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REFINING CONCEPT MAPS: METHODOLOGICAL ISSUES AND AN EXAMPLE

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ABSTRACT

This paper describes a concept mapping exercise conducted with a group of public school teachers for the purpose of formulating a plan to integrate computer technology into a conventional educational setting. The exercise involved the generation of conceptual entities through a structured brainstorming session, and a session in which participants subjectively rated the brainstormed entities according to perceived similarities between them. This was followed by a multidimensional scaling and hierarchical cluster analysis of the similarity ratings, and interpretation of the map.

Initial results indicated that there was a confounding effect on the final map because of perceived semantic groupings based on surface characteristics which were not germane to the intended focus of the conceptualization exercise. The paper describes a method that was used to control the effects of these strong, but experimentally irrelevant, category-based associations which subjects in this study made among certain items in a subset of the data. The initial map is presented along with the final map which shows the effect of the attempt to correct for this methodological artifact.

This paper has two purposes. First, it provides an example of the use of the concept mapping procedures outlined by Trochim (this volume) for examining the integration of computers into the school curriculum. In the process of conducting the concept mapping, however, it became apparent that because of the way the brainstorming was handled, the major topic of interest became obscured in the final map. Specifically, the intent of this project was to examine how computers could be integrated into the educational environment. Two separate brainstorming sessions were conducted—one focused on curriculum issues, while the other emphasized computer activities. The hope was that when the statements from these brainstorming sessions were combined and sorted, the computer activities would be distributed across curriculum areas throughout the map. Instead, however, participants perceived the similarity between computer activities as salient and tended to sort most computer items together. Consequently, the resulting map showed most computer items clustered together—an outcome not particularly useful if one is interested in looking at how computer activities relate to curricular areas.

To deal with this perceived semantic distinction (between computer items and curricular activities) a reanalysis of the data was undertaken. All similarity values between computer items in the $N \times N$ group similarity matrix were set equal to zero. Thus, when the map was recomputed using multidimensional scaling, computer-related items were only allowed to be related to curricular issues and not to each other. This reanalysis led to a map which was more appropriate to the issue of integrating computers into the curriculum.

Serendipitously, it seems that this analytic method may have general utility for further refining a concept map or for exploring secondary issues. It can be used whenever one is interested in seeing how subsets of items might intermix, even though they appear in different areas on the original map. For instance, if concept mapping is used for planning purposes within an organization, one might initially obtain several clusters describing separate areas of organizational activity,

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with one of those clusters describing personnel issues. While this may be of interest in and of itself, it may also be desirable to explore how the individual personnel issues fall *within* other activity area clusters. This might be useful in identifying how certain personnel problems are related to other organizational activities. Even though the personnel items might be placed together as a group on the original map, because of their salience as a group, the methodology outlined here could be used to force these items to intermix with the other conceptual groups on the map.

In the following sections, the original concept mapping is described, the reanalysis is presented along with the revised map, and the implications of the reanalysis are discussed.

METHOD

Subjects and Procedure

This study was conducted with a group of 18 teachers from a school district in upstate New York, who had formed a committee to investigate computer usage within the district, and to recommend a plant for its implementation over the next several years. For the structured brainstorming session, the larger group was divided into sub-groups and asked to generate responses to two general questions, each of which was posed separately:

1. Which areas or tasks associated with teaching or with the curriculum do you find particularly boring, tedious, or repetitive; and, which curriculum areas do students typically have a hard time grasping?
2. What types of activities, in either general or specific terms, do computers perform well?

Groups were given approximately 20 minutes to brainstorm each of these questions. Open discussion and non-judgmental attitudes were encouraged during the sessions.

Items generated from questions 1 and 2 were combined for the second session. The lists were first edited to remove redundant items and to settle ambiguities; the final list consisted of 50 entities which represented those items most frequently generated during the brainstorming session. The complete list is given in Table 1. Each of the 50 entities was numbered and printed on a separate slip of paper. Each member of the group was instructed to sort all 50 entities into groups of items which he or she perceived to be similar. No constraints were imposed on the participants in regard to the dimensionality or cognitive constructs on which their various sorting strategies could be based. This sorting process was repeated three times by each participant. After each sort, participants recorded the number of separate piles of items and the identifying number of each item sorted into each pile.

