Identifying Core Issues in Concept Maps

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Abstract

Preliminary informal investigations carried out by our research group suggest that concept maps often contain a small number of identifiable core issues. Studying several concept maps which were referred to in various sources as typical examples of maps which were created by experts and novices, the result remains strikingly the same: The higher the expertise of the person who created the map, the easier the identification of these core issues seems to be.

In this paper we attempt to formally investigate this statement. More specifically, in this paper we study two hypotheses: (a) concept maps are built around a small number of core issues and (b) core issues may be identified by human evaluators and specialized software.

These hypotheses are investigated by examining 45 concept maps from various fields developed by novices or experts.

1. Introduction

A concept map is a graphical tool for organizing and representing knowledge, theories or part of our real world. Concept maps are diagrams that show the relationships between elements (concepts). However, the reality we are called upon to comprehend and to express does not directly emerge from the connections among the elements but from the connections of structures which consist of elements [1]. In accordance with this line of thought, in this paper we define as a "core issue" every distinctive part of a concept map containing significant information content.

A strictly hierarchical concept map contains a root concept and branches which are resolved in sub branches, etc. In such a concept map every branch could be considered as a weak core issue. We use the term "weak" because in this case, a branch a) does not have a rich internal structure and b) is not connected with other branches except for only one way through the upper level concept.

It is widely acceptable that valid cross links express the creativity of the concept map creator much more appropriately than the hierarchical links or the number of hierarchical levels. According to [2, 3], creativity and originality of a mental construction is expressed through the valid linking between remote structures of a domain, i.e. by creating associations [4] between these structures. In this paper, we focus our efforts on a type of structure that is created mainly by this type of linking. These structures, in which we refer with the term "core issue", are parts of a concept map.

We define a core issue of a concept map as an informational structure that has the following three characteristics: a) a rich internal structure, b) it is connected with other such structures and c) it is semantically valid.

The type of linking that is essential for the creation of a strong and well organized core issue is the cross linking. Cross linking is necessary for the creation of cyclic structures and generally for the existence of multiple ways of connecting two concepts in the same or in different structures. A core issue has to be semantically valid as well as structurally rich. This means that in order to define core issues, we ought to move on these two levels.

In this paper, we investigate the extent to which the structures in a concept map, which result from applying pure topological criteria, are the real core issues of that map. In other words, we investigate, if the structurally determined groups of concepts are also semantically appropriate in order to be characterized as core issues.

We use concept maps from various fields and with various numbers of concepts. These concept maps, which are presented as typical concept map examples in various research papers, were categorized based on the expertise of the people who created the map.

2. Searching for core issues in a concept map

Just as with text, we can say that a concept map represents a number (usually a one-digit number) of core issues and also that these issues are connected to each other. These structures are broader entitities compared to concepts and they are composed of concepts.
As implied in the previous section, the search for defining core issues consist of two consecutive steps. First, the search for appropriate structures, and secondly the evaluation of these structures, based on the semantics that these structures express.
In order to start the search for core issues contained in a concept map, we use a topology-based method, which was invented in 2004 by the Newman-Girvan [5] and has been applied with great success to various types of graphs. The specific algorithm is based on the concept of shortest-path betweenness and consists of the following steps:
- Count the shortest distances between all pairs of nodes.
- Calculate the number of shortest paths that pass through each edge.
- Find the edge with the greatest number of paths and delete them from the network.
- After deleting repeat step 1.

The logic of this method is that the structures we aim to analyze the map in, have as boundaries the edges where there is maximum information flow. Indeed, the maximum flow of information cannot pass through the edges that belong to a core issue, but from the edges that connect the core issues, since these edges connect loads of structures rather than concepts.
In figure 1 a small concept map is depicted. Due to the small number of concepts that this map contains, it is easy to see that there is only one core issue and two concepts that are connected to this issue. The concepts, “Graph”, “Nodes”, “Linking lines” and “Linking words” and the lines by which these concepts are connected, define the core issue “Graph”. This core issue is connected with the concept “Concept map” and with the concept “Concepts”.

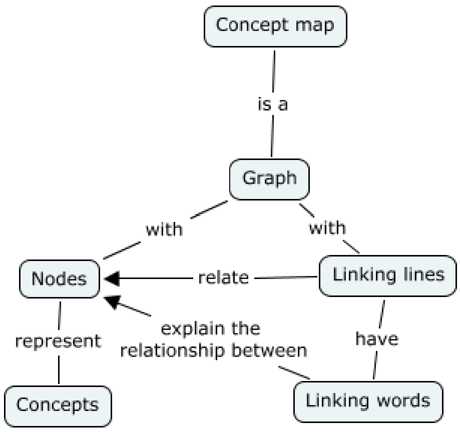

Fig.1: A small concept map.

