire before he can engage in rule using or rule finding behavior. The course therefore can be organized around problem situations which require the student to use a rule or find a rule. Step 3 of the content analysis process requires the subject matter expert to identify the half dozen or less types of problems that the course will enable the student to solve.

How does a mastery model differ from a problem situation? Sometimes they don't. If a real world mastery situation is such that it can be observed and evaluated immediately following the course then it probably should comprise the problem situation(s) described in the previous section. More often, however, the mastery situation requires longitudinal evaluation over a considerable period of time and makes direct and immediate evaluation difficult or impossible. Problem situations on the other hand should be such that observation of the rule using or rule finding behavior is possible as part of the course experience. This latter case is an inference situation. That is, based on the performance in the problem situation one makes inferences about the students probable performance in the mastery situation. Divergence between course and problem situations and real world mastery situations is directly related to the confidence of the inference. Courses are often ineffective, even when the objectives are realized, because the mastery models have not been specified and no inference is attempted or because the gap between real world mastery and course problems is so great as to make confident inference improbable.

<u>Step 4 - Select and Sequence Content</u>. Once the problems have been identified in Step 3 it is time to combine the two analyses. Each problem is

examined and the change or relational rules needed to solve the problem are selected from the content analysis. If two or more rules are involved, an ordering operation should be identified for these rules.

Component concepts have already been identified as part of the content analysis. Starting with the first rule to be applied one examines the component concepts. Before one can teach the rule using behavior it is necessary for the student to be able to classify instances of the component concepts. If these concepts involve concept attributes which the student has not previously acquired a previous step to teaching such concepts is to teach the student to classify instances of the attributes. A continuation of this process results in a combined vertical and horizontal hierarchy for teaching a student to solve the problems identified and increasing the probability that he will approach the mastery model. Since generalities and instances have already been identified as part of content analysis, one should be ready to proceed with instructional design. It should be noted that your final hierarchy may not include all of the content identified as part of your content analysis.

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Footnotes

[1]It has been found that up to 80% of the content in most courses can be adequately taught with only two of these levels of behavior - classification and rule using.

[2]The reference to students during this "instruction free" analysis is merely an attempt to avoid unnecessary analysis. Obviously we could continue to apply the descriptive operations indefinitely.

[3]The emphasis of this paper focuses on cognitive transfer situations. Other techniques are more appropriate for the analyses of courses where memory or psychomotor behavior is emphasized or where the primary goal is increased motivation or attitude change.

[4]The author is indebted to his colleague C. Victor Bunderson for ideas related to needs, goals and mastery models.

[5]In education technology the word "task analysis" has come to be used for the entire process of behavioral and content analysis instead of merely descriptions of real world jobs as it was originally used.

FIGURE 1

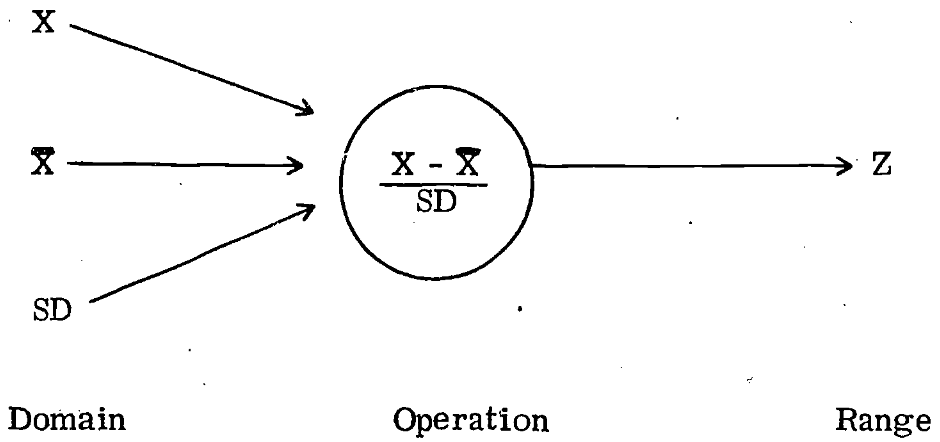


Figure 1 - Relationship between some concepts in the area of mental measurement -- Standard score rule.

FIGURE 2

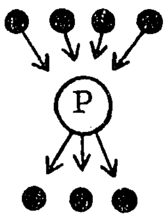
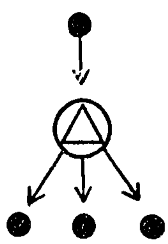
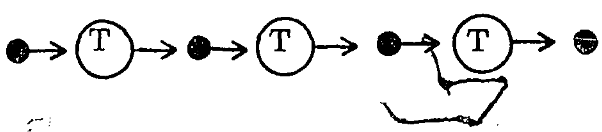
Mean ($\bar{X}$)	=	22			
Student A Score (X)	=	15	$\frac{15 - 22}{7} = -1$		Standard Score (Z) = -1
Standard Deviation (SD)	=	7			
Instances of Domain			Instance of Operation		Instance of Range

Figure 2 - Instance of the Standard Score measurement rule stated in Figure 1.

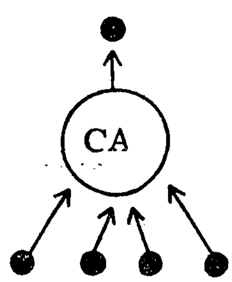
FIGURE 3 - CONTENT OPERATIONS

Note: ● is the symbol for a concept. ○ represents an operation. The arrows represent the directional nature of most operations.

