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CMAP CONSTRUCTION: CHALLENGES FOR THE FIRST TIME USERS AND PERCEPTIONS OF CMAP'S VALUE, A QUALITATIVE STUDY

Natalia Derbentseva, Defence Research and Development Canada
Frank Safayeni, University of Waterloo, Canada

Abstract. Constructing a Concept Map (CMap) is not an easy and straight forward process even for a seasoned CMapper. In order to get a better understanding of the specific challenges that CMap creators experience we collected subjective reports of difficulties that novice CMappers experienced during construction of their first map and what they perceived to be the advantages of this form of representation. Comment analysis revealed that the major sources of difficulty for the novice map creators were associated with creating concepts and relationships, planning and organizing the information, keeping their maps focused and avoid including irrelevant information. The design of the study and participants' comments are discussed in detail. This information may be particularly useful to the CMap instructors who train novices.

1 Introduction

Concept Maps (CMap, Novak, 1998) have gained a widespread popularity in educational and knowledge management settings, and it is safe to imply that more and more individuals learn to use this tool. There is a considerable body of research on the application of CMap to improve learning new material (Daley, 2004; Markow & Lonning, 1998; Edmondson, 1995), as a knowledge elicitation methodology (e.g. Coffey et al., 2004; Zanting, Verloop, & Vermunt, 2003; Hoffman et al. 2002; Anderson et al. 2000), and for evaluating knowledge of learner (e.g. Ali & Ismail, 2004, Kinchin, 2000; Roberts, 1999; Williams, 1998). Some authors have reported CMap users' attitude towards this tool (e.g. Markow & Lonning, 1998), or commonly experienced difficulties (e.g. Novak & Cañas, 2008; Cañas & Novak, 2006), however the investigation of attitudes and subjective experiences was not a primary goal of these studies.

In this paper we turn our attention to novice CMappers and examine their experience with constructing a map, namely what difficulties they experience constructing their first map and their subsequent attitude toward this form of knowledge representation. In our study we asked our participants to first build their own CMap on a well studied and familiar topic, and then elaborate on the difficulties they experienced and perceived advantages of CMap form of representation. Since the questions posed to the participants were open-ended, all the reported difficulties and attitudes towards CMap were identified by the participants rather than suggested by the researchers.

A related question to the variety of difficulties that map creators experience is the question of how these difficulties might be mitigated. As a result, another interest we pursued with this study was to investigate whether starting CMap construction with a quantified root concept reduces CMap construction difficulty, at least partially. Quantification significantly reduces ambiguity in the root concept by selecting a dimension within the concept and setting it in motion (Safayeni et al. 2005). As a result, quantification of the root concept narrows down possible set of concepts and linking phrases that could be connected to it. It is then reasonable to expect that building a map starting with a quantified root concept should reduce difficulty with selection of concepts and relationships.

This paper reports on the initial systematic investigation of user experiences and attitudes towards CMap.

2 Method

We conducted a qualitative study through a structured open-ended questionnaire that followed a CMap construction task.

2.1 Participants

150 undergraduate university students participated in this study. All participants were enrolled in a 3rd year Organizational Design and Technology course and received partial course credit for their involvement in the study. The participants were 2nd and 3rd-year students from the faculties of Engineering (83%) and Arts and Sciences (17%). Majority of the participants (88%) had never used CMaps before the study, and 12% of the participant indicated that they had used or seen CMaps in some capacity before.

2.2 Procedure

The study was conducted in a classroom setting. Each participant received a 7-page booklet with instructions. The study was organized in the following way: first, the participants were asked to carefully read all the instructions at least twice, then construct a CMap answering provided focus question, and finally, answer two open-ended questions about their experience with the map construction activity.

