

# ADVANCED MULTIPLE REPRESENTATION CONCEPT MAPS FOR CONSTRUCTING SHARED CONCEPTUAL ARTIFACTS

Pasi Silander

*University of Joensuu & Hame Polytechnic University of Applied Sciences*

Jorma Tarhio

*Helsinki University of Technology*

Erkki Sutinen

*University of Joensuu*

## ABSTRACT

Computer aided concept mapping can be considered as a primary mind tool of constructivist learning approaches. However, concept mapping has serious limitations in the cognitive learning perspective. We are working on a pedagogically meaningful technique for constructing shared cognitive representations and conceptual artifacts in a knowledge building process. We started with a pilot study on the possibilities and challenges of computer aided concept mapping in a learning process. Based on the observations of the pilot study, we propose a model for advanced multiple representation concept maps (AMRCM) that relies on the agent technology based on the conceptual modeling that utilizes Internet search engines. AMRCM forms ontologies and projections between maps enabling examination of concept maps in several ways. AMRCM provides a novel framework to facilitate the learner's cognitive processes and collaborative learning.

## KEYWORDS

Concept map, shared representation, conceptual artifacts, computer based concept mapping

## 1. INTRODUCTION

Concept mapping as a technique have some major limitations in the cognitive learning perspective; even though they have seen as a knowledge representation tool that should attempt to incorporate representational mechanisms isomorphic to users' cognitive representations (see e.g. Alpert 2003). Learners' cognitive representations are always the products of individuals' own mental processing and differ from individual to individual. In addition, all parts of the cognitive representations are not able to be externalized as a form of conceptual presentation.

Limitations of concept maps are related to the issue that concept maps provide neither unique representation forms nor mechanism for describing simultaneously multiple contexts. Concept maps works best for single and well-defined contexts with emphasis on a relatively hierarchical and unambiguous structure. In addition, there is also a lack of various types of semantic relations between the concepts in most of the concept mapping techniques. Instead of knowledge representations, concept maps should be seen as an important pedagogically tool for the knowledge creation process in a constructivist learning situation. However, existing computer based concept mapping tools are mainly based on the content and they do not pay enough attention to learners' learning processes and to the psychological mechanisms of human learning.

Our central goal was to create a pedagogically meaningful concept mapping technique for constructing shared cognitive representations and conceptual artifacts in a knowledge building process. This has been

done based on the exploring the possibilities and challenges of using computer based concept mapping in a learning process with a conducted pilot study. In addition, the practical limitations of traditional concept maps that can be exceed only by computer aided concept mapping led us to develop a model for *Advanced Multiple Representation Concept Mapping* (AMRCM) that relies on agent technology based on conceptual modeling that utilizes search engines on the Internet as metasearch tools.

In this regard, our approach to foster students' process of constructing shared cognitive representations and conceptual artifacts focusing simultaneously on multiple contexts is innovative. *Advanced Multiple Representation Concept Mapping* that forms ontologies and projections between maps enabling examination of concept maps on various abstraction layers as well on various semantic and syntactic exploration angles, is a novel step in this direction. It provides a framework to facilitate a learner's cognitive processes and collaborative learning with concept maps providing scaffolds for a learner.

## 2. CONCEPT MAPPING IN A LEARNING SITUATION

Concept mapping (Novak & Gowin 1984, Novak 1990) is a creative activity in which learners exert effort to specify and describe concept meanings in domain knowledge by identifying important concepts, establishing the relationships between the concepts. Concept mapping may be seen also as a technique to regulate learners' cognitive processes (Kommers & Lanzing 1997)

eLearning practices in a learning situation are influenced by the pedagogical, technical and content contexts. Educators have to use different means to foster learning in networked environments (like web or mobile learning environments) than in traditional classroom teaching. The traditional teaching process does not apply to the e-learning process, because traditional teaching is based on the teaching process, whereas web-based teaching has to be based on the design of the learner's learning process (Koli & Silander 2003).

There are various software packages for concept mapping (e.g. *MindManager*, *SemioMap*) on PC as well as on hand held devices for creating individual maps and tools for co-operative and collaborative concept mapping, like *Pocket PicoMap* (Luchini et al. 2003). By these tools the learner constructs a concept map by creating new concepts and links between them, while software provides him/her the visual representation of a concept map.