The sort information was aggregated and a two-dimensional multidimensional scaling and cluster analysis were performed as described in Trochim (this volume).

Interpretation of the Map

Interpretation of the MDS plot involves a process of defining clusters of entities on the plot, meaningfully labeling those clusters, and then providing a rationale for the particular groupings and for the labels that have been given to them. Interpretations for this exercise were conducted by the author, and later by the original participants in a group session. There was a high degree of correspondence between these two interpretations; an abridged description follows of the clustering of the school-related items.

Interpretation of the plot suggests that participants perceived four conceptually distinct areas within the original set of items: (a) Teacher Management: teacher management and organizational tasks; (b) Curriculum Delivery; day to day teaching and learning activities involving the established curriculum; (c) Higher-Order Thinking: cognitively based higher-order thinking skills; and (d) Attitudes and Values; psychological factors which may or may not be addressed by the educational process, but which are crucial in some respect to that process.

Within these four regions, Clusters 6, 8, 9, and 10 appear to represent the teacher management and organizational activities: for example, creating lesson plans and materials, grading papers, reporting grades, etc., and has therefore been labeled the "Teacher Management" cluster. Cluster 10, containing items involving library skills and locating information, was apparently perceived as also being closely related to teacher management activities: it involves activities outside of the immediate classroom, and tends to involve organizational skills. Cluster 10, therefore, was also subsumed into the Teacher Management cluster.

Clusters 3 and 1, which make up the Curriculum Delivery region, are comprised almost entirely of items pertaining to specific areas of the curriculum: for example, reading skills, math concepts, social studies skills, constitution and government, etc. These are interspersed with entities associated with personal skills and study habits which are generally considered to be necessary to students' success within a formal schooling environment, such as recall of facts, general study skills, and communication skills.

Cluster 2 contains the items "following directions" and "comparison and categorization skills." In Figure 1, this cluster stands by itself under the region named Higher-Order Thinking.

TABLE 1
LIST OF STATEMENTS FROM BRAINSTORMING

1. Recall of facts
2. Application of concepts/skills; practice in applying concepts to practical situations
3. Math concepts: word problems; knowing how to set up math problems
4. Reading skills, comprehension
5. Social studies skills
6. Scientific principles
7. Attitudes and values, responsibility, citizenship
8. Organizational skills: keeping track of things, creating organizational systems
9. Study skills
10. Creating lesson plans
11. PSEN
12. Spelling: recognizing misspelled words, correcting misspelled words
13. Correcting papers
14. Reporting grades; taking attendance
15. Enrichment of basic curriculum
16. Logic and reasoning
17. Following directions; getting instructions; having to repeat instructions
18. Providing variety; encouraging variety in the curriculum, in student work
19. Review of facts
20. Computer simulations: ability to model behavior of systems, scientific principles, social situations, etc.
21. Locating or finding information or things: reference sources; parts and materials; library-related skills
22. Communication skills: listening, reading, understanding, expression
23. Cause and effect (simple and complex)
24. Charts, graphs, tables, time lines, etc. (teaching and understanding)
25. Comparison and categorization
26. Decision making skills
27. Teaching analogies; understanding analogies
28. Self image/self concept
29. Vocabulary (and meaning): commonly used vocabulary; specialized vocabulary
30. Constitution and government: Understanding social and governmental systems
31. Solid geometry
32. Fractions
33. Planning ahead: prediction, understanding option and consequences
34. Motivation: to try, to learn, to succeed
35. Creating materials; repetitive materials
36. Library related tasks: cataloguing, circulation, inventory and purchasing
37. Graphics capabilities of computers: aid to visualization, pictures, graphs, charts, animation
38. Computer drill (ability to repeatedly present simple problems and check answers
39. Potential of computers to provide positive reinforcement, praise, reassurance, suggestions, help, etc.
40. Computers (can) save paper and paperwork
41. Computer managed instruction: diagnosis of skill level; prescription/remediation; individualized instruction
42. Student-computer interaction: computer accepts input and responds; one-to-one involvement
43. Computer information storage and retrieval capabilities: can store different kinds of information; can retrieve information on demand
44. Computer telecommunications: remote communications; remote data bases and information services; remote group projects
45. Computer processing speed: saves time; makes very large tasks possible
46. Computer programmability: can perform according to instructions that are given to it
47. Computer ability to solve problems according to formulas or other instructions
48. Computer aided research, data collection and statistics
49. Word processing: spelling correction, neat printouts
50. "Hemisphericity" issues: teaching to the "right brain", visualization, intuition/creativity