Applying the previous algorithm to this map, on the first iteration, we get the deletion of the edge “is a” whereas on the second iteration, we get a second deletion for the edge “represent”. Therefore, after two iterations the algorithm detects a well-organized structure which consists of four concepts and five linking lines. Using traditional and well-establish terminology, we could say that this structure has two cross links namely “relate” and “explain the relationship between” and three hierarchical links. The structure is also semantically valid and therefore consists of a core issue.
In the next sections, we present the methodology we use and the results of our investigation regarding the extent in which the structurally determined groups of concepts satisfy semantically based criteria in order to be characterized as core issues.

3. Methodology and results

We analyzed forty five concept maps. These concept maps have been used by researchers, and are presented in the corresponding research papers, for the investigation of various issues regarding the concept mapping learning activity. We created a suitable software application to apply the algorithm and we codified the maps in .cxl format. For each map, the subject, the specific field that the map

belongs to, the number of concepts, the degree of expertise of the map's creator, the number of structures that the algorithm detected, how many of these structures were semantically valid, and how many iterations were needed to determine the structures, have been recorded.
We have to notice that the algorithm we used finds "natural" divisions among the concepts without requiring the user to specify how many structures there should be, or placing restrictions on their sizes. If we leave the algorithm to execute as many iterations as possible then the algorithm will divide the map in as many structures as there are concepts of the map. Therefore, the user has to see step by step the results of the algorithm in order to judge the structures that the algorithm finds regarding their semantic validity.

The results of the analysis are presented in the following table 1.

	Field	Number of concepts	Creator's expertise	Number of structures	Semantically valid structures	Iterations needed	Source
1	Biology	7	Low	0	0	0	[6]
2	Biology	8	High	4	4	2	[6]
3	Learning	18	Medium	5	5	7	[7]
4	Learning	6	High	3	3	2	[8]
5	Biology	11	Medium	4	4	4	[9]
6	Physics	20	High	5	3	11	[10]
7	Learning	27	High	4	3	7	[11]
8	Physics	12	High	3	3	4	[11]
9	Physics	9	Medium	5	5	5	[11]
10	Design	29	High	2	2	1	[11]
11	Physics	24	High	5	5	8	[11]
12	Physics	31	High	3	3	4	[11]
13	Engineering	18	High	4	4	5	[12]
14	Social sciences	19	Low	4	4	3	[12]
15	Social sciences	43	Medium	8	8	7	[12]
16	Social sciences	14	Medium	4	4	5	[13]
17	Information systems	24	Medium	4	4	4	[14]
18	Learning	11	High	3	3	4	[15]
19	Information systems	13	Medium	3	3	3	[16]
20	Information systems	9	Low	2	2	1	[16]
21	Geology	15	Medium	3	1	5	[16]
22	Geology	7	Medium	3	2	3	[17]
23	Physics	31	Medium	9	9	19	[18]
24	Physics	44	High	2, 8	2, 8	7, 15	[18]
25	Physics	19	Medium	3, 5	3, 5	3, 5	[18]
26	Biology	15	Medium	6	6	6	[19]
27	Biology	11	Medium	3	3	4	[19]
28	Biology	12	Medium	2, 5	2, 5	2, 5	[19]
29	Biology	16	Medium	4	4	4	[20]
30	Biology	18	Medium	3	3	2	[20]
31	Social sciences	23	High	3, 4	3, 4	3, 5	[21]
32	Environmental sc.	24	Medium	2	2	1	[22]
33	Learning	20	Medium	8	8	8	[23]
34	Learning	17	Medium	5	5	4	[23]
35	Biology	11	Low	0	0	0	[23]
36	Social sciences	24	High	3	3	5	[23]
37	Biology	15	Medium	0	0	0	[23]
38	Design	14	Low	4	4	4	[23]
39	Design	22	Medium	4	4	7	[23]
40	Design	26	High	4	4	7	[23]
41	Design	27	Low	4	4	4	[23]
42	Design	35	Medium	4	4	5	[23]
43	Design	56	High	5, 7	5, 7	4, 7	[23]
44	Physics	17	High	2	2	1	[24]
45	Physics	16	Low	2	2	1	[24]
Total				163, 177	157, 171		

Table 1: Concept maps' analysis

The column “Number of structures” refers to the number of parts that the algorithm divides the concept map into. For example, the algorithm divided the concept map of figure1, which is the concept map of the forth record of the table1, in three parts after two iterations. One of them is a well-organized structure (core issue) while the other two are isolated concepts, which the learner may wish to develop further or not. In some cases (records 24, 25, 28, 31, 43) using the algorithm we can further divide the initial structures into smaller structures, which are also semantically valid. In three cases (records 1, 35, 37) the concept map had no internal structure. In the first case the map was simply a star structure, while in the other two the whole map was a single structure.
It is remarkable that in 41 out of 45 cases, every structure that the algorithm finds was semantically valid. However, this fact does not mean that the there are not alternative or more suitable structures that the learner could use to develop the map. The finding of existing structures is simply a feedback and not a final evaluation for the concept map creator.