CHANGE OPERATIONS

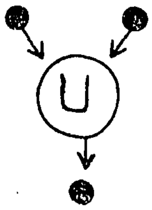
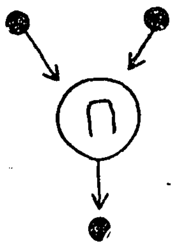
Symbol	Name	Description	Example
	Production	A given set of concepts (domain) are combined to produce another set of concepts (range).	Domain: Distance, time, mass Operation: Laws of motion Range: Speed, velocity, acceleration
	Delta or Decomposition	A given concept (domain) is decomposed into a set of concepts (range).	Domain: Water Operation: Electrolysis Range: Hydrogen, oxygen
	Transformation	A given concept (domain) is transformed into another concept (range, domain) which may then be transformed into another concept, etc.	Domain: Prophase Operation: Mitosis Range: Metaphase Operation: Mitosis Range: Anaphase

DESCRIPTIVE OPERATIONS[1]

Symbol	Name	Description	Example
	Characteristics or Attributes	Membership in a given concept class (range) is determined by a set of relevant attribute concepts or characteristics (domain).	Domain: Stressed followed by unstressed syllable Range: Trochee

[1] Operations are not listed in the example for descriptive or relational operations since they are forms of logical operations and don't have specific instances.

Figure 3, Continued

Symbol	Name	Description	Example
	Union	A given concept (range) is formed by the presence of two or more component concepts (domain).	Domain: Subject, Predicate Range: Sentence
	Intersection or Limitation	A given concept (range) is restricted by the intersection of two or more attributes or characteristics (domain). Identities are identified by such restrictive modification.	Domain: Four iambic pentameter lines with abab rhyme Range: Quatrain of Shakespearian sonnet

RELATIONAL OPERATIONS

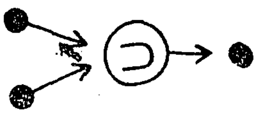
Symbol	Name	Description	Example
	Order	Ordering between two concepts on dimensions such as time, space, chronology.	Domain: Fall Range: Winter
	Inclusion	A given set of concepts (domain) are included as subsets of a more general concept.	Domain: Dogs, cows, etc. Range: Mammals
	Complement	When a more general class is completely exhausted by two or more concepts then the concepts are complementary. This is a bi-directional operation which means either can be range or domain.	Domain: Adjectives Range: Adverbs The complementary components of the more general concept "single word modifiers."
	Identity	Two concepts are exactly identical. Synonyms. This is a bi-directional operation.	Domain: Mean Range: Arithmetic average

Figure 3, Continued

Symbol	Name	Description	Example
● ↔ (EX) ↔ ●	Exclusion	Two concepts are mutually exclusive. Bi-directional.	Domain: Men Range: Women
● ↔ (AN) ↔ ●	Analogous	Two concepts resemble one another while being very different.	Domain: Voltage Range: Water pressu

FIGURE 4
SAMPLE CONTENT NETWORK DIAGRAM FOR MENTAL MEASUREMENT

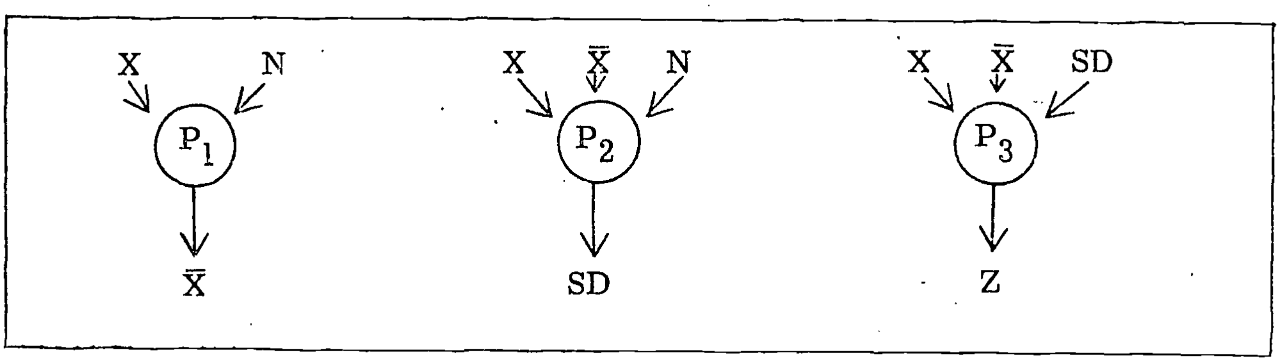
A. List of Concept Names

Standard deviation (SD)
Raw score (X)
Mean ($\bar{X}$)
Standard Score (Z)
Sample size (N)

D. Descriptive & Relational Operations

(CA)	Raw score units	(AN)	Mean deviation
(CA)	Number, interval scale	(C)	Number correct or wrong
(≡)	Arithmetic average	(⊃)	Measures of central tendency
(CA)	+ or - decimal integer usually between + 5	(⊃)	Measures of variance
(≡)	Number of scores	(CA)	Integer

B. Change Operations



C. Change Operations[1]

P_1 Σ X/N

P_2 $\sqrt{\Sigma (X - \bar{X})^2}$

P_3 $\bar{X}$ - X/SD

E. Roster Rules

(X, N; $\bar{X}$; P_1)

(X, $\bar{X}$; SD; P_2)

(X, $\bar{X}$, SD; Z; P_3)

[1]The production operations each introduce a number of arithemtic concepts and operations. A complete analysis might identify all of these concepts but for purposes here they are assumed.