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ABSTRACT

In recent years, there has been increasing interest in finding ways of promoting and evaluating structural knowledge (knowledge of how ideas, events, and principles are interrelated). Research has demonstrated that students' numerical judgments of the strength of relatedness among ideas drawn from a domain provide insights into how they have organized their knowledge of that domain. When these judgments are analyzed through multidimensional scaling, a graphic array can be generated in which highly related ideas are grouped together and less related ideas are located farther apart. These graphic arrays are called "cognitive maps" because they map out a student's understanding of the structural interrelationships that exist among ideas. The use of multidimensional scaling-produced cognitive maps provides a systematic way of presenting structural knowledge which, because of the sequential nature of traditional lectures and texts, might not otherwise be presented at all. (Authors/FG)

Using Multidimensional Scaling-Produced Cognitive Maps to Facilitate the Communication of Structural Knowledge

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Abstract

In recent years there has been increasing interest in finding ways of promoting and evaluating "structural" knowledge; i.e., knowledge of how ideas, events, principles, etc. are interrelated. Research has demonstrated that students' numerical judgments of the strength of relatedness between ideas drawn from a domain provide insights into how these students have organized or structured their knowledge of that domain. When these judgments are analyzed through multidimensional scaling, a graphic array is generated in which highly related ideas are depicted as points located close together in space and less related ideas are located further apart. These graphic arrays are called "cognitive maps" because they map out a student's understanding of the structural interrelationships that exist between the ideas that were judged. Three studies are discussed in this paper in which an instructor's relationship judgments were used in generating cognitive maps for ideas from introductory psychology, history & systems, and statistics. These maps were then used in teaching (rather than assessing) structural knowledge. Test scores obtained from students taught using cognitive maps were superior to those of students taught in traditional ways. The use of multidimensional scaling-produced cognitive maps provides a systematic way of presenting structural knowledge which, because of the sequential nature of traditional lectures and texts, might not otherwise be presented at all.

Using Multidimensional Scaling-Produced Cognitive Maps

to Facilitate the Communication of Structural Knowledge

Although any statement of educational goals can be argued, it is certainly true that one of the immediate goals of classroom instruction is to communicate to students a knowledge of both the meaning of individual concepts and an understanding of the ways in which these concepts are interrelated. This knowledge of relationships has been variously called internal connectedness, integrative understanding, or structural knowledge, and it may be argued that it is an essential level of understanding, since in many theories of long term memory structure, the meaning of any one concept is given by its pattern of relationships to other concepts in the knowledge structure.

It is unfortunate, then, that so few students emerge from our classrooms with any clear sense of structural understanding. It is even more disheartening to observe that this is usually the consequence of our failure to teach structural knowledge. Admittedly, teaching at the structural level is difficult. The sequential nature of language means that lectures and texts will necessarily deal with first one idea, then another and another. Rarely are there opportunities to stop and systematically explore the relationships that exist between ideas presented at different times and in different contexts.

The research discussed here was conducted during the last two years at Midwestern State University to develop and assess a method by which teachers may systematically (a) become more aware themselves of the structural interrelationships that exist among the concepts they teach, and (b) better communicate this information to students.

For several years, various investigators (e.g., Diekhoff, in press; Fenker, 1975; Shavelson, 1974; and Weiner & Kaye, 1974) have found that when college students are given pairs of concepts (for example, REINFORCEMENT - PUNISHMENT, COGNITIVE DISSONANCE - BALANCE THEORY, or CLARK HULL - KURT LEWIN) with instructions to use a numerical scale in rating the degree of similarity or relatedness existing within each pair, their numerical judgments often provide useful information through which understanding at the structural level may be evaluated. Typically, the similarity between a student's judgments and those of his instructor as well as the test-retest reliability of a student's judgments have been shown to be significantly correlated with traditional measures of structural understanding, including essay test scores. Given that a student's relationship judgments carry important information about structural knowledge, it follows that an instructor's judgments might provide a medium through which structural knowledge could be conveyed to students.

However, relationship judgments in their raw form contain an enormous amount of information. It is necessary to find a way to condense this information into a more palatable package. Multidimensional scaling analysis (MDS) provides an ideal means of reducing and summarizing the structural information contained within a set of relationship judgments.

Consider this step-by-step description of how relationship judgments for a set of concepts taken from general psychology might be analyzed through MDS analysis.

STEP 1. A set of key concepts is selected from the domain being taught: INTELLIGENCE, GENETICS, REINFORCEMENT, PREJUDICE, NEUROSIS, ATTITUDES,

PUNISHMENT, INK BLOT TESTS, and LANGUAGE.

