# Facilitating the Creation of Graphical Knowledge Representations for Brainstorming and Decision Support[1]

**John W. Coffey[1,2], Alberto J. Cañas[1], Joesph D. Novak[1], Robert R. Hoffman[1], Mary Jo Carnot[1], and Andrea Jost[1]**
**[1]The Institute for Human and Machine Cognition**
**[2]Department of Computer Science**
**The University of West Florida**
**Pensacola FL 32514**

**Abstract**

This paper contains a description of the use of Concept Maps for facilitated brainstorming sessions. Concept Maps were originally used to assess the conceptual knowledge of school children. It has since been realized that the creation of Concept Maps can be useful for knowledge elicitation and representation, including for brainstorming. This paper describes basic issues pertaining to the facilitation of brainstorming sessions with Concept Maps and presents a case study of a brainstorming workshop on alternate scenarios for Mars exploration carried out by participants from NASA Ames Research Center and researchers at the Institute for Human and Machine Cognition (IHMC), Pensacola, FL.

## 1. Introduction

At no other time in human history has such a premium been placed on managing knowledge to support good decision-making. Making good decisions going forward often relies upon considering (and utilizing or rejecting) the acquired understandings of the past. Such knowledge may vary qualitatively. For example, the distinction has been made between knowledge that is personalized and that which is codified (Hansen, et al., 1999). This basic distinction goes to the difference between knowledge that can be represented in retrievable knowledge objects in a database and that which remains in humans and is elaborated by dialogs between individuals. Hansen, et al., suggest that some knowledge is not susceptible to codification, and in such situations, reliance on individuals is key.

Brainstorming is "a method for developing creative solutions to problems. It works by focusing on a problem, and then deliberately coming up with as many deliberately unusual solutions as possible and by pushing the ideas as far as possible" (Mind Tools, 2002). As described in the next paragraphs, graphical representations of ideas are useful for brainstorming.

Several graphical representations have been created to represent knowledge. Semantic Networks (Fisher, 1990), Mind Maps (Buzan & Buzan, 1996), Knowledge Maps (Lambiotte, Skaggs, & Dansereau, 1993) and Concept Maps (Novak & Gowin, 1984) have all been used to represent knowledge. One method of brainstorming that has received only passing notice in the literature is facilitated, "on-the-fly" creation of graphical representations of knowledge by a group. The facilitation in such an effort requires specialized skills for the realization of an optimal result. There are both good and bad points with regard to a facilitator who is part of the group of experts, or who is expert in knowledge elicitation and tools to support brainstorming with graphical representations.

This paper contains a discussion of the issue of facilitating brainstorming and decision-making sessions with Concept Maps. The success of such efforts hinges on several factors that are described here. The discussion will start by describing Concept Maps as a tool for knowledge elicitation and representation. A survey of some relevant literature will be presented. This paper will address issues from the facilitator's perspective, challenges in performing this type of work, and the sorts of results that can be obtained from the effort. The paper will close with a case study on the use of Concept Maps to facilitate brainstorming.

## 2. Concept Maps

Concept Maps are graphical representations of knowledge that are comprised of concepts and the relationships between them. A concept is defined as a perceived regularity in events or objects, or a record of events or objects, designated by a label (Novak, 1998). Relationships between concepts are indicated by connecting lines that link them together. Typically, the linking lines are labeled to specify the relationship between the concepts. The label for most concepts is a single word or a short phrase. Concept-link-concept triples form propositions, which are meaningful statements about

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some object or event. Figure 1 is a Concept Map from an interactive brainstorming session that is the subject of a case study that will be discussed in Section 5 of this paper.

