Usability Analysis of Concept Maps as Knowledge Discovery Tools

Abdus Sattar Chaudhry, Nanyang Technological University, 31 Nanyang Link, SCI Building, Singapore 637718; E-mail: aschaudhry@ntu.edu.sg
Lee Yee Fuang, Nanyang Technological University, 31 Nanyang Link, SCI Building, Singapore 637718

ABSTRACT

The potential application of concept maps in knowledge discovery is examined using a framework comprising usability, learnability, and task & technology fit. An online survey and follow-up interviews indicated that teachers and administrators at the Ministry of Education in Singapore were comfortable in using concept maps. They expressed that concept maps should to be integrated with search engine tools. Usability analysis suggested that enhancements in functional design of concept maps, improvement in quality of contents, and regular updating of resources were important to attract mass usage of concept maps.

INTRODUCTION

Concept maps are one of the most notable methods for representing relationships between concepts. Using this premise as a basis for further investigations, many researchers have begun to analyse various applications of concept maps, including organising and presenting information to aid knowledge discovery. Concept maps have their roots in education. The idea was grounded in the sound learning theories of Ausubel (Novak & Gowin, 1984) who posited the importance of prior knowledge in learning new information. The fundamental idea is assimilation theory where learning takes place by the assimilation of new concepts and propositions into existing concepts and prepositional frameworks held by the learner.

Concept maps are tools for organizing and representing knowledge that include concepts; usually enclosed in circles or boxes of some type; and relationships between concepts or propositions; indicated by a connecting line between two concepts. Words on the line specify the relationship between the two concepts. The basic graphical elements are nodes and links, which are organised using common patterns, such as branches, arrows, groups, notes, lists and so on. Nodes (points, vertices, icons, and so on) represent the concepts, and links (lines or arcs) represent the relationships between concepts. Figure 1 portrays an example of a simple concept map.

Concept maps are representations of a set of concepts and their relationships and concept mapping is a technique for representing knowledge or information in graphical form by listing relevant concepts and then drawing lines between them to represent their interrelationships. When two or more concepts are connected, a meaningful statement or proposition is formed. Propositions are statements about some objects or events in the universe, either occurring naturally or constructed (Cañas et al. 2003). They are also called semantic units, or units of meaning. Typically a concept is expressed using one or a few words with labelled links. These links are lines or curves with phrases that connect concepts to form relationships. A linking phrase is used to join concepts to form a meaningful proposition, which is a basic unit of knowledge according to the theory of meaningful learning. Nodes in a map do not carry any information. Arrowheads in the links specify directions which determine the logical connection of the relationships. Curved lines can be used when straight lines cannot be used to link the nodes, thus providing the flexibility to avoid rearrangement. Another important element of concept maps is Cross-links. Cross-links make explicit relationships between or among concepts in different domains within the concept map.

Much research on users' perceptions of concept maps has been done in the context of the tool's application in education. Santhanam and Dawson (1998) investigated the effects of concept mapping to students taking subjects in genetics. Uzuntiryaki and Geban (2002) examined concept mapping instruction in the science subject by comparing it to traditional instruction. Potelle and Rouet (2003) studied the effects of concept maps on low and high knowledge students.

Figure 1. An example of a concept map

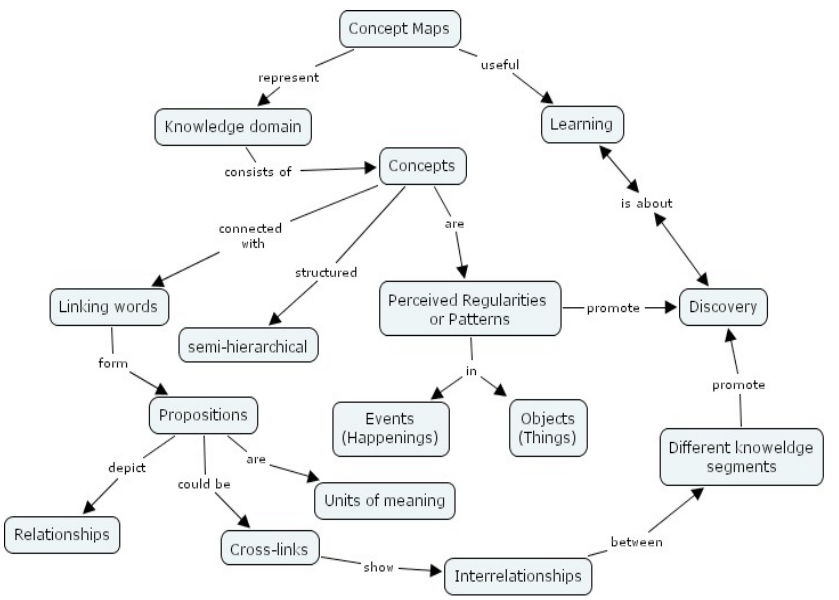