2.2.1 Map construction

The instructions in the booklet contained a description of CMap and its elements, example of CMap taken from Cañas and Novak (2006), and step-wise instructions on how to construct a map. CMap was defined as a graph representing knowledge. Definition and description of concepts, relationships, propositions, and overall organization of CMaps with examples were included in the instructions. The focus question and root concept were provided to the participants. All participants constructed their maps answering the same focus question to allow for future content and structure analysis of the maps. The goal of the task was to construct a map that provides a comprehensive answer to the given focus question using no more than 10 additional concepts.

The topic chosen for the CMap task was Ashby's Law of Requisite Variety, which was extensively covered throughout the course. The vast majority of the students in the course had a good grasp of this material – an average mark for a quiz on this topic written not long before the study was 94%. The focus question for the map construction task was "How does change in external variety affect an organization?" The root concept was non-quantified ("External variety") for one half of the participants (N_{NQ} = 76), and it was quantified ("As external variety increases") for the other half of the participants (N_Q = 74). The study booklet contained two pages for map construction – one for practice and one for the final copy – that were blank except for the root concept and the focus question.

2.2.2 Post CMap construction questionnaire

The last page of the booklet contained two open-ended questions, which were to be completed at the end of the study, after the CMap was constructed. The two questions were

1. What difficulties did you experience constructing your map? Please elaborate as this information is very important to us.
2. Do you find that a CMap-representation of this information has any advantages over a usual text representation? If yes, in what context? Please explain your answer.

In this paper we only report on the results of our analysis of participants' responses to the above two questions.

2.3 Data analysis

There were 793 lines of text from 150 participants in response to the first question and 753 lines of text from 149 participants in response to the second question. Participants' responses for each of the questions were categorized based on the similarity of their meaning. The unit of analysis was a comment, which constituted a comprehensive idea regarding an experienced difficulty (question 1) or perceived advantage of CMap representation (question 2). Responses were analyzed with QSR N6 (QSR International Pty Ltd, 2002) qualitative data analysis software.

3 Findings

3.1 Difficulties with CMap construction

Our participants provided 418 distinct comments (on average, 2.8 per participant) pertaining to the various difficulties that they experienced during their CMap construction task. We organized these comments into four general themes, namely difficulties associated with:

- *Concepts and relationships*, 38% of all the comments
- *Planning and organizing* information in a CMap form, 31%,
- Maintaining the *focus* and defining the *scope* of their CMap, 16%, and
- Specific constraints of *experimental task design*, 15%.

Each of the above themes combined several categories of comments. Table 1 provides a detailed breakdown of the four general level themes into categories with respective frequencies of comments from the quantified

root concept group, non-quantified root concept group, and the overall for each of the categories. The "Theme/Category/Sub-category" column in Table 1 reports the various categories and sub-categories that contributed to each of the themes. The three "Number of comments" sub-columns report the number of comments for each category provided by the participants in each of the groups and the totals. The "% of comments" column report the percent of all the comments (n = 418) in each category. Below we discuss each theme in more detail illustrating categories with examples of comments.

THEME/CATEGORY/SUB-CATEGORY	# of comments			% of comments (n = 418)
	Non-quant. root concept group	Quant. Root concept group	Total	
1. Concepts and relationships	***81***	***78***	***159***	***38%***
1.1 Identifying and selecting meaningful relationships	30	33	63	15%
1.2 Identifying and selecting concepts	27	16	43	10%
1.3 Wording	19	23	42	10%
1.4 Distinguishing between concepts and linking phrases	5	6	11	3%
2. Planning and organizing	***63***	***68***	***131***	***31%***
2.1 "System" organization	*[21]*	*[19]*	*[40]*	*[9%]*
2.1.1 Establishing flow among several concepts	13	10	23	5%
2.1.2 Limiting effect of existing concepts	5	5	10	2%
2.1.3 Representing reciprocal relationships	3	4	7	2%
2.2 Beginning construction and prioritizing information	17	19	36	9%
2.3 Structural issues	*[14]*	*[17]*	*[31]*	*[7%]*
2.3.1 Overcoming top-down organization/choosing structure	6	12	18	4%
2.3.2 Avoid overlapping lines	3	5	8	2%
2.3.3 Spatial organization	5	0	5	1%
2.4 Lack of solid understanding of the topic	11	13	24	6%
3. Focus and scope	***40***	***28***	***68***	***16%***
3.1 Staying focused, avoid including irrelevant information	29	21	50	12%
3.2 CM does not allow to explain	11	7	18	4%
4. Experimental task design	***30***	***30***	***60***	***15%***
4.1 Limit of 10 concepts	14	10	24	6%
4.2 New to CMap	7	12	19	5%
4.3 Given root concept was a constraint	5	6	11	3%
4.4 Attempt to mimic the example	4	2	6	1%
Total:	**214**	**204**	**418**	**100%**