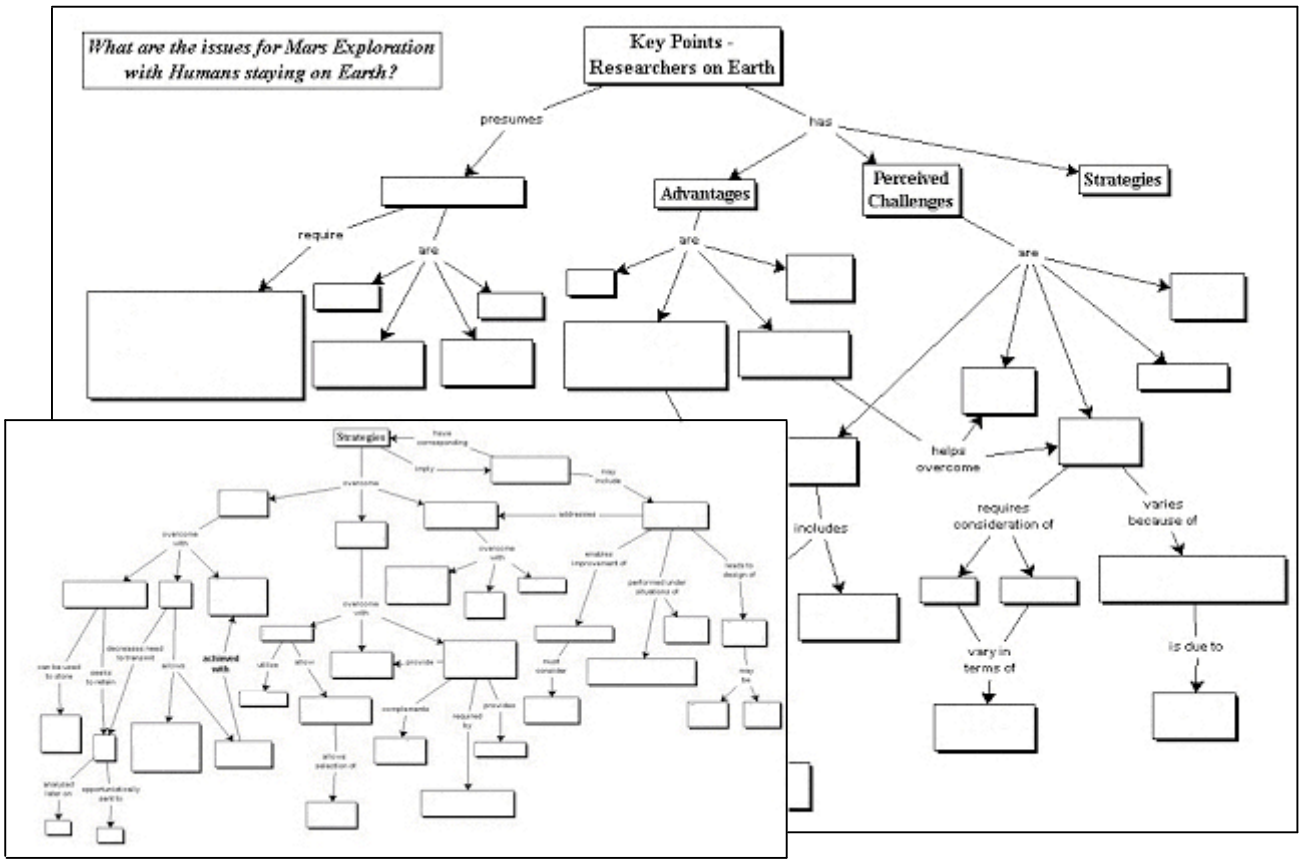


**Figure 1. A Concept Map on high-level issues pertaining to Mars Exploration.**

Figure 1 illustrates several characteristics of Concept Maps. The focus of this session was to determine key issues in the scientific investigation of Mars if humans work from earth. The topic of the map can be determined by reading the focus question that appears in italics in the top-left corner of the larger Concept Map to the back. The concepts are in the shadowed boxes, and the linking phrases are the words on the lines between the boxes. Concept, linking phrase, concept triples can be read propositionally as, for example the propositions that an approach with researchers on earth has advantages, perceived challenges and strategies. This Concept Map illustrates the idea of subsumption (Ausubel, 1968) in which more specific concepts are subsumed under more general ones, creating a hierarchy from general to specific from the top to the bottom of the map. The smaller, onlaid concept map entitled "Strategies" provides detail on the "Strategies" concept that appears in the top right of the more general map.

