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# Concept mapping and network analysis: An analytic approach to measure ties among constructs

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ABSTRACT

Group concept mapping is a mixed-methods approach that helps a group visually represent its ideas on a topic of interest through a series of related maps. The maps and additional graphics are useful for planning, evaluation and theory development. Group concept maps are typically described, interpreted and utilized through points, clusters and distances, and the implications of these features in understanding how constructs relate to one another. This paper focuses on the application of network analysis to group concept mapping to quantify the strength and directionality of relationships among clusters. The authors outline the steps of this analysis, and illustrate its practical use through an organizational strategic planning example. Additional benefits of this analysis to evaluation projects are also discussed, supporting the overall utility of this supplemental technique to the standard concept mapping methodology.



## 1. Introduction

Concept mapping is a mixed-methods approach that integrates qualitative group processes with multivariate statistical analyses to help a group describe and visually represent its ideas and their interrelationships on a topic of interest (Kane & Trochim, 2007; Trochim, 1989). Since concept mapping's inception in the evaluation field, other scholars have introduced methods that they also refer to as concept mapping, but that are used for different purposes and that typically represent individual thinking (Novak, 1990; Novak and Gowin, 1984). To distinguish the concept mapping described in this paper from other methods of the same name, we refer to our method of focus as "group concept mapping." Group concept mapping recognizes the aggregation and depiction of individuals' combined thinking as a key distinguishing feature.

Stakeholders often describe and interpret group concept maps with reference to points, clusters, and their relative distances on the map. The practical and theoretical value of these characteristics in describing how groups think about an issue is widely accepted, and has been applied in a range of contexts including research on aging (Anderson, Day, & Vandenberg, 2011), public health (Trochim, Cabrera, Milstein, Gallagher, & Leischow, 2006), education (Streeter, Franklin, Kim, & Tripodi, 2011), social work (Davis, 2009), mental health (Conrad et al., 2011), and biomedical research and evaluation (Trochim, Marcus, Masse, Moser, & Weld, 2008).

Group concept mapping has also been described as a methodology that can be used to represent complex systems thinking. Group concept maps describe participants' collective perspectives on a given topic, and allow us to hypothesize about how the concepts articulated by clusters relate to one another (Trochim and Cabrera, 2005; Trochim et al., 2006). To date, cluster-to-cluster relationships are inferred based on proximity and described largely qualitatively. Means for quantifying relationships among clusters has yet to be explored in depth.

Recent work has nonetheless suggested potential value in quantifying elements of a concept map, specifically through the lens of network analysis (McLinden, 2013). Network structure is typically understood and represented as the spatial arrangement of network elements, within which patterns of interdependencies and interrelationships among entities are analyzed (Newman, 2003). As McLinden (2013) presents, group concept maps can be thought of as networks of ideas, such that the participant sort data represented in the total similarity matrix can be subjected to network analyses. McLinden applies commonly used network measures, including density and betweenness centrality, as supplements to the standard concept mapping analysis. Through these analyses, statements and clusters acquire individual quantifications that can be used to compare map elements in

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the context of the conceptual framework. McLinden compares cluster densities to determine if the ideas in certain clusters are more highly connected to one another than the ideas in other clusters. He also calculates betweenness of statements (a measure of the extent to which a statement sits between other statements) to consider whether an idea acts more or less as a "bridge" or connector among other ideas of the map.

Whereas these analyses can be useful for quantitatively comparing individual entities of a map, we propose that concept mapping may also benefit from quantification of the ties among elements. In this paper, we describe an alternative means for applying principles of network analysis in a way that quantifies ties between clusters. Our interest is less in deriving measures for individual clusters, and more in quantifying the strength and directionality of relationships between them.

The purpose of this paper is to demonstrate an application of network analysis that articulates the strength of relationships within and across clusters, and to suggest how this analysis may enhance the interpretation and utility of group concept maps in planning and evaluation. First, we describe the group concept mapping process using an example of a strategic planning project. We then introduce our analysis and demonstrate its application using this example map. We follow by discussing how this analysis helps to inform map interpretation, and suggest ways the method may benefit from this supplemental technique. We conclude with a discussion of the strengths, weaknesses and limitations of this approach, and a call for researchers to consider exploring this analysis further in their own group concept mapping work.