In the Attitudes and Values region, Cluster 4 includes the items "attitudes and values" and "self image/self concept." Cluster 5 is somewhat more tangential to this region but includes items like "motivation" and "providing variety." Cluster 7 was included here because it emphasized attitudinal issues relating to computing: "potential of computers to provide positive reinforcement."

What has become of the computer-related items? In Figure 1, computer items are indicated by dots with circles around them while non-computer items are shown as dots alone. In the figure, all of the computer items congregated on the left side of the map, predominantly in the Teacher Management region. While this is probably a fair reflection of how the people sorted the items, it does very little to tell us about how computer activities are interrelated with curricular matters, an issue which is discussed next.

Eliminating Unwanted Semantic Groupings

One objective of this study was to represent the relationship of individual computer items to specific clusters of school and curriculum items. This objective was implied in the stated purpose of the exercise: to find ways in which computer related activities, being relatively new phenomena, could be integrated into the already existing structure of the curriculum. The salient semantic grouping among the computer items, therefore, was taken to be a confounding factor in the original map because it tended to obscure the issue of primary interest.

To correct for the semantic based clustering of the

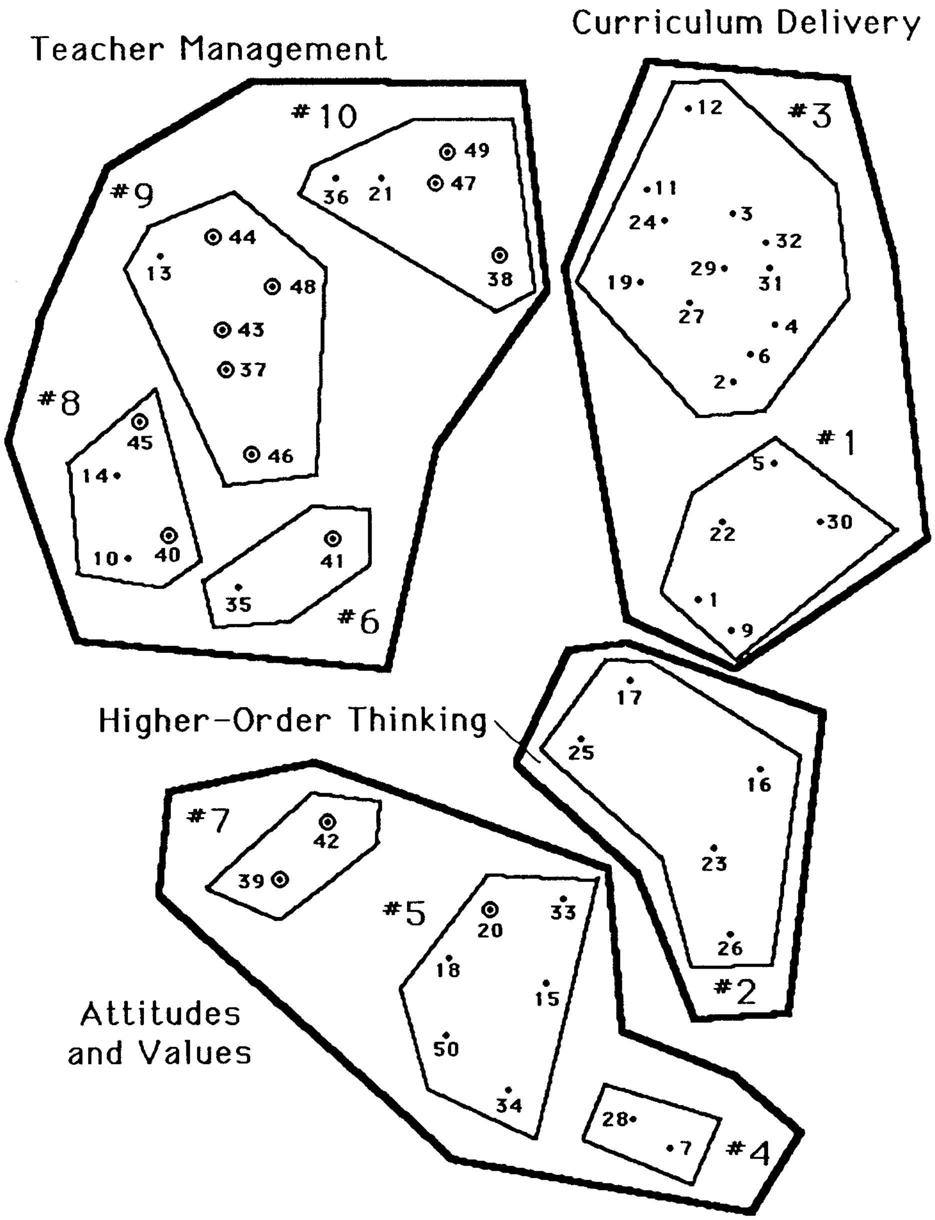

Figure 1. Initial concept map.

computer items in the original plot, an assumption was made that if the perceived relationships between all computer items were eliminated from the original similarity matrix, then the placement of those items on the map would be determined solely by their relationships to all school and curriculum items, rather than by their direct relationships to each other. It was further assumed that any clustering of computer items that might result from this manipulation of the matrix would be determined only by their similarities to various school and curriculum items. To investigate these assumptions, the cells representing all comparisons between the 14 computer items in the original input matrix were given values of zero, and the altered matrix re-submitted to the multidimensional scaling and cluster analysis procedures. The resulting plot is shown in Figure 2.

A visual inspection of Figure 2 indicates that the altered input matrix produced a restructuring of the map which more appropriately addressed the research interest. Many of the previously closely clustered computer items have been dispersed more evenly throughout the plot, and their resulting positions, in many instances, now fall into curriculum clusters in a way which appears to be more intuitively correct than in the original solution. For example, computer item 38, "drill and practice," now lies in the cluster representing spe-