**3. Associated Literature on Brainstorming with Graphical Representations**

Nosek and McNeese (1997) discussed issues that pertain to group knowledge creation and brainstorming. They described the decreasing time frame that people have to make decisions, and the need for knowledge modeling and management to help people make sense of “emerging situations.” Nosek and McNeese are proponents of Concept Mapping as a general strategy through which to achieve such goals. On the basis of their experiences, they perceive the need to develop a better understanding of the types of groups that should be assembled, the types of knowledge that should be elicited, and processes to support well-targeted group elicitations.

They present a view of group interaction that addresses social, technological, ecological and cognitive factors in collaborations among experts. They identify several requirements relative to group knowledge elicitation including the need:

- to create tools that increase the speed of knowledge capture,
- to improve the ability to view Concept Maps,
- for information filtering to limit visual confusion in graphical representations, and

- for new techniques to reconcile individual and group maps.

Citera, et al., (1995) described the use of Concept Mapping to elicit and represent knowledge in order to identify how multidisciplinary teams can be more effectively supported with information technology. The work involved interactive sessions in which the Concept Maps were built "on-the-fly." The sessions included the expert, a Concept Mapper and a team of interviewers. Concept Maps were drawn on white boards. Each session was between one and three hours duration. A total of six Concept Maps were produced. A computer program named "Concept Interpreter" was used to analyze the Concept Maps.

Kremer and Gaines (1994) described a Concept Mapping tool named KMap, and a groupware Concept Mapping tool named Accord. The authors state, very generally, that the idea behind both tools is to support the creation and communication of knowledge. They described a three-person group with no prior experience in Concept Mapping that used Accord to produce a Concept Map pertaining to the implications of introducing a Networking system into an organization. The group created a 35 node Concept Map in 90 minutes. While very clear in expressing the view that the brainstorming process was improved as a result of Concept-Mapping, the paper is rather weak in its description of the methods that were used. The authors described the capability of navigating from nodes in the Concept Maps to other Maps or associated documents. They cited the possibility of emulating the visual languages and graph-like appearance of other knowledge representations such as PERT diagrams, Petri nets, etc.

**4. Facilitating Concept Mapping for Brainstorming and Decision Support**

Specialized skills are required to facilitate brainstorming sessions effectively, and it is typically the case that facilitators are not experts in the domain to be considered. This fact begs several questions such as the nature of preparations facilitators should make (if any), the role of the facilitator with regard to the level of interaction with the experts during the session, the types of group dynamics that are encountered in such sessions, etc. The following sections address these issues.

**4.1 Bootstrapping and other Preparations**

It is highly desirable for facilitators to prepare before a session. Preparation encompasses a number of aspects and may be carried out in a variety of ways. The facilitator must gain some facility with the basic ideas and the vernacular of the domain. Alternative means of doing this include independent reading of materials identified by the facilitator or provided by the expert, perusal of company records and other documentation, preliminary, informal meetings with principal participants, etc. This component has been described as "bootstrapping" in the literature on KE (Hoffman, et al., 1995).

The facilitator is essentially a knowledge engineer who should have some understanding of expertise, including an ability to assist in the determination of who should be in the group. A variety of more or less formal methods may be employed to determine who should participate in the work. It is also critical that the facilitator establish a positive rapport with the expert or experts who will participate. The nature of the relationships that are established can have significant bearing on the success or failure of the endeavor. Another important part of the preparation is the articulation of a clear focus question for the sessions. It is not enough to assume that the participants know what they want to discuss.

**4.2 Facilitation and Group Interactions**

The facilitator can assume a range of rolls in the facilitation process from essentially being a recorder to being highly pro-active in moderating the proceedings. The level of intervention is determined by group dynamics and the skill of the facilitator. It is typically the case that the participants will tend to stray from the focus of the session, and it is the responsibility of the facilitator to keep the session from straying too far. A caveat to this responsibility is that in some cases, the digressions may turn out to be of sufficient interest that particulars should be retained for follow-up.

One major concern for the facilitator is the nature of the interactions within the group. Groups must be well-constituted to ensure that a range of expertise and viewpoints are included. However, well-constituted groups alone do not guarantee a good result. If an individual in the group is very high-verbal, that person might dominate the proceedings. If individuals are more passive, they must be drawn out. Sometimes groups have significant tendencies to digress or move off the focus of the session. It is the facilitator's responsibility to keep the session properly focused. In some cases, a high level of contention may exist within the group, and it is the facilitator's responsibility to mediate.