Table 1: General level themes and categories of difficulties with their respective frequency of mentioning during CMap construction

3.1.1 Difference between the quantified and the non-quantified root concept groups

Contrary to our expectations, we did not find any significant differences in the reports of difficulties between the group that started building their map with the quantified root concept and the group that started building their map from the non-quantified root concept.

Some observed differences were in the expected direction, e.g. fewer participants from the quantified root concept group than the non-quantified group reported experiencing difficulty with identifying and selecting concepts (category 1.2, Table 1) and the focus and scope theme (theme 3, Table 1). On the other hand, more participants in the quantified root concept group than in the non-quantified group reported difficulty with overcoming top-down organization and selecting structure for their map (sub-category 2.3.1, Table 1) and dealing with the novelty of CMap form of representation (category 4.2, Table 1).

However, none of the differences in the themes and categories between the two groups reached statistical significance. We combined the data from the two groups for further analysis.

3.1.2 Theme 1: Concepts and relationships

The most frequently mentioned theme of difficulties was *Concepts and relationships* (theme 1, Table 1). This theme combined comments related to difficulty in *identifying and selecting relationships* (category 1.1, Table 1) and *concepts* (category 1.2, Table 1), difficulty with *wording* them (category 1.3, Table 1), and *distinguishing between concepts and linking phrases* (category 1.4, Table 1). Table 2 provides examples of typical comments for each of the categories in the *Concepts and relationships* theme. The "Frequency" column in Table 2 reports the percent of participants (N = 150) that reported experiencing each particular category of difficulties.

Not surprisingly, the most frequent category in this theme was *identifying and selecting meaningful relationships* among concepts. It is worth noting that there is a qualitative difference between the comments in the category *wording* and the categories of *identifying and selecting concepts* and *relationships*. In the latter two categories the difficulty is conceptual, i.e. thinking of relevant concepts/relationships in the context of the given topic and selecting the most appropriate ones. In the *wording* category the difficulty is rather related to phrasing already identified and selected concepts/relationships in a concise and understandable manner.

The least frequent category in the first theme was *distinguishing between concepts and linking phrases*. It was reasonable to expect that this difficulty might naturally arise in the quantified root concept condition of the map construction activity, since root quantification introduces verbs as part of the concept, thus blurring the difference between concepts and linking phrases. However, there was no significant difference in the frequency of comments for this category between the conditions. Thus, it seems that this difficulty was not related to the specific root concept.

Category	Frequency	Typical comments
1.1 Identifying and selecting meaningful relationships	42%	(a) "A lot of the nodes are inter-related, so it was difficult to see which nodes should link to which node so that it helps to answer the question" (b) "After finding the important nodes it is hard to understand how they might relate"
1.2 Identifying and selecting concepts	29%	(a) "It was difficult to determine all related concepts." (b) "I had a lot of difficulty with determining what nodes to include in the CMap."
1.3 Wording	28%	(a) "Trying to find the right words to explain a whole concept or relationship between concepts (*was difficult*)." (b) "I found it difficult to appropriately phrase the propositions, which caused me to doubt my answers."
1.4 Distinguishing between concepts and linking phrases	7%	(a) "Experienced some uncertainty as to what ideas should be framed as concepts and what ideas should instead be framed as relationships between concepts." (b) "Hard to distinguish between concepts and relationships"

Table 2: Categories, their frequencies, and examples of comments for the *Concepts and relationships* theme.

