Comparison of Individuals' Ideational Knowledge Structures Derived by Concept Mapping and Ideational Knowledge Mapping

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Abstract

Knowledge Map is an external visual representation of an individual's ideational knowledge (also called cognitive structure, or propositional, declarative or conceptual), and we deal with two methodologies to produce such representations, Concept Mapping and Ideational Knowledge Mapping. This paper describes and shows samples of the maps the two methodologies produce, compares their graphic elements, and outlines the abstract characteristics unique to the Ideational Knowledge Map. Based on the content and structure of the Ideational Knowledge Map a theorization of the Ideational Knowledge Space is proposed and some of its implications and problems discussed.

Keywords: Knowledge representation; Concept map; Ideational Knowledge Map; Theorization; Ideational Knowledge Space.

Introduction

Knowledge Map is an external visual representation of an individual's ideational knowledge (also called cognitive structure, or propositional, declarative or conceptual), and we deal with two methodologies to produce such representations, Concept Mapping and Ideational Knowledge Mapping. We first describe the different maps they produce, proceed to compare their graphic elements and abstract characteristics, and conclude with a description of the content and structure of the ideational knowledge that is reflected by these features.

Concept Mapping and Ideational Knowledge Mapping

Concept Mapping (Novak, 1998) is based on Ausubel's (Ausubel, 1968) theory of cognition, whose basic units of cognitive structure are concepts and propositions, which are organized in a strictly hierarchical structure according to their abstractness, comprehensiveness, or generality. The individual represents her or his ideational knowledge in a domain by constructing a personal Concept Map (Figures 1 and 2).

The construction begins by ordering the concepts hierarchically from most important or "general" to the most specific, and continues by sequentially connecting pairs of concepts (in the same or different parts of the map) and labelling them by tags that describe their relation. The Concept Map has 3 graphic components: *Concept* (one- or two-word p*hrase)*, *line* (plain or directed, continuous or broken, single or split, extending from one concept to another, and c*alle*d link)*, an*d *text,* label, or tag (a one- or two-word term written on or in a line, and called *relation*).

Ideational Knowledge Mapping was developed from Concept Mapping by removing the hierarchy requirement. The individual constructs from a set of 14 or 15 concepts a Ideational Knowledge Map (Figures 3 and 4) in a standardized, structured and low-directive face-to-face interview. The interviewee is told that there will be no constraints on the nature of the map. The interviewee first arranges the concepts and the interviewer draws that array on a large sheet of paper. This is done in order to relieve the cognitive load and facilitate the knowledge retrieval. Then the interviewee tells the interviewer sequentially which lines or nodes to draw, where (links or encircling concepts), and what text to write on them.

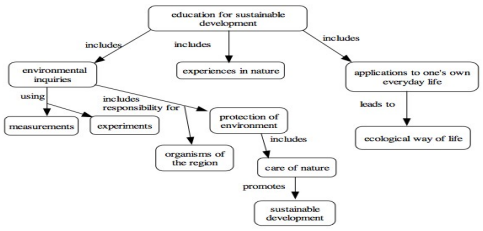

Figure 1: Sample Concept Map.

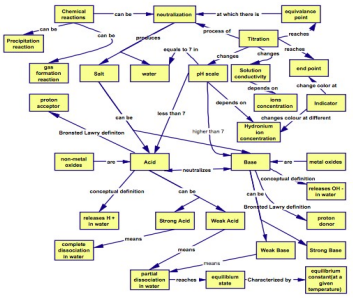

Figure 2: Sample Concept Map.

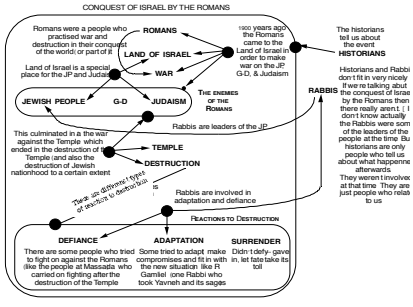

Figure 3: Sample Ideational Knowledge Map.