**4.3 Individual versus Paired-Team Facilitation.**

Facilitation of a brainstorming session essentially has two components: moderating the discussion, and recording the proceedings as they unfold. Although it is possible for an individual to facilitate sessions, the efficiency of the process is improved by having two facilitators, an interviewer who moderates the session, and a recorder who actually builds the Concept Maps. Both have challenging jobs to do. The moderator must simultaneously keep track of what the experts are

saying and the recorder's progress in keeping up with the discourse. The recorder must simultaneously monitor the discussion for new ideas as they unfold, and record the ideas that have emerged so far. The moderator may be a designated group leader from among the experts. However, this person would need some experience to be able to ensure that the recorder is properly supported. If the moderator is a knowledge engineer who lacks understanding of the domain, it is important to avoid asking potentially naive, leading questions.

**5. A Case Study: Alternate Missions to Explore Mars**

An exercise in Concept Map-facilitated group brainstorming was recently carried out at the Institute for Human and Machine Cognition (IHMC), Pensacola FL, with researchers from NASA Ames Research Center. The goal of the two-day workshop was to brainstorm the relative advantages and disadvantages of three types of missions to research Mars. The three scenarios were:

- Conduct research remotely, with humans remaining on earth,
- Get humans to Mars but leave them in orbit, perhaps at the libration point, or
- Conduct research with humans on the surface of Mars.

The Concept Map in Figure 1 is taken from a session in which the group was weighing high-level advantages and challenges of carrying out Mars exploration with researchers on Earth. Each of the scenarios has numerous advantages and disadvantages. The goal of the workshop was to draw the best conclusions possible regarding the best approach.

Initially, three sub-groups were formed to consider the three scenarios separately. The groups were balanced with each having representatives from NASA and other people from a variety of technical disciplines. One of the major themes was the balance between what humans could do and what would need to be done with mobile robotic agents within each of the mission scenarios. Although one person was designated the group leader, the sessions tended to be quite well-balanced in terms of the various participants making contributions.

Knowledge modeling software named *CmapTools* (2001), which is in on-going development at the IHMC, was used for the sessions. The approach was to project the computer screen so that everyone in the group could easily see the Concept Maps. Several hierarchically ordered Concept Maps were created by each group. Each of the group facilitators had significant experience at Concept Mapping in real-time for brainstorming. The sessions started with the elicitation of the most general ideas that occurred to the group members. As these ideas were elicited, they were grouped and arranged from more general at the top of the screen to more specific toward the bottom of the screen. After a number of concepts had been elicited, the facilitators asked the participants to characterize the relationships among the concepts, and the Concept Maps emerged. During this phase of the workshop, a total of 21 Concept Maps were created on issues pertaining to the various missions.

Following these breakout sessions, the groups convened and compared what they had determined. Each group leader reported to the participants with the Concept Maps of the sessions serving as the presentation materials for the talks. The Concept Maps were critiqued and updated to reflect comments from the group. Following these presentations, a global Concept Map was created to summarize what the three groups had concluded. The Concept Maps themselves served as the report of the workshop. Concept Map representations are highly concise, and if well constructed, highly explicit and less ambiguous than textual accounts.

The creation of Concept Maps is iterative in the sense that, after being deeply engaged in the process for several hours, the group typically reaches a point of diminishing returns on the effort. Resuming after a break tends to yield fresh insights on what has been elicited so far and good new ideas. In the case of the Mars workshop, the first integrated group maps were viewed as the starting point for the clarification of the various issues. The Concept Maps were reviewed and modified in an iterative fashion in the weeks following the workshop. The various versions of the Concept Maps were archived for two purposes:

- The evolution of thought could be traced through the iterations, and
- older versions could be reviewed for issues that had fallen by the wayside but later seemed salient.

Since the Concept Maps were created with *CmapTools*, a network-enabled knowledge modeling software suite, the participants and other interested parties could view and critique the Concept Maps, which reside on a server at IHMC, from anywhere by using the *CmapTools* client and an Internet connection. The project is still ongoing.