Although concept mapping can be used during the whole learning process, in this paper we focus on the critical elements of the knowledge building process. The various phases of knowledge building, like setting up own problems and questions, context creation and externalization of prior knowledge as well as creating one's own conceptual artifacts are heavily emphasized in various pedagogical models and methods (e.g. Progressive inquiry (Hakkarainen et al. 1999), Activating instruction (Lonka & Ahola 1997), and Problem Based Learning (PBL) (see e.g. Albanese & Mitchell 1993). In this context concept mapping is seen not just as a mediator of learning activity/collaboration but as a trigger and platform that includes guidance and support for the learning methods and learning process.

The use of concept maps in a learning situation can be generally divided into basic categories based on the students' activity (see Table 1). In addition, the categories describe the role of concept maps as a tool for learning.

Table 1. The use of concept maps in a learning situation divided into the basic categories. Categories are not mutually exclusive

<i>Category</i>	<i>The role of the concept map in the category</i>	
<b>Exploring/browsing of existing maps</b>	<i>Knowledge acquisition</i>	Ready-made concept maps are used to present conceptual information in the form of concepts and relations between them. Maps may be used in order to describe the overall picture of the subject/phenomenon.
<b>Construction of individual concept maps</b>	<i>Physically distributed cognition</i>	To present one's conceptual constructions or to organize, to develop and to learn new conceptual constructions.
<b>Construction of collaborative concept maps</b>	<i>Socially shared cognition</i>	To create collaborative conceptual constructions, to share individuals' constructions and to achieve joint conception.
<b>Assembling concept maps on the basis of existing maps or primitives</b>	<i>Physically distributed cognition and knowledge acquisition</i>	To modify the concepts and relations in an existing map.

### **3. PILOT STUDY: "HOW WOULD TEACHERS USE CONCEPT MAPPING IN A LEARNING SITUATION AND WHAT KINDS OF COGNITIVE PROCESSES STAND BEHIND DESIGNED STUDENTS' ACTIVITY?"**

#### **3.1 Questions and Methodology**

Our long-term formative research aims at exploring the possibilities and challenges of computer-based concept mapping in a learning process, like supporting knowledge construction by concept maps. In this study, we examined how teachers could use concept mapping with their own students. More precisely, we aimed at exploring 1) *how concept maps would be used as a framework and as a foundation for learners' knowledge building activity*, 2) *what kind of learning task would be needed when using a search engine that visualizes results as a concept map* and 3) *what kind of cognitive processes would stand behind learners' activities*. In this setting, we utilized the *Kartoo* search engine ([www.kartoo.com](http://www.kartoo.com)) that visualizes search results as a navigable concept map. The focus of the research was on the educational design of the learning situations, as carried out by teachers.

The research methods used were the qualitative analysis of questionnaires and the content analyses of learning tasks compiled by teachers. The web-based questionnaire used for data gathering consisted of three separate parts: educational use of concept mapping, utilization of *Kartoo* and concept mapping in learning tasks, and potentials of concept mapping in the participants' own teaching practices. Questionnaires provided predominantly qualitative data for our investigation, which was based on the grounded theory (Glaser & Straus 1967, Straus & Corbin 1994).

#### **3.2 Participants and Procedure**

This pilot study involved 19 teachers who had previous experience in web-based teaching. Teachers were attending to an in-service training programme organized by the Finnish National Board of Education and they were working with the development projects of web-based education. All the teachers were familiar with concept mapping tech done on paper before participating in this study. Some of the teachers had used graphical software packages or organizers like *MindManager* in order to create concept maps on a computer by themselves.

The *Kartoo* search engine was presented to the teachers on the white board. *Kartoo* visualizes search results as a navigable concept map. After presentation, the teachers were instructed to try out searches of

their own and make themselves familiar with the features of *Kartoo*. The teachers were asked to answer the first part of the questionnaire concerning the concept mapping. In the second part of questionnaire they were asked to choose a couple of key concepts of their domain and try them out with *Kartoo*. Secondly, the teachers were asked to design a learning task for their students in which students would utilize *Kartoo*'s concept map functions. In addition they answered the questions of the third part of questionnaire concerning how concept maps could be utilized in the learning and teaching in their own subject domain.