4. Discussion and conclusions

The development of a mental construction cannot be accomplished effectively and efficiently, as has been proved, even in quantitative terms by Simon [25], without the use of modules. Therefore, it is crucial to find ways to guide the learner through this process. The presented method gives feedback regarding the structures contained in the map. More than 95% of the structures proposed, by the algorithm, proved to be semantically valid. However, during the development of a concept map, the learner has to be asked to judge not only the semantic validity of these structures but mainly, to adopt or rethink the way that he/she has decided to develop the concept map. This is necessary because the semantic validity of the proposed structure does not imply semantic optimality. As the Pellegrino, Chudowsky & Glaser [24] have shown, an expert uses semantically fertile modules to develop a concept map.

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References

[1] Minsky, M. (2007). *The emotion machine: Commonsense thinking, artificial intelligence, and the future of the human mind*. Simon and Schuster.
[2] Mednick, S. (1962). The associative basis of the creative process. *Psychological review, 69*(3), 220.
[3] Baars, B. J. (2002). The conscious access hypothesis: origins and recent evidence. *Trends in cognitive sciences*, *6*(1), 47-52.
[4] Granovetter, M. S. (1973). The strength of weak ties. *American journal of sociology,* 1360-1380.
[5] Newman, M. E., & Girvan, M. (2004). Finding and evaluating community structure in networks. *Physical review E*, *69*(2), 026113.
[6] Kinchin, I. M. (2001). If concept mapping is so helpful to learning biology, why aren't we all doing it?. *International Journal of Science Education*, *23*(12), 1257-1269.
[7] Freeman, L. A., & Urbaczewski, A. (2002). Concept Maps as an Alternative Technique for Assessing Students' Understanding of Telecommunications.
[8] Ruiz-Primo, M. A. (2000). On the use of concept maps as an assessment tool in science: What we have learned so far. *REDIE: Revista Electrónica de Investigación Educativa*, *2*(1), 3.
[9] Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of research in science teaching*, *33*(6), 569-600.
[10] Ruiz-Primo, M. A., Shavelson, R. J., Li, M., & Schultz, S. E. (2001). On the validity of cognitive interpretations of scores from alternative concept-mapping techniques. *Educational Assessment*, *7*(2), 99-141.
[11] Novak, J. D., & Cañas, A. J. (2008). The theory underlying concept maps and how to construct and use them. *Florida Institute for Human and Machine Cognition Pensacola Fl, www. ihmc. us.[http://cmap. ihmc. us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps. htm].*

[12] Turns, J., Atman, C. J., & Adams, R. (2000). Concept maps for engineering education: A cognitively motivated tool supporting varied assessment functions. *Education, IEEE Transactions on*, *43*(2), 164-173.

[12] Chiu, C. H., Huang, C. C., & Chang, W. T. (2000). The evaluation and influence of interaction in network supported collaborative concept mapping. *Computers & Education*, *34*(1), 17-25.

[13] Halttunen, K., & Järvelin, K. (2005). Assessing learning outcomes in two information retrieval learning environments. *Information processing & management*, *41*(4), 949-972.

[14] Doorn, D., & O'Brien, M. (2007). Assessing the gains from concept mapping in introductory statistics.

[15] Chang, K. E., Sung, Y., Chang, R., & Lin, S. (2005). A new assessment for computer-based concept mapping. *JOURNAL OF EDUCATIONAL TECHNOLOGYAND SOCIETY*, *8*(3), 13.

[16] Leake, D., Maguitman, A., & Reichherzer, T. (2004). Understanding knowledge models: Modeling assessment of concept importance in concept maps. In *Proceedings of the twenty-sixth annual conference of the cognitive science society* (pp. 795-800).

[17] Van Zele, E., Lenaerts, J., & Wieme, W. (2004). Improving the usefulness of concept maps as a research tool for science education. *International Journal of Science Education*, *26*(9), 1043-1064.

[18] Rye, J. A., & Rubba, P. A. (2002). Scoring concept maps: An expert map‐based scheme weighted for relationships. *School Science and Mathematics*, *102*(1), 33-44.

[19] Rice, D. C., Ryan, J. M., & Samson, S. M. (1998). Using concept maps to assess student learning in the science classroom: Must different methods compete?. *Journal of Research in Science teaching*, *35*(10), 1103-1127.

[20] Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research*, *76*(3), 413-448.

[21] Available on line at **www.science-west.ca/GettingAround**.

[22] Walker, J. M., & King, P. H. (2002, June). Concept mapping as a form of student assessment and instruction. In *Proc. 2002 ASEE Annual Conf. and Exp.*

[23] Pellegrino, J. W., Chudowsky, N., & Glaser, R. (2001). *Knowing what students know: The science and design of educational assessment*. National Academies Press.

[24] Simon, H. A. (1962). The architecture of complexity. *Proceedings of the american philosophical society*, 467-482.