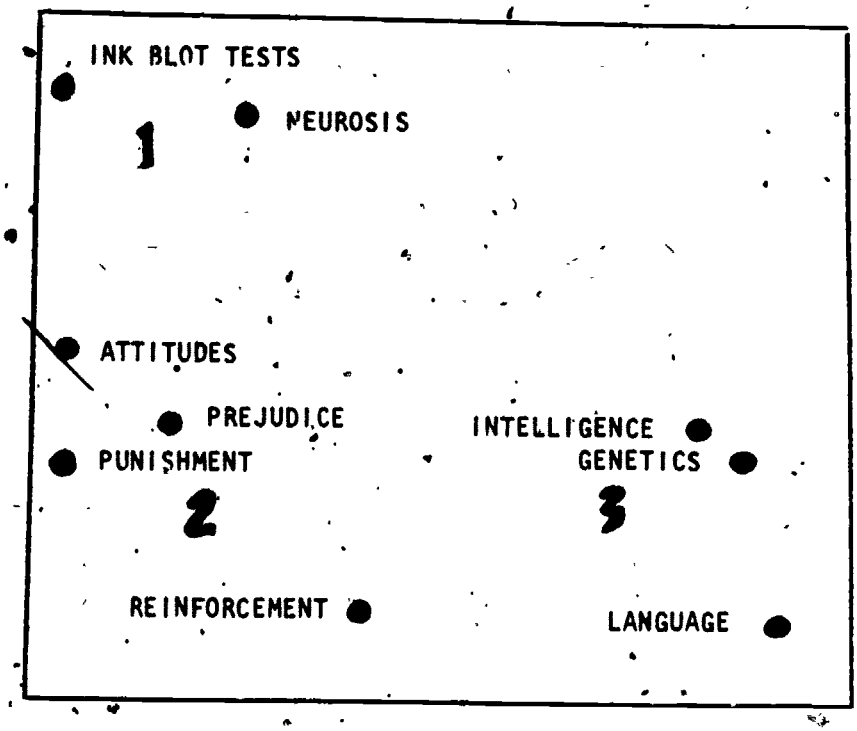
STEP 2. All possible pairs of these concepts are formed and each pair is rated for relatedness using a 1-9 scale, with 1 representing little or no relationship and 9 representing a strong relationship. Relationship judgments are converted to decimal form (i.e., 1 becomes .1, 2 becomes .2, etc.) and 1's are inserted into the diagonal of the matrix.

	INTELLIGENCE	GENETICS	REINFORCEMENT	PREJUDICE	NEUROSIS	ATTITUDES	PUNISHMENT	INK BLOT TESTS	LANGUAGE
INTELLIGENCE	1.0	.8	.3	.5	.5	.4	.2	.1	.8
GENETICS		1.0	.5	.2	.6	.1	.1	.1	.8
REINFORCEMENT			1.0	.8	.4	.8	.9	.1	.8
PREJUDICE				1.0	.6	.9	.4	.2	.1
NEUROSIS					1.0	.7	.8	.9	.1
ATTITUDES						1.0	.7	.5	.1
PUNISHMENT							1.0	.1	.1
INK BLOT TESTS								1.0	.1
LANGUAGE									1.0

Although the task of generating relationship judgments may seem fairly subjective and difficult, experts show good reliability in their judgments over time, and comparisons between the judgments obtained from different experts typically show a high degree of similarity. Generating relationship judgments is not an impossible task, although it can become tedious if many concept-pairs are involved.

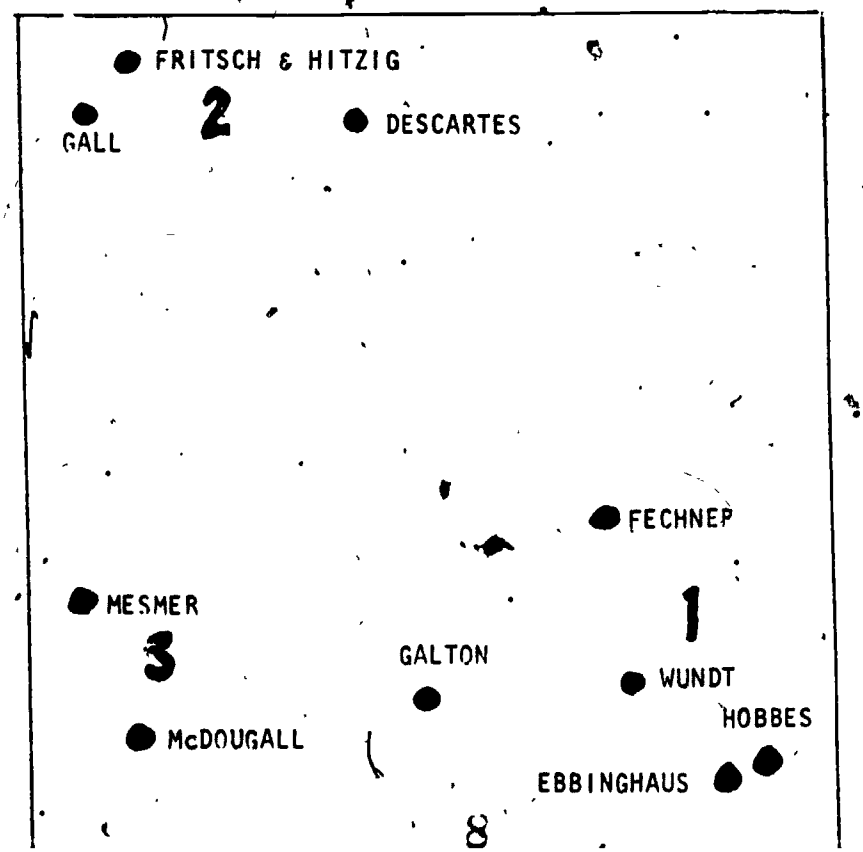
STEP 3. The matrix of relationship judgments is next analyzed through principal components analysis as though the relationship judgments were correlations--vector-product multidimensional scaling (Nunnally, 1978). Although other variations of MDS are available, we have focussed on vector-product analysis as nearly all colleges and universities now have access to "canned" principle components analysis programs (e.g., SPSS).