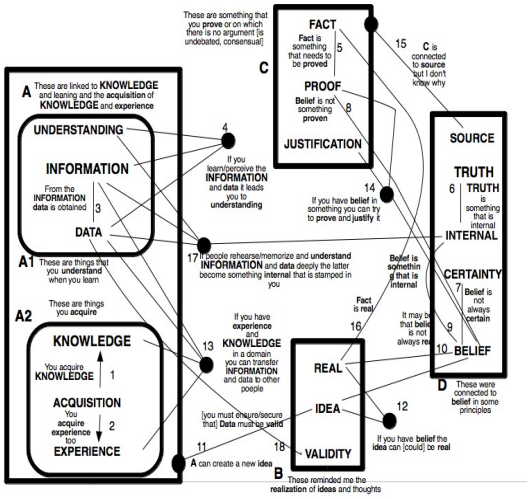

Figure 4: Sample Ideational Knowledge Map.

Comparison of Ideational Knowledge Mapping and Concept Mapping

The Ideational Knowledge Mapping methodology was introduced as an alternative to the traditional Concept Mapping for the externalization of individuals' ideational knowledge and further explore the nature of individuals' ideational knowledge. So we will show several aspects in which that new methodology is advantageous to the older one.

The graphic components

The Ideational Knowledge Map and the Concept Map share the 3 graphic components of solitary concept, bi-concept link, and text yet they also differ in their graphic components and their nature as shown in Tables 1 and 3.

Figures 1-4 and Table 1 show that the Ideational Knowledge Map has 5 unique graphic components (that not necessarily appear in every map). A concept cluster, which is an encircled set of different graphic elements (possibly sub-clusters); a clustered concept, that is included in a concept cluster; a multi-component link (symbolized by a node/black circle) that connects 3 or more components (concepts or concept clusters) and is symbolized by a node; a text (of any length and linguistic form) on a link, node or on the circumference of a concept cluster; a spatial arrangement that can be of any kind (not necessarily hierarchical); and numbers on the links indicating the temporal retrieval order of a link or cluster.

Table 1: Graphic components of Concept Map and Ideational Knowledge Map

Component	Concept Map	Ideational Knowledge Map
Concepts	Retrieved from memory, extracted from a text, or given	Given or added by mapper
Lines	Connect pairs of concepts and can be directed	Connect graphic components and can be directed or delineating a cluster
Nodes	None	Connected by lines to at least 3 graphic components or positioned on the circumference of a cluster
Clusters	None	Basic and compound clusters
Texts	A one or two-word terms written on or in lines	Long sentences written on all lines, besides all nodes, on the circumference of all clusters, or outside the map

The Relations Between the Graphic Components

The Ideational Knowledge Map can be analyzed both visually and conceptually. The visual examinations of the perceptual properties of the web and its components yields such properties as the number of links emanating from a node, and the constituents of a concept cluster. The content analysis of the texts and the abstraction of features of the graphic components unfolds features like the validity of a statement on a line, the mean number of basic ideas in a map and the homogeneity of a cluster.

There are two types of relations among graphic components, namely, inclusion and connectedness. Inclusion is the proper containment (actual or metaphoric-analogical) of some elements in others, and connectedness, which encompasses all kinds of links between the components. These relations are depicted in Table 2, with the whole map as the largest graphic object. Table 2 shows that the inclusion pertains to all the graphic elements and the connectedness applies only to the concepts and clusters. An interesting observation is that the concept cluster is outstanding as both including and connected to all other types of components. The new Linkage is a virtual umbrella for the links and concept clusters, because these two coalesce in different ways, graphic components. The concept cluster includes its sub-clusters, its in- and outbound links, the ideas expressed in its texts.

Table 2: Relations among graphic elements of Ideational Knowledge Map.

Element & Text		Inclusion				Connectedness	
		Concept	Link	Cluster	Idea	Concept	Cluster
Linkage	Concept	Yes	Yes	No	Yes	Yes	Yes
	Link	Yes	No	Yes	Yes	No	No
	Cluster	Yes	Yes	Yes	Yes	Yes	Yes
	Map	Yes	Yes	Yes	Yes	No	No

Note. Yes and No indicate that a particular relation holds or does not exists between the pair of elements, respectively.

It is noteworthy that this analysis necessitated the formation of inclusion combinations of some components that are more "metaphoric" than observable. An example is the reciprocal relations between a concept of an entity: on the one hand contains ideas (mostly implicit) about that entity and its interrelations with its neighboring entities, and on the other hand a concept is a constituent of idea.