**6. Summary and Discussion**

This paper presents a discussion of issues pertaining to facilitated, "on-the-fly" Concept Mapping for the support of group brainstorming, and a brief case study on how the process can be made to work. Nosek and McNeese raised a number of issues regarding such processes, including the need to create tools that increase the speed of knowledge

capture, to improve the ability to view Concept Maps, to employ means to limit visual confusion in graphical representations, and to originate new techniques to reconcile individual and group maps. This work addresses each of these concerns. While it is recognized that the "Knowledge Acquisition bottleneck" is still a daunting challenge, the use of two skillful facilitators, a moderator and a recorder, can noticeably improve the efficiency of knowledge elicitation.

The creation of highly intuitive tools such as *Cmaptools* fosters an iterative process of collaboration. While the optimum means of conduct of brainstorming sessions remains face-to-face collaborations, network-enabled tools such as *CmapTools* minimize the difficulties imposed by lack of co-location of the participants once the project is underway. Furthermore, the Concept Maps that are created comprise a concise, permanent record of the proceedings. With regard to the issue of the need to improve the ability to view the knowledge and to limit confusions in graphical representations, good progress has been made. Concept Maps are disambiguated by ensuring that all concept-link-concept triples comprise individual semantic units. The visual confusion that can ensue in a large, tangled Concept Map, with many nodes and links, can be ameliorated by creating hierarchically ordered maps. As an example, more detailed Concept Maps were created from each of the four second-tier concepts in the map in Figure 1. The inset map is the detailed concept map on the subject of "Strategies." This sort of organization keeps any given Concept Map from growing excessively large. One of the special skills of a facilitator-recorder is knowing when to remove detail from a map at a given level and to create a more detailed concept map of the detail. Finally, a means of archiving and sharing Concept Maps over a network as they evolve helps to address the issue of integrating separate Concept Maps into an integrated global view.

**References**


Ausubel, D.P. (1968). *Educational psychology: A cognitive view.* New York: Rinehart and Winston.

Buzan, T., & Buzan, B. (1996). *The Mind Map Book: How to Use Radiant Thinking to Maximize Your Brain's Untapped Potential*: Plume.

Citera, M., McNeese, M.D., & Brown, C.E. (1995). Fitting information systems to collaborating design teams. *Journal of the American Society for Information Scienc,* 46 (7), 551-559.

CmapTools. (2001). IHMC Concept Map Software: a knowledge construction toolkit. [online] available: http://cmap.coginst.uwf.edu/

Fisher, K.M. (1990). Semantic Networking: The New Kid on the Block. *Journal of Research in Science Teaching,* 27 (10), 1001-1018.

Hansen, M.T., Nohria, N., & Tierney, T. (1999). What's your strategy for managing knowledge? *Harvard Business Review,* 77 (2), pp 106-116.

Hoffman, R.R., Shadbolt, N.R., Burton, A.M., and Klein, G. (1995), “Eliciting knowledge from experts: A methodological analysis”, *Organizational Behavior and Human Decision Processes,* 62, pp.129-158.

Kremer. R., & Gaines, B. (1994). *Groupware concept mapping techniques. Proceedings of SIGDOC '94*: ACM 12th Annual International Conference on Systems Documentation. pp. 156-165. New York, ACM Press.

Lambiotte, J., Skaggs, L. and Dansereau, D. (1993). Learning from lectures: Effects of knowledge maps and cooperative review strategies. *Applied Cognitive Psychology,* 7, pp.483-497.

Mind Tools (2002). *Mind Tools - Helping you to think your way to an excellent life!* [online] available: http://www.demon.co.uk/mindtool/brainstm.html

Nosek, J.T., & McNeese, M.D. (1997). *Issues for knowledge management from experiences supporting group knowledge elicitation and creaton of ill-defined, emerging situations*. [online] available: http://ksi.cpsc.ucalgary.ca/AIKM97/nosek/KMNG_JMI_tow_col2.htm

Novak, J.D. (1998). *Learning, creating, and using knowledge: Concept Maps(R) as facilitative tools in schools and corporations.* Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J.D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.