This analysis essentially translates relationship judgments into distances, so that highly related concepts are seen as being close together in space and unrelated concepts are further apart. This pattern of distances, then, can be used in creating a graphic array of concept-points in space, sometimes called a "cognitive map."



Once a cognitive map is generated in this fashion, it provides a graphic synopsis of the structural interrelationships that exist among the concepts used in generating the map. Such a map can be used as the focus of classroom discussions that necessarily focus on structural relationships. For example, why are some concepts clustered tightly together? Why are some concepts in different clusters? Why are some clusters closer together than others? How can the various clusters be linked together or related?

Maps of this sort have been used successfully in undergraduate general psychology where 50-minute in-class discussions of the instructor's maps yielded significantly higher essay test scores than were obtained from students who were not exposed to the maps (Diekhoff & Diekhoff, 1982). In a class covering history and systems of psychology as well, names of famous figures in the history of psychology were substituted for the concepts used in the preceding example to produce maps like the one shown below (Diekhoff, 198



In-class discussions of these maps forces structural-level thinking that would be difficult to accomplish otherwise. The following comments illustrate those that typically emerge during such discussions. Cluster 1 contains the names of those of a mentalistic orientation whose contributions are still recognized as important and valid. Those in Cluster 2 all were involved in early attempts to destribe the physiological bases of behavior and mental processes. Cluster 3 contains the names of those who offered nonphysiological "false starts" to psychology. Galton falls between Clusters 1 and 3, reflecting the fact that while he introduced the important ideas of mental measurement and correlation (Cluster 1), he mistakenly attempted to use sensory and motor measures of intelligence (Cluster 3).

Although cognitive maps have proven useful in enhancing the communication of structural information to students, Phil Wigginton and I have used MDS in a slightly different way to teach the concepts of statistics to psychology students. The process begins as always with the selection of concepts to be judged for relatedness. Relationship judgments are generated for all possible pairs of these concepts and the judgment matrix is analyzed through principal components analysis. However, instead of centering discussions around a cognitive map produced from one such prihcipal components analysis, we run a series of analyses. The first extracts only two principal components, the next, three, and so on until the concept clusters that comprise each principal component are no longer interpretable.

The first two principal components represent very general conceptual categories. Extraction of the third principal component causes one of the first two categories to break down into two somewhat narrower categories. The

fourth principal component results in a similar breakdown of one of the previous categories, and so forth.

As an example, consider the concept heirarchy shown below. Beginning with two very general concept clusters, each successive analysis creates another, more specific level of the heirarchy.

BIVARIATE STATISTICS

Scatterplots
Construct Validity
Predictive Validity
Reliability
Correlation
Non-linear Relationships
Differential Validity
Causal Relationships

UNIVARIATE STATISTICS

Frequency Distributions
Skewness
Percentiles
Mean
Median
Range
Variance
Standard Deviation
Standard Scores
Standard Normal Curve
Normal Distribution
Probability

BIVARIATE STATISTICS

Same as above

DESCRIPTIVE STATISTICS

Frequency Distribution
Skewness
Mean
Median
Range
Variance
Standard Deviation

STD. NORMAL DIST.

Percentile
Std. Score
Std. Normal Curve
Normal Distribution
Probability

BIVARIATE STATISTICS

Same as above

CENTRAL TENDENCY

Frequency Dist.
Skewness
Mean
Median
Range

DISPERSION

Range
Variance
Std. Deviation
Std. Score

STD. NORMAL DIST.

Same as above

PSYCHOMETRICS

Construct Validity
Predictive Validity
Reliability
Differential Validity

CORRELATION

Scatterplot
Correlation
Non-linear Rel.
Causal Rel.

CENTRAL TENDENCY

Same as above

DISPERSION

Same as above

STD. NORMAL DIST.

Same as above

A pilot study in which small groups of students were led through discussions of concept heirarchies like this one indicated that the discussions were effective in getting students to think about structural interrelationships in statistics and boosted scores on tests designed to tap this kind of knowledge.

In conclusion, cognitive maps and concept heirarchies produced through multidimensional scaling of an instructor's relationship judgments are potentially valuable instructional tools. Still coming are more rigorous tests of their effectiveness.

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