Concept Mapping – a proposed theoretical model for implementation as a knowledge repository

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Abstract

This working paper is an official research output for the Carnegie project, forming part of subproject 1 (ICT competencies in the workplace). Mind maps are inspected as a possible knowledge presentation tool, but are found to be unsuitable. Concept maps, based on Ausubel and Novak’s work, appeared to hold promise as a vehicle for implementation of the knowledge repository. A number of software programs are available to assist in the creation of concept maps, and one of them was used in the preliminary model. A large number of applications of concept maps in education was found in the literature, with mostly positive research results. Healthcare and related fields, as well as other less often covered areas were also represented in the literature. Based on the positive feedback, a preliminary model of a concept map was designed, and it proved to be relatively easy to construct and use. This result, plus the positive feedback from the literature survey, prompted the start of the planning phase of the implementation of the proposed knowledge repository.

Keywords

concept mapping, higher education, knowledge, repository
Concept Mapping: A literature review and a proposed model

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1. **Introduction and Background**

The Carnegie Corporation of New York invited applications for funding from South African tertiary institutions in 2000. The University of the Western Cape, in co-operation with the other four Higher Education Institutes in the Western Cape, submitted a proposal in response. The proposal, when accepted, was titled: "**Information and communications technologies in Higher Education**", and is now referred to as the Hicte project. The other institutions involved are The Cape Technikon, Peninsula Technikon, and the Universities of Cape Town and Stellenbosch.

The Hicte project has been subdivided into three sub-projects:
- ICT competencies in the workplace,
- ICT in the management of tertiary education and
- ICT in the delivery of tertiary education.

This working paper resorts under the first heading above, with the specific aim of creating a knowledge repository to be used as the major resource in the offering of a Master’s degree program starting in 2004. As such it is the second deliverable in this sub-project, the first having been a similar paper on gender equity in the IT workplace. It is based on a literature review, coupled with a proposed theoretical model to be used as the knowledge repository.

See Hicte at: http://www.uwc.ac.za/ems/is/hicte/ for more detail on the Carnegie project.

A number of possible vehicles exist on which to build the knowledge repository, as discussed below.

1.1 **Mind Maps**

Mind Maps represent one method of classifying and representing information. One main concept is taken as starting point, and becomes the “central word” or concept. A further five or 10 main ideas (also called child words) are then plotted around the central word, with links back to the central word. Another five or 10 ideas can be added to any one of these child words, creating an ever-growing network of concepts around the central one (Buzan 1989).

An example of how a mind map could be used to plot the different elements of a corporate website is given in Figure 1. The homepage is used as the central word in this example.
A preliminary conclusion reached at this point is that mind mapping does not seem to be a usable alternative as the main vehicle for the knowledge repository. The material which is being envisaged as filling the repository will be covering a wide range of topics, and it is believed that a number of subtopics, not just one, will become evident as the size of the repository grows.

1.2 Concept Maps

Concept Maps provide a second method to represent information. They have been defined as follows: “Concept maps are two-dimensional representations of cognitive structures showing the hierarchies and the interconnections of concepts involved in a discipline or a subdiscipline” (Martin 1994:11).

Novak developed the idea of concept mapping in the 1960’s, in an attempt to visually represent the structure of information (Novak 1991:45). The method also indicated relationships between different sets of information. Such a concept map (also called a Knowledge Graph) typically consists of network nodes (points or vertices) and links (edges or arcs). Each node represents a concept, while each link represents a relationship between concepts (Lanzing 1997). These links could be one-way, two-way or non-directional.
The main difference between mind maps and concept maps is that the first has only one central concept, while a concept map could have a number of them.

An example of a simple concept map illustrating nodes and links is given in Figure 2.

![Concept Map Example](image)

**Figure 2**

The original work done on concept mapping was based on Ausubel’s theory of meaningful learning. This theory was produced after Ausubel’s work on how learners learn large amounts of useful information from textual and verbal inputs. Ausubel’s subsumption theory is based on the premise that the acquisition of new knowledge is dependant on what is already known (Ausubel 1968).

Trochim claims that planning and evaluation processes can be enhanced considerably by the use of a concept map. In planning, the setting of major goals, determining of available resources and capabilities, and many other plan dimensions can be represented with a concept map. On the evaluation side, dimensions such as programs, samples, measures, outcomes and settings can be effectively incorporated in a concept map (Trochim 2003b).

A number of advantages of the use of concept maps for educational purposes are supplied by some prominent authors:

- users can distinguish between essential and nice-to-know outcomes,
- themes are easy to discover,
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- set ways of thinking are challenged,
- concepts which are key to more than one discipline can be identified,
- appropriate instruction materials can be selected,
- conceptual relationships used for intended program and course outcomes can easily be explained,
- concept maps provide a basis for discussion and
- concept maps support a holistic style of learning.

A number of others were also listed (Allen and others 1993, Dyrud 1994, Edmondson 1993).