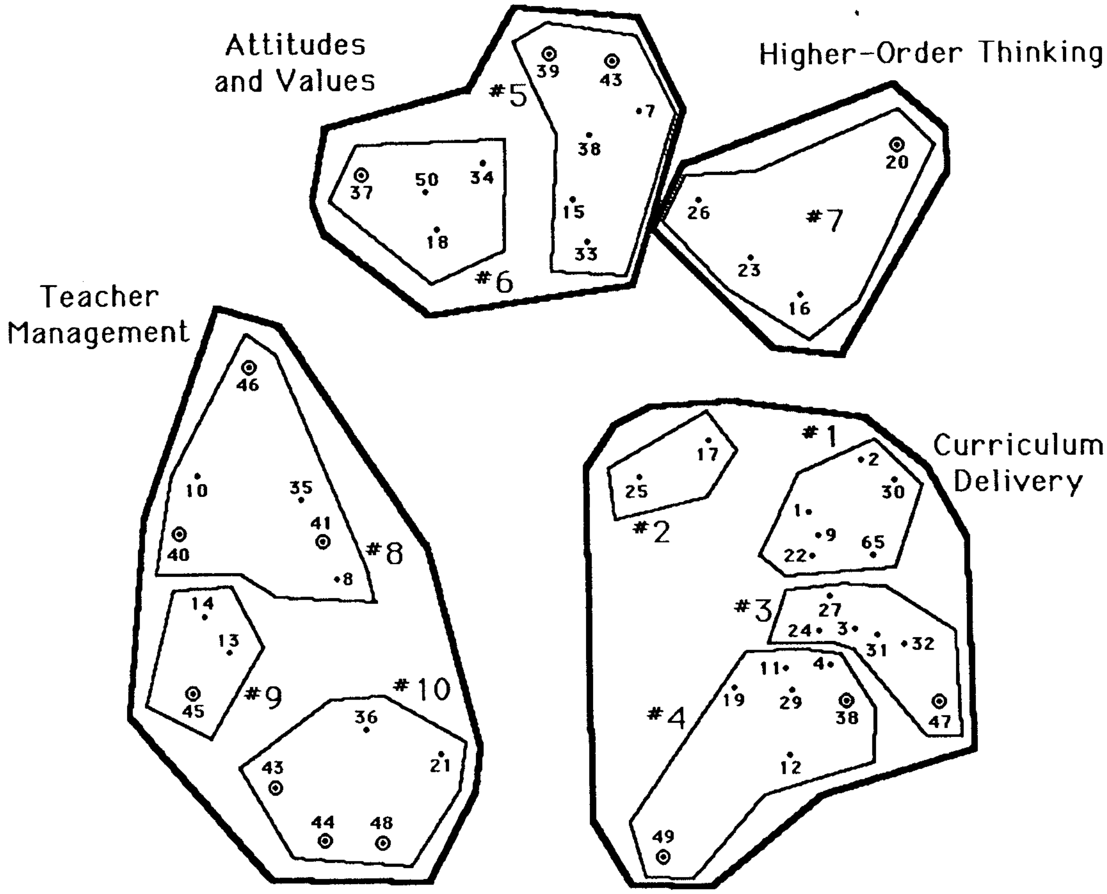

Figure 2. Revised concept map with computer-computer item similarities set to zero.

cific, factually based curriculum items. Computer item 37, "graphics capabilities," now lies in the same cluster as "hemisphericity/right-left brain issues" and "variety." Computer item 39, "computer positive reinforcement," and computer item 42, "student-computer interactions," now lie in the cluster containing "self-image" and "attitudes and values." The cluster containing items related to library activities now contains computer items 43, 44, and 48: respectively, "computer information storage and retrieval," "telecommunications," and "computer-aided research." Computer item 47, "computer problem solving capabilities," now lies in the cluster containing math curriculum items, and computer item 20, "simulations," now lies in the cluster representing higher order thinking skills.

Because the map represents the perceived similarity-distance between each entity and all other entities, zeroing out the relationships between computer items also produced some differences from the original plot in regard to the school and curriculum item clusters. These changes appear to be minimal, however, in that the integrity of most of the original clusters has been maintained, and the spatial order of the clusters remains essentially unaltered, although rotated somewhat in the two plots.

CONCLUSION

Conceptualization research of the type described in this volume is frequently concerned with representing intra-relationships among entities which may belong to distinct semantic groups. Quite often, the objective of the conceptualization exercise is to uncover hidden and implicit structure in the data set, beyond the obvious surface distinctions. Such structure is based on the nature of the free associations that subjects in the study make between entities, and for that reason it is often not desirable to impose constraints on the judgement process. On the negative side, unconstrained sorting and rating strategies often result in irrelevant semantic groupings which, at best, contribute little to the intended focus of the study.