### *1.1. Group concept mapping overview*

The concept mapping process requires participants first to brainstorm a large set of statements relevant to a topic of interest using a single guiding question or focus prompt. Second, each participant individually sorts these statements into piles based on how he or she perceives them to be related, and rates the statements on one or more scales. Third, multivariate analyses are conducted that include two-dimensional, non-metric multidimensional scaling (MDS) of the aggregated sort data. The resultant maps show the individual statements in two-dimensional ($x$, $y$) space with statements more similar in meaning located closer to one another. Hierarchical cluster analysis then groups the statements into clusters based on their MDS coordinates, partitioning the space on the map. Whereas the placement of points in two-dimensional space is a fixed determinant of MDS, the hierarchical clustering process is quite flexible and responsive to the context of the project. Users typically explore multiple cluster solutions before determining the most parsimonious arrangement of the statements for the purpose of their project. In some cases, the final cluster solution is determined in consultation with stakeholders, whose expertise can assist in recommending the optimal fit for interpreting the content.

Finally, the participant group interprets the results through a process designed to help them understand the maps and label the clusters in a substantively meaningful way, based on the statements that each cluster includes and the fundamental purpose of the project. Cluster labels serve as heuristics that articulate the higher order themes of the concept map, and are used to define the territory of the conceptual framework. By grouping statements into clusters, we create a smaller number of higher order meaning-making devices to interpret an otherwise overwhelmingly diverse set of ideas and their interrelationships. As with the statements, we can infer clusters' relatedness based on their relative proximity: the closer two clusters (concepts) appear on the map, the more similar they are understood to be; the more distant clusters are, the less similar they are thought to be in meaning.

### *1.2. Example: group concept mapping in strategic program planning*

We present an example of group concept mapping applied in a strategic planning context to illustrate the standard process and results. We revisit this example in subsequent sections to demonstrate the supplementary methodological approach under consideration. Our example focuses on the Office of Behavioral and Social Sciences Research (OBSSR) of the National Institutes of Health (NIH). The OBSSR mission[1] is to stimulate behavioral and social sciences research throughout NIH, and to integrate these research areas more fully into the NIH health research enterprise. OBSSR is a federal integrator, funder and technical support provider for research in the behavioral and social sciences. The organization also conducts primary research. In this project, group concept mapping was used to create a shared conceptualization of those factors most pertinent to OBSSR's strategic integration of intramural and extramural research developments to fulfill its mission.

For this inquiry, the focus prompt was: "What specific actions should OBSSR undertake to maximize the contributions of the behavioral and social sciences to the overall organizational mission?" The 208 individuals invited to generate ideas included the organization's management team, representatives from OBSSR consulting clients, and researchers and academics from relevant fields. The diversity of this participant group ensured that the conceptualization included perspectives of organizational management, partners, and stakeholders that conduct external research and receive OBSSR's consultative advice. Participants generated 247 ideas in response to the focus prompt, which were reviewed and synthesized by the research team to a final representative set of 93 ideas. Participants then individually sorted the 93 ideas into groups based on how they perceived them as related to one another and rated each statement on 1-to-5 Likert scales to gather opinions on importance and feasibility.

Following the participatory activities, each individual's sort data is represented as a binary $N \times N$ similarity matrix, where $N$ is equivalent to the number of ideas in the statement set. If a participant sorted ideas $a$ and $b$ together, a '1' is placed in $X_{ab}$; if the participant did not sort ideas $a$ and $b$ together, a '0' is placed in $X_{ab}$. For the present inquiry, a binary $93 \times 93$ similarity matrix represented the sort data of each of the forty-eight sorting participants. These 48 matrices were then summed, resulting in a total similarity matrix. The number in each cell of the total similarity matrix represents the total number of respondents that sorted those two ideas together. The largest possible number in the total similarity matrix is the total number of participants (i.e. all participants sorted those two statements together), and the lowest possible number is zero (i.e. none of the participants sorted those two statements together). The total similarity matrix therefore represents the extent to which participants agreed that two ideas are related or similar in the context of the research question.

Next, the total similarity matrix was subjected to non-metric multidimensional scaling (MDS). The resultant point map displays each of the 93 ideas in two-dimensional ($x$, $y$) space. This representation was then subjected to hierarchical cluster analysis, by which statements were grouped together into non-overlapping clusters based on their spatial proximity, allowing the organization to consider the relatively large list of 93 statements within a smaller set of higher order themes. The project planning team considered various cluster arrangements before deciding that an eight-cluster solution was optimal for meaningfully interpreting the results.

A subset of the organization's management team, researchers, and consultative advisees assisted in labeling the eight-cluster

[1] http://obssr.od.nih.gov/about_obssr/mission/mission.aspx