It does appear as if concept mapping has a solid application base in education:

“Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures” (Novak and others 1983).

Questions which could arise in the reader’s mind at this point could be: “Why another way to represent information? What is wrong with standard web pages?”

According to van Gie, a structural correspondence does exist between a concept map and a hyperlinked knowledge network. Both can be viewed as a directed or a knowledge graph (van Schie 2002).

An interesting study was done by Carnot and others by comparing web pages and concept maps as storage mediums, and inspecting how effectively users search for information using both interfaces. Their results suggest that concept map based interfaces lead to higher accuracy in search performance than a typical webpage based browser (Carnot and others 2003).

A preliminary conclusion reached at this point is that concept mapping could be a usable alternative as the main vehicle for the knowledge repository. The wide range of topics and subtopics which is being envisaged would appear to fit in well with the general structure of a concept map.

2. **Literature Survey**

The literature search has identified the following researchers as some of the most prolific authors/researchers in the field of concept mapping: Coivas, Chu, Gowin, Novak, Rico, Rossi and Trochim. An attempt was made to investigate at least some of their seminal papers.

The first thread which became evident from the literature was the large number of software programs that exists to assist the user in creating concept maps. Secondly, a
number of application fields became evident: from educational, through medical to other fields less often covered such as law and tourism. These elements are covered in sequence below.

2.1 Available software

The literature search has provided links to a number of software products which could be used to create and maintain concept maps – some are free, others are commercial products.

2.1.1 IHMC Cmap Tools v2.9.1
This product is available as a free downloadable program, and has been used to create the sample concept map available (cmap.coginst.uwf.edu/samples/index.html).

2.1.2 Inspiration.
This product is sold at $69. (www.educationworld.com/a_tech/tech108.shtml).

2.1.3 Kidspirations.
This product is sold at $69. (www.educationworld.com/a_tech/tech108.shtml).

2.1.4 EDGE Diagrammer V4.14
Between $50 and $790, depending on features.
http://www.pacestar.com/links/trial.htm

2.1.5 Semnet Software.
No price could be found. http://trumpet.sdsu.edu/Semnet.sit

2.1.6 MindManager.

2.1.7 Smart Ideas
www.smarttech.com

2.1.8 Visimap
www.visimap.com

2.1.9 Thinkmap
www.thinkmap.com

No doubt are there more examples, but the list above is an indication that many products do exist and that concept mapping is an accepted and established concept.

2.2 Educational Applications

By far the largest number of applications found for concept mapping was in the educational area. At least 13 articles described in a variety of ways and levels of detail how concept maps were used to address some area(s) involving teaching or training.
2.2.1 Adsit claims that concept maps are excellent vehicles for curriculum design, both in student-centred and problem-centred situations. It is claimed that the emphasis of the knowledge transfer process moves from “what do I want to teach” to “what do I want students to learn”. (Adsit 2002).

2.2.2 Hughes and Hay did a study on the integration of various course designers’ perspectives in the development of e-learning materials, using concept mapping. A constructivist methodology was used at Surrey University, where a design team and other stakeholders produced their own concept maps. These individual maps were then integrated by the project manager to produce an overall map, and the process produced positive results which enabled a more holistic approach to the design process (Hughes and Hay 2001: 557).

2.2.3 Ruffini found that mind and concept maps could be used with positive results in education. The creation of an online course map was found to be a useful tool for assisting teachers to organize and communicate course content to the advantage of their learners (Ruffini 2002:1,17).

Three studies were found on collaboration and concept mapping:

2.2.4 Cicognani found that concept mapping enhances collaborative learning in a study on the use of concept mapping as a tool to enhance online learning. However, it is admitted that much research has to be done before strong conclusions can be made on the value of concept mapping in this field (Cicognani 2000 150, 156).

2.2.5 Canas and others did a study, similar to Cicognani above, on collaborative learning in Latin America. Although financial support has since been withdrawn, many of the schools having participated in this project are still using the system (Canas and others 2003).

2.2.6 De Simone and others focussed on the support of the learning process using collaborative concept mapping. Three tools were combined in an effort to advance student learning: collaborative learning, concept mapping and electronic technologies. It was found that, although students required instruction on the use of these concepts, concept mapping and collaborative learning complemented each other positively (De Simone and others 2001:263, 282).

2.2.7 Chang and others completed an interesting study, by running three parallel sessions where students are encouraged to construct their own concept maps using one of three possible methods. The effectiveness of “construct-by-self”, “construct-on-scaffold” and “construct by paper-and-pencil” respectively are compared. It was found
that the second method was more efficient for biology learning (Chang and others 2001:21, 32).

2.2.8 Ruiz-Primo and others looked at the cognitive interpretations of scores generated by alternative concept mapping techniques. Again three different methods of presenting incomplete concept maps to students were used and compared (see Chang and others above). They found that the “construct-a-map” technique was the most content-rich, and provided the students with the most freedom (Ruiz-Primo and others 2001:133).