### 3.3 Results

Our findings are based on the analysis of the questionnaires including the content analysis of the learning tasks compiled by the teachers. The content analysis of the learning tasks was conducted by using the qualitative data analysis software ATLAS.ti. The grounded theory was used in order to create classes in the analysis process. The learning tasks were classified at the first stage based on the role of the concept map and students' activity in a learning situation. At the second stage the learning tasks created by the teachers were examined more closely in order to investigate what kinds of cognitive processes they would initiate and require from students when using concept map in order to accomplish the given task. In the learning tasks naturally acquisition of conceptual knowledge and seeing the whole picture and relations between the concepts were emphasized in students' learning processes, but in addition, the role of comparison/classification and reflection were found. Learners' cognitive processes that were found based on analysis of the learning tasks (utilizing *Kartoo*'s concept maps) designed by teachers are presented in Table 2.

Table 2. Learners' cognitive processes based on the analysis of learning tasks designed by teachers

<b><i>Cognitive process</i></b>	<b><i>Freq</i></b>
<i>Information acquisition</i>	9
<i>Realize the relations between the concepts and the whole picture</i>	4
<i>Comparison</i>	4
<i>Explaining the phenomenon by own words based on a concept map</i>	3
<i>Reflection</i>	3
<i>Synthesizing</i>	2
<i>Classification</i>	2
<i>Modification of a concept map</i>	1
<i>Anchoring in real life</i>	1
<i>Delimit and define the subject</i>	1

Table 3. Pedagogical roles of concept maps in learning and teaching in addition to drawing maps by students reported by teachers

<b><i>Concept maps may facilitate students in</i></b>	<b><i>Freq</i></b>
<i>Understanding the relations between wholeness and its parts</i>	7
<i>Knowledge building as a base structure with some ready made primitives</i>	6
<i>Understanding various angles and aspects</i>	4
<i>Structuring and organizing information</i>	3
<i>Gathering new ideas</i>	1
<i>Internalizing procedural information</i>	1
<i>Understanding the mechanism of effects</i>	1
<i>Knowledge building with scaffolded construction process</i>	1

The same method was used in order to analyze the pedagogical roles that concept maps could have in a learning situation, in addition to drawing concept maps. In summary, it can be stated that concept maps may have various pedagogical roles in a learning setting (Table 3), but the roles are created by the context of the learning process, like learning tasks, not the concept map by itself. The results suggest that the teachers are, in addition the traditional use of concept mapping, willing to use concept maps in various domain fields enabling various learners' cognitive processes that facilitate learning. Noteworthy observation is that the

concept mapping technique does not give any functional support to the most of these pedagogical roles of concept maps or to students' cognitive processing.

#### **4. ADVANCED MULTIPLE REPRESENTATION CONCEPT MAPPING – BREAKS THE LIMITATIONS OF THE TRADITIONAL CONCEPT MAPS AND SUPPORTS SCAFFOLDING TO CONSTRUCTION PROCESS**

We have developed a model for *Advanced Multiple Representation Concept Mapping* (AMRCM) triggered by the results of former pilot study. AMRCM, a model for computer aided concept mapping, relies on agent technology based on the conceptual modeling that utilizes search engines on the Internet as metasearches. AMRCM utilize agents in order to exceed the limitations of traditional concept maps and in order to provide pedagogical support like scaffolding (Wood et al. 1976, Bruner 1985) for the construction process. AMRCM concept map works as a basis for learning and for further knowledge building. In addition, it creates a pedagogical structure and a framework for the knowledge building activity.

*The structure of AMRCM concept map* is formed based on the various types of the relations between the concepts in a singular concept map as well as relations between the concepts appearing in different concept maps. Concept maps form ontologies and projections between maps that enable examination of the concept maps on various abstraction layers as well on various semantic and syntactic exploration angles. This is not possible to describe on the paper or by graphical concept map applications, the use of complex data structures of computer science is needed. Ontologies may also be generated automatically based on the quantitative results (like measures for conceptual centrality or conceptual density) available searches done via the web search engines (e.g. *Altavista* or *Google*) or based on the documents provided by a teacher.