In some cases, it may be possible to alleviate the formation of unwanted semantic groupings by attempting to ensure that the target set of conceptual entities is essentially unidimensional. If potentially unwanted groupings can be identified prior to the sorting or rating process, it may be possible to instruct participants to avoid making associations solely on the basis of those groupings. For example, it may have been possible to instruct participants in the school-computer integration study to avoid sorting items solely on the basis of their identity as school-related or computer-related entities.

The approach described here of nullifying certain inter-group associations may be primarily desirable for situations in which the multidimensional scaling output is confined to a two-dimensional solution. It is also possible that a similar effect could be achieved by specifying MDS solutions with increased dimensionality, and then examining higher orders of 2-dimensional plots; for example, dimension 2 vs. dimension 3, or dimension 2 vs. dimension 4, etc. Some of the plots may adequately describe confounding semantic groupings, while others may more accurately describe the relationships of interest. This approach remains an area for further investigation.

This paper outlines a method that was used to further explore conceptual structure in a concept mapping context by controlling for strong semantic associations which initially obscured the relationships of primary interest. While it may be best to try to eliminate such artifacts in the brainstorming step, in some cases this tactic may prove to be difficult or impossible in practice. The method outlined here might be used as a *post hoc* corrective procedure, or, perhaps more promisingly, as a tool to better refine the exploration of implicit relationships in any concept mapping process.

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Guest Editor

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CONTENTS

(Continued on next page)

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(contents continued)