2.2.9 Willson and others considered the use of concept mapping in the evaluation of the effectiveness of a programme which was designed to develop the understanding of primary teacher's view of scientific concepts. Concept mapping was found to be a flexible method, easy to administer. However, post-course support would be necessary to elevate the level at which about ¾ of the teachers was operating (Willson and others 1994:121, 125).

2.2.10 Sturm and others did an empirical experiment with learning disabled students and the writing of descriptive essays, using (again) one of three support systems: no-map, hand-map and computer-map support. The third method produced significantly more positive attitudes towards writing, while the last two methods increased a number of factors in a positive direction (Sturm and others 2002:124, 137).

2.2.11 Chang and others did a study on the effect of concept mapping as a graphic organizer in assisting towards text learning, again using three different concept mapping approaches. Results proved that one method enhanced text comprehension and summarization abilities, while another method facilitated summarization abilities (Chang and others 2002:5, 20).

2.2.12 Sungur and others used 10th graders in a study on their perception of the human circulatory system. They found that concept mapping instruction provided a positive effect on the students' understanding of the topic.

2.2.13 Kinchin found that the use of concept mapping in UK classrooms is not widespread. It appears that the two main reasons for the existence of this situation are beliefs of the teachers and the underlying philosophy of the curriculum.

With one exception, these studies all produced some positive results on the use of concept maps in education. Some reservations were mentioned, and should not be ignored when viewing the overall picture. However, it does appear that research has proven that concept mapping as a tool to organize and present educational materials has value.
2.3 Healthcare and related Applications

2.3.1 Kim and others did a study on physiology tutorials and causal concept mapping. It was found that concept mapping facilitated the learning process in the educational environment (Kim and others 2002:61).

2.3.2 Trochim and others used a support employment program for persons with severe mental illness in a study based on concept mapping. A number of staff members of a psychiatric rehabilitation agency interpreted a concept map based on their specific program activity statements. The implications of this methodology were considered, and it was found that concept mapping can be used to enhance the evaluation of programs (Trochim and others 1994).

2.3.3 Marchand and others used a set of diabetic patients as subjects in a study on their cognitive structure before and after having followed an educational programme. The study has proven that concept maps are a suitable technique to explore patients’ prior knowledge and to visualize what they have learned after having gone through an educational programme (Marchand and others 2002:90).

2.3.4 Finally, Kane and others investigated concept mapping as a method to improve health care decision making, and came to the conclusion that it can bring order to a task that is otherwise difficult for a group or organization to achieve (Kane and others 2002).

As with the research done on the role of concept maps in education above, evidence seems to indicate that concept maps had a positive effect in all four these programs.

2.4 Other focus areas

2.4.1 Fong claims to have done the first study on the use of concept maps in the law arena. A group of students completed an assignment using concept maps, and an analysis of their reactions has shown that concept maps assisted the majority of the students in understanding the subject (Fong 1999:1, 14).

2.4.2 Bigne and others used concept mapping as a tool in marketing research, to establish the determinants of loyalty from the consumer’s point of view. It was found that concept mapping added objectivity to the results of group dynamics, as found in focus groups (Bigné and others 2002).

2.4.3 Trochim used a slightly different form of concept mapping as an aid in planning and evaluation, in an attempt to bring order to a task which is difficult for groups or organizations to accomplish. Although it is admitted that concept mapping is not the only way in which group conceptualization can be achieved, its pictorial presentation makes it a very useful procedure for group presentations (Trochim 2003b).
3. **Preliminary Model**

A preliminary test model was set up, using the software listed in 2.1.1 above. This was done to test the concept, and evaluate the ease of use of translating a body of knowledge from an existing format to a concept map. This sample concept map is available on http://www.mwe.co.za/carnegie.htm.

Including the time taken to get to know the new program, it took approximately 6 hours to generate this concept map. This includes the time required to find examples of video, audio and other files on the Internet, as support for the concept map.

4. **Conclusion**

It appears from the literature that concept mapping is an established procedure, used especially when information needs to be organized, presented and retrieved by humans. Education as an application area is most visible, with a large number of studies having been done on humans interfacing to knowledge via a concept map.

Bar some provisions and qualifications made by researchers in the research covered here, all results found were positive. Concept maps appear to:

- increase the efficiency of information retrieval,
- increase the efficiency of teaching via better course content communication,
- enhance collaborative learning,
- produce positive attitudes toward learning,
- enhance text comprehension,
- increase students’ understanding of topics and
- bring order to complex tasks.

Furthermore, the relative ease with which the preliminary model was set up proved that in principle, concept maps would be easy to implement as main vehicle for a knowledge repository.

These results have urged the author to base further work on the creation of the proposed knowledge repository on concept mapping.

5. **References**


Edmondson, K.M. 1993. Concept mapping for the development of Medical Curricula. The annual Conference of the American Educational research Association, Atlanta, GA.


6. Further reading


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ICT in Higher Education

Sub project 1: Information Management Competencies

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