Full scale comparison of the two methodologies

We will now compare the two methodologies on several features and greater detail (Table 3), that shows how the Knowledge Mapping methodology is more advantageous to the concept mapping methodology in two major respects.

First, it is rooted in an established and widely accepted theoretical framework which provides nearly restrictions-free construction of a standard and flexible probe, by which adequate external representations of the ideational knowledge can be attained. Second the latter representations contain highly rich data amenable to several rigorous analyses, which yield descriptions of a large number of qualitative and quantitative characteristics of the components of Knowledge Maps.

Table 3: Features of Concept Mapping and Ideational Knowledge Mapping.

	Concept Mapping	Ideational Knowledge Mapping
Visual appearance of the map	Contains concepts, lines, and labels. Hierarchical with the unintegrated components extending over the map. Strong similarity among the Concept Maps.	Contains concepts, lines, nodes, texts and basic and compound clusters. Not necessarily hierarchical, lumpy-chunky and highly integrated. No visual resemblance between the Knowledge Maps.
Links in the map	The number of links is 15 to 35; they connect pairs of concepts; they are mostly directional; few are between-segment links. Labels consist of 1 or 2 words.	The number of links is 10 to 30; they typically connect 3 to 5 components (concepts and clusters); they are mostly nondirectional Labels consist of long texts.
Ideas in the map	Concepts rather than ideas appear as the core of the map. Concept Maps contain small number of ideas; most ideas are basic with limited content; compound ideas are expressed in long indecisive and hard-to-follow series of links.	Links with their texts and clusters are the focus of the map. Knowledge Map includes large number of ideas; most ideas are compound and are expressed as a single linguistic string.
Concepts in the map	Concept maps in a study can, and usually include 15 to 25 concepts that moderately overlap. A concept has typically 2 to 4 links with other concepts.	Knowledge Maps in a study include the same set of 14 or 15 concepts. A concept has typically 4 to 6 links with other concepts.
Instructions for map construction	Are theory-driven and highly restricting. Essentially similar in all versions, vary between settings. Possibly biasing, sometimes inform about the *good* maps. Require prior experience with Concept Maps. Can be executed by a lone individual.	Are theory-free and non-constraining. Standard, apply in all settings. Highly non-directive: Do not restrict the construction or hint as to the nature of map or its components. No prior experience with Knowledge Maps is required. Can be executed only in an interview settings.
Analysis and scoring of the map	Varied analysis and scoring techniques that are mostly quantitative. Scores from different analyses are frequently incompatible. Moderate support of the psychometric quality of the scoring systems; inter-rater reliability and certain types of validity. Measures mainly characterize the components, and to a small extent the whole Map. Measures represent small portions of ideational knowledge which have not been combined to represent larger portions of ideational knowledge. Knowledge is represented compactly by the value (mostly quantitative) on a single (or few) of its features.	Standard analysis schemes assign straightforwardly qualitative and quantitative values to established dimensions. Scores are comparable. The scoring system has moderate psychometric reliability and edumetric construct validity (Carver, 1974). Measures characterize all value levels of the components and the whole Map. Measures represent large portions of ideational knowledge that can combine to represent larger portions of ideational knowledge. Knowledge is represented by values (qualitative or quantitative) on over 60 of its dimensions.
Methodology and role of theory	Theory prescribes precisely the map construction and partly the analyses.	Theory provides for diverse idiosyncratic arrangements and bottom-up analyses and generalizations.
Theoretical basis	Ausubel's theory of hierarchical cognitive structure.	Semantic memory theories.
Relation of map to theory	The theory determines the structure of the map as an isomorph of the cognitive structure.	The theories do not inform about the nature of the map, as the form of the ideational knowledge is not specified.

To illustrate these features of the two kinds of map we will compare briefly the expert chemist's Concept Map (Figure 2) and the doctoral student's Ideational Knowledge Map (Figure 3). The expert's Concept map includes 35 basic ideas (propositions) and 5 compound ideas (consisting more that 2 concepts), and has no hierarchical structure that is required from a concept map. This in-adherence to the basic prerequisite for hierarchicality is common to most Concept Maps, except in domains that have parts where strict hierarchies exist, such as zoological taxonomies or mental diseases. Additionally, certain concepts appear several times in this Concept Map, and like other Concept maps no rationale is given or insinuated for their "organization," making them strongly similar to the obsolete associative memory theory. It is also challenging and highly difficult if not impossible to detect the map's arrows so to decipher and assemble the expert's ideas and her chemical knowledge, and not at the least her overall view and organization of the specific topic. Furthermore, as ordered, this expert, like other Concept Map users, had to form only basic ideas (i.e., propositions) and therefore found it cumbersome to express her complex ideas and causal arguments. This short list of undesirable features of the Concept map is quite convincing that it is not a proper candidate for a contemporary generalization of ideational knowledge.