The overwhelming difficulty with identifying, selecting, and wording concepts and relationships that significant proportion of our participants identified was not surprising as even experienced CMappers find creating propositions to be the most challenging aspect of building a concept map (Novak & Cañas, 2008; Cañas & Novak, 2006). The aspect of the *Concepts and relationships* theme unique to novices might be associated with *distinguishing between concepts and linking phrases*, although, no doubt, more data is needed to investigate this further.

3.1.3 Theme 2: Planning and organizing

Planning and organizing theme (theme 2, Table 1) was the second most frequently mentioned theme that emerged from our data. This theme combined comments related to difficulty in *"System" organization* (category 2.1, Table 1), *Beginning construction and prioritizing information* (category 2.2, Table 1), *Structural issues* (category 2.3, Table 1), and *Lack of solid understanding of the topic* (category 2.4, Table 1). Table 3 provides examples of typical comments for each of the categories in the *Planning and organizing* theme. The "Frequency" column in Table 3 reports the percent of participants (N = 150) that reported experiencing each particular category of difficulties.

The issues that comprised the *"System" organization* category (category 2.1, Tables 1 and 3) were associated with *Establishing flow among several concepts* (sub-category 2.1.1, Table 1), *Limiting effect of existing concepts* (sub-category 2.1.2, Table 1) *Representing reciprocal relationships* (sub-category 2.1.3, Table 1). These issues, although not very frequently identified by our participants, do point to a different source of difficulty in map construction than just creating propositions. The issues raised by our participants point to the

necessity that they felt to unite the existing propositions in a map into a coherent "system," rather than having them as more-or-less independent statements.

Category	Frequency	Typical comments
2.1 "System" organization	27%	(a) "It was tricky to connect several relationships together so that they formed a linked network" (b) "(*I found myself to be*) more preoccupied with finding concepts that fit the existing relations in the map than illustrating the true flow between these concepts"
2.2 Beginning construction and prioritizing information	24%	(a) "It was difficult to start creating the CMap, I wasn't sure what ideas would be valid." (b) "In constructing a CMap, it is difficult to prioritize and relate information in a logical manner. For instance, in this exercise, I had difficulty prioritizing the nodes that meaningfully describe the topic."
2.3 Structural issues	21%	(a) "It was difficult to not to think linearly and draw CMap as two distinct top-down paths without any shared nodes." (b) "Another difficult part of constructing a CMap was to choose a structure, it is hard to clearly define a structure that will work best to answer the question"
2.4 Lack of solid understanding of the topic	16%	(a) "(*it was difficult because you*) need to understand everything before starting your CMap. Essentially, there need to be nodes and relationships in your mind about the topic before you can construct CMaps… It can only best be constructed after learning the stuff that you intend to construct."

Table 3: Categories, their frequencies, and examples of comments for the *Planning and organizing* theme.

Another interesting aspect highlighted by some of our participants was the limiting effect of existing concepts in their maps that constrained the search and selection of other concepts to be included. Individuals felt that the necessity to fit the existing nodes and relationships took priority over representing "the true flow" among the significant ideas. As well, perceived inability to represent reciprocal relationships constrained participants' ability to explain the topic.

3.1.4 Theme 3: Focus and scope

Theme *Focus and scope* (theme 3, Table 1) combined comments in two categories *Staying focused, avoid including irrelevant information* (category 3.1, Table 1) and *CM does not allow to explain* (category 3.2, Table 1). Table 4 provides examples of typical comments for both categories in the *Focus and scope* theme, following the format of Tables 2 and 3.