The former application (/solution) solves the problem the traditional concept maps have: the traditional concept maps provide neither unique representation forms nor a mechanism for describing simultaneously multiple contexts. In addition, this application (/solution) enables better to apply automatically especially the following pedagogical roles of the concept mapping reported based on the committed pilot study (see Table 2): *facilitation of the understanding various angles and aspects*, and *facilitation of the knowledge building as a base structure with some ready made primitives (half done framework)*.

*Collaborative concept maps* can be build up easily either by linking individual ontologies together (generating relations between the maps base on the algorithm utilizing quantitative and qualitative results of metasearches) or by emerging to individual concept maps based on the similar concept and calculated conceptual centrality and relevance values. In the other words, the synthesis of concept maps or collaborative concept mapping is not placing the concept at the same map, but generating relations between various ontologies preserving the structures of individual maps that enables mechanism for describing simultaneously multiple contexts.

*Scaffolds* of various kinds can be used in order to support and to initiate learner's cognitive processes when creating conceptual artifacts in a form of a AMRCM concept map. Scaffolds (Table 4) are facilitators as well as indicators for constriction process making concept mapping to be a pedagogically structured process. Scaffolding is generated automatically based on the software components or agents that utilize quantitative results of metasearches (e.g. measures for conceptual centrality or conceptual density) conducted via existing search engines on the Internet.

Table 4. Scaffolds that may be used in order to provide pedagogical support for student's learning process and cognitions when constructing AMRCM concept maps

***Scaffolds***

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- Sequence of questions presented to students in order to construct AMRCM (a question path)
- Providing semantic clues / indicators concerning concepts
- Providing syntactic clues / indicators concerning the structure and the type of the relations between the concepts (cf. grammar)
- Describing the contextual relevance of a concept by utilizing the measure of conceptual density and centrality (based on the base documents and metasearch information)
- Describing the relevance of the relations between the concepts by utilizing the measure of conceptual density and centrality (based on the base documents and metasearch information)
- Propositions for close related concepts
- Propositions for relations (and type of relations) to the related concepts
- Describing how a concept exists(/appears) in other ontologies
- Linking concept to other ontologies base on the relevance, centrality and density measures
- Reflection of one's constructed map to other ontologies or to a model concept map
- Organizing and presenting one's concept maps from different aspects / angles
- Presenting a model concept map created automatically based on the information gather from metasearches or from designated documents provided by a teacher

Former enables supported learners' processes like conceptual modeling, externalizing conceptual constructions and developing conceptual artifacts describing multiple contexts simultaneously. In addition, mechanisms of scaffolds may be used in automatic assessment of concept maps.

## **5. SUMMARY AND FURTHER PERSPECTIVES**

We have proposed a model for *Advanced Multiple Representation Concept Mapping* (AMRCM) that relies on the agent technology based on the conceptual modeling that utilizes Internet search engines. AMRCM forms ontologies and projections between maps enabling examination of concept maps in several ways. AMRCM provides a novel framework to facilitate the learner's cognitive processes and collaborative learning. Various scaffolds can be used for the AMRCM construction process, making concept mapping to be a pedagogically structured process.

The challenge with ARCM will be the accuracy of automatically generated ontologies and models that are based on various measures. Technical implementation can be done based on the existing technologies combining them and using them in fresh ways.

The analysis of the conducted pilot study reveals that the learning process with concept maps is influenced significantly by the context of the learning process where concept mapping is used, like learning tasks, not the concept map by itself. In addition, concept maps may have various pedagogical roles in a learning setting.

Formative research combining both, developing of hard (new educational technology and softwares) infrastructures and developing soft (new pedagogical and learning methods) infrastructures is most decidedly needed in order to create and implement successful educational technologies. The emphasis should be on the educational technologies (like concept mapping) that are easy to implement in various contexts and conditions of learning.

The next step probably is to find precisely which are the most distinctive features of this Advanced Multiple Representations Concept Mapping (ACMR) and how they could be incorporated or/and compensated in the students learning process and cognitions when constructing AMRCM concept maps with scaffolds.

Game-like elements (e.g. scores, levels, story) could be used in order to create motivation and to guide learners' learning processes. The idea is to encourage students especially to create upper-level concepts and relations (abstractions) as well as explore various angles and ontologies. In addition, adaptation can be used to generate indicators and scaffolds in order to activate students and to guide the individual learning process on cognitive level.

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