The Ideational Knowledge Map of the doctoral student, like numerous Ideational Knowledge Maps, is richer in ideas than the expert chemist's Concept Map, as it includes 13 basic ideas and 13 compound ideas (consisting of more that 2 propositions) expressed either in linkages or cluster titles. It has visually discernible organization and structure whose rationale is expressed explicitly, it either has clusters or consists of solitary linked concepts, and it includes many

complex lengthy unambiguous ideas that are read without stopping to wonder how to navigate in the Ideational Knowledge Map. These features stand in sharp contrast to the afore mentioned characteristics of the Concept Map, and make the Ideational Knowledge Map a better candidate for a generalization about the nature of Ideational Knowledge, which will be attempted in the last part of this paper.

The Dimensions of the Graphic Components

The aforementioned analyses yielded various features of the graphic components (Hoz, 2009), some of which are presented briefly.

The *numerosity* of a graphic component is the number of its linked components or its subcomponents . Sample cases are (a) the number of links that a concept or cluster has its with other components, (b) the number of links among the subcomponents of a cluster, (c) the number of a cluster's subcomponents, or (d) the number of the concepts in a multi componential link.

The *depth* of a component is the number of embedding components (similar to Schank's (1982) schemata depth). For instance, in Figure 4 the depth of the cluster B is 0, that of the sub-cluster A1 is 1, and that of the concept INFORMATION is 2.

The *composition* of a component (concept cluster or link) is its constituents or bound (sub)components.

The *structure* of the cluster or the whole map is the familiar (e.g., linear, hierarchical, or circular) or unfamiliar spatial configuration of their components. This is contrary to the characteristic Concept Map's hierarchical tree or the trunk and branches.

The *integration* of a cluster, sub-cluster and the whole Map is the connectedness of its constituent components.

The *coherence* of a cluster, sub-cluster and the whole Map is its domain-specific belongingness and fitting together of its components (differing from those of, e.g., Ioannides & Vosniadou's (2002), or diSessa, Gillespie, & Esterly's (2004)).

The *homogeneity* of a cluster is the domain-specific fitness of its subcomponents.

The *abstractness* of a graphic component is its conceptual remoteness, difference or distance from its constituents that is expressed by the title of a cluster or the text of a multi componential link.

The *validity* of a link or cluster is their domain-specific correctness within their domain that is, the correctness of the ideas in the link's text or the composition and title of the cluster.

The dimension of *voice* is the origin(s) of the ideas and the structure (and possibly of other components).

These dimensions presumably reflect at least roughly and imprecisely certain features of the individuals' Ideational Knowledge.

Summary

The methodology of Ideational Knowledge Mapping provides the individual with a means to externalize and represent graphically parts of her or his ideational knowledge by the Ideational Knowledge Map. That map has many unique kinds of components and ideas that are expressed in diverse ways and render the map amenable to varied analyses whose application provide a gamut of interesting and important visible and abstract features of the map. In these respects the Ideational Knowledge Mapping is much more advantageous than the Concept Mapping methodology, and constitutes a better, albeit more difficult to employ, alternative to the popular and widely used Concept Mapping.

Hypothetical Nature of the Ideational Knowledge Space

A theorization of the Ideational Knowledge Space has to be as compatible as possible with contemporary theories. Hence, as shown earlier, the Ideational Knowledge Map is more qualified than the Concept Map as a possible base for the theorization. This candidacy is supported and justified by the following two sources, theoretical and practical. Theoretically there is many-to-many correspondence between the components of the Ideational Knowledge Map and those of the Ideational Knowledge Space (Figure 5).