Category	Frequency	Typical comments
3.1 Staying focused, avoid including irrelevant information	33%	(a) "It was easy to wander off-topic, shift focus/emphasis to related concepts rather than staying on the original concept." (b) "(*it was difficult*) staying focused on question and not including irrelevant relationships: I had to erase some concepts and relationships when I got carried away. It was hard not to get caught up in the details"
3.2 CM does not allow to explain	12%	(a) "Using a CMap to answer a question was difficult, since a question may need more in-depth explanation than is possible in a map." (b) "There was no way to explain the relationship, e.g. "[mechanistic structure] -> does not well handle -> [external variety]", but I couldn't explain why."

Table 4: Categories, their frequencies, and examples of comments for the *Focus and Scope* theme.

Although, the frequency of comments that fall under the theme *Focus and scope* was not very high, one category that contributed to this theme, *Staying focused, avoid including irrelevant information* (category 3.1, Table 1) was the second most frequently mentioned category in the whole set, after the *Identifying and selecting meaningful relationships* (category 1.1, Tables 1 and 2). The difficulty with staying focused on the topic seems to be conceptually related to the *limiting effect of existing concepts* issue from the *Planning and organizing* theme, even though our participants did not make this connection explicitly. Tendency to include concepts in the map that best fit with the existing concepts might easily derail the map construction process. In addition, the explicit requirement to answer the specified focus question might have exacerbated the conflict between including irrelevant information and answering the focus question.

3.1.5 Theme 4: Experimental task design

The last theme of comments, *Experimental task design* (theme 4, Table 1), was the least frequent among the four themes and combined all the comments related to the specifics of the experimental task design that contributed to the participants' difficulty in creating their CMap. Such categories as *Limit of 10 concepts* (category 4.1, Table 1), *New to Cmap* (category 4.2, Table 1), *Given root concept was a constraint* (category 4.3, Table 1), and *Attempt to mimic the example* (category 4.4, Table 1) contributed to this theme.

The main difficulty associated with the task design was the constraint on the number of allowed concepts. Overall, 16% of the participants felt that allowing 10 additional concepts was too constraining, while one individual appreciated this constraint as helping him/her to stay focused. In addition, 13% of the participants commented that they experienced some initial difficulty constructing their CMap since they had not done it before the study and needed to learn the concept of CMap itself. Also, 7% of the participants indicated that the given root concept, i.e. "External Variety" or "As external variety increases," was limiting and made map construction more difficult in comparison to choosing their own root concept. Last, 4% of the participants mentioned that they attempted to mimic the example of a CMap provided in the instructions, which made their map construction more difficult.

3.2 Perceived advantages of CMap form of information representation

In response to the question "Do you find that a CMap-representation of this information has any advantages over a usual text representation," 48% of the participants responded affirmatively and provided reasons why they thought it was the case; 8% of the participants did not find any advantages in CMap representation; and 44% articulated both advantages and disadvantages of CMap form of representation.

Our participants provided 305 comments outlining the reasons why they thought CMap had an advantage over the text representation. Table 5 summarizes these comments providing frequency of mentioning and proportion of all the comments.

CMap advantages	**% of participants (*N* = 149)**	**% of comments (*n* = 305)**
Shows relationships	47%	23%
Shows the big picture/summary	38%	18%
Provides visual representation	32%	16%
Easier to understand/faster access to information	26%	12%
Concise/leaves out unnecessary detail	21%	10%
Facilitates creative thinking	13%	6%
Good way to represent cause-effect relationships and chain/cycle of events	10%	5%
Easier to memorize material	9%	5%
Shows the flow/has different routes	9%	4%

Table 5: Perceived advantages of CMap form of information representation.

The three most frequently mentioned advantages of CMaps were showing relationships among concepts and making them explicit (47% of the participants), providing a summary and a big picture of the topic (38%), and providing visual representation (32%). Interesting issues related to facilitating creative thinking, representing cause-effect and cycle of relationships, and facilitating memorization of the material were also identified, providing a wide spectrum of CMap added value over the text representation.