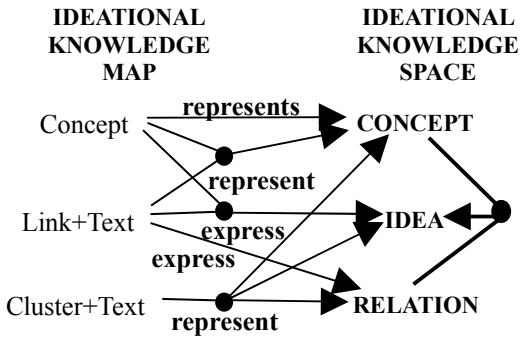

Figure 5: Correspondence between Ideational Knowledge Map and Ideational Knowledge Space.

Practically there is Wilkes' (1997) notion of knowledge updating that is necessitated when people's new knowledge becomes incongruent with their extant knowledge (e.g., when there is new legislation or supreme court verdict). Yet, as noted by Wilkes (private communication) such knowledge updating may not apply to big bodies of knowledge that require the modification of large numbers of ideas and structural reorganization, and it seems easier and more economical to store the newly acquired knowledge elsewhere and link it to the extant knowledge.

Based on these considerations we propose the following theorization:

> *The Ideational Knowledge Space is an assemblage of large **patches**, each of which is a isomorph of an Ideational Knowledge Map, and the patches can be connected through their shared concepts.*

In that space, a concept can have multiple copies that are asterisked and mutually linked, and in different clusters or patches, and several clusters can overlap.

There are many implications of this theorization of which 3 are presented below.

(a) The large patches represent well defined or fuzzy domains or subjects (e.g., scientific, social, political), they can have common concepts and ideas, they can embed sub-patches, and they can be arranged in a two- or three-dimensional space, and in the latter case they can be stacked on top of each other. In many respects the Ideational Knowledge Space is analogous to our universe, with the patches playing the role and having the structure of nebulae, but unlike the non-overlapping nebulae the patches can share components and be connected.

(b) The Ideational Knowledge Map-like subparts of the large patches can include clusters with shared concepts and are therefore overlapping (as is the case in people's knowledge but is not allowed in the Ideational Knowledge Map in order to facilitate their preliminary analyses).

(c) The Ideational Knowledge Space has the status of a non-standard theory like, for instance, Morton & Bekerian's (1986) headed records.

There are several problematic aspects to this theorization of which 4 are presented herein.

(a) There is an inherent conceptual circularity in the representation of ideational knowledge by concepts, relations and ideas. The component of ideational knowledge are concepts, which themselves include ideational and probably other kinds of knowledge. This dual nature of the "concept" resembles that of light, which is conceived both as matter (photons) and wave. Apparently, cognitive psychology has not provided a solution or relief to this circularity and duality.

(b) Concepts are knowledge packages that can be represented by (or linked to) other knowledge representation, such as schema or image. Yet that concept's content is not shown in the Ideational Knowledge Map, because the individuals were not asked to define or characterize what the concepts meant to them. This difficult issue was eschewed in our theorization and these missing concepts' representations were neither dealt with nor introduced to the Ideational Knowledge Space.

(c) The theorization violates a basic principle of semantic memory, namely, that a concept is represented (or exists) only once in a semantic network. Yet such theories had not proposed a solution to this problem.

(d) Doubts are cast on the vague nature of clusters because they were formed prior to the linkages production, but the internal links among their sub-components were neither retrieved sequentially for each cluster (as shown by the numbered retrieval sequence (Figure 3)), nor were all of their sub-components linked.

Conclusion

The methodology of Ideational Knowledge Mapping provides the individual with a means to externalize and represent graphically parts of her or his ideational knowledge by the Ideational Knowledge Map. That map has many unique kinds of components and ideas that are expressed in diverse ways and render the map amenable to varied analyses whose application provide a gamut of interesting and important visible and abstract features of the map. In these respects the Ideational Knowledge Mapping is much more advantageous than the Concept Mapping methodology, and constitutes a better, albeit more difficult to employ, alternative to the popular and widely used Concept Mapping. Consequently, the representation in memory of ideational knowledge was theorized as a gross simile of the cosmos and its component nebulae: A*n assemblage of large* ***patches****, each of which is a simile of an Ideational Knowledge Map, and the patches can be connected through their shared concepts*. Further inquiry, clarification, and adaptations are required on both the advantageous and problematic aspects of this theorization.

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