Although we did not explicitly ask our participants to elaborate on the disadvantages or possible shortcomings of CMap form of representation, 52% of the participants volunteered this information in 120 comments. There were more than twice as many comments regarding CMap advantages than shortcomings. Table 6 summarizes these comments and their frequency.

Predominant disadvantage of CMap form of representation was identified as the lack of detail and not providing explanations, which echoed the category of difficulty with CMap construction, *CM does not allow to explain* (category 3.2, Tables 1 and 4) from the theme *Focus and scope*. This shortcoming could be partially due

to the design of the task as it was a paper and pencil activity and did not allow utilizing advanced capabilities of software packages that might have mitigated this problem.

CMap disadvantages	**% of participants (*N* = 149)**	**% of comments (*n* = 120)**
Lacks detail/does not provide an explanation	26%	33%
Becomes too complicated if large	11%	14%
No logical flow of information	9%	11%
Depends on the content and audience	8%	10%
Need to have background knowledge to understand CMap	7%	8%
Not a good way to learn new material	5%	7%
Does not answer the question	5%	7%
Harder to construct and make changes to	5%	7%
Not effective way to represent one's knowledge	3%	4%

Table 6: Perceived disadvantages of CMap form of information representation.

However, other points raised, such as CMap becomes too complicated when it gets large, having no logical flow of information (i.e. no predetermined sequence for reading the CMap), and necessity of background knowledge for comprehension, etc. might not be easily resolved with the use of technology and might serve as a caution for potential CMap application.

4 Conclusion

Although the most frequently mentioned difficulty with CMap construction were associated with creating propositions, our analysis revealed other issues that CMap creators experience. These are the difficulties with planning and organizing a CMap and maintaining focus and scope. Especially worth noting are the difficulties associated with organizing propositions into a coherent system, prioritizing information, and realizing the inadequacy of one's knowledge of the subject revealed by the map construction process.

Some of the difficulties that our participants identified seem to be more persistent than others. For example, creating propositions (i.e. concepts and relationships) have been reported to be the biggest challenge even for experienced concept map users (Novak & Cañas, 2008; Cañas & Novak, 2006). Whereas other difficulties might be specific to novice CMap creators and could eventually diminish with more practice. At this point, our study cannot identify which of the difficulties are precisely novice-specific as we do not have comparable data from the experienced CMap users. This is an interesting direction for further investigation.

The vast majority of the participants (91%) were able to articulate greater value of CMap form of representation over the usual text after only a single encounter with the tool. The most valuable features of CMaps were articulating the relationships, providing a big picture of the topic, its visual form, and allowing for easier understanding of the material. Yet other advantages of CMap not as frequently mentioned but important to note included facilitating creative thinking, representing cause-effect and cycle relationships, and helping to memorize material in the CMap form.

Still 52% of the participants elaborated on possible shortcomings of the use of CMap without an explicit prompting for this information. Some of the issues identified as difficulties or disadvantages, such as CMap's not providing/allowing for explanation, might be significantly mitigated with the use of CMap software, such as CmapTools. CmapTools allows appending additional information to both concepts and linking phrases in the form of text, images, video, etc., thus providing an opportunity to explain. Yet still other issues e.g. lack of logical flow or difficulty with "system" representation might require a different approach to addressing them.

The use of the open-ended questions in our study ensured that all the reported difficulties and attitudes towards CMap were genuinely generated by the participants rather than suggested by the researchers. It is reasonable to assume that the participants reported the most predominant issues they had experienced with the task; however, it does not imply that the lists provided were exhaustive. As a result, it might be premature to dismiss some of the raised issues on the basis of their low frequency of occurrence. Low frequency does not mean that other participants who did not explicitly stated that particular issue did not experience it, and further

investigation through a structured closed-ended questionnaire or an in-depth interview method will provide more information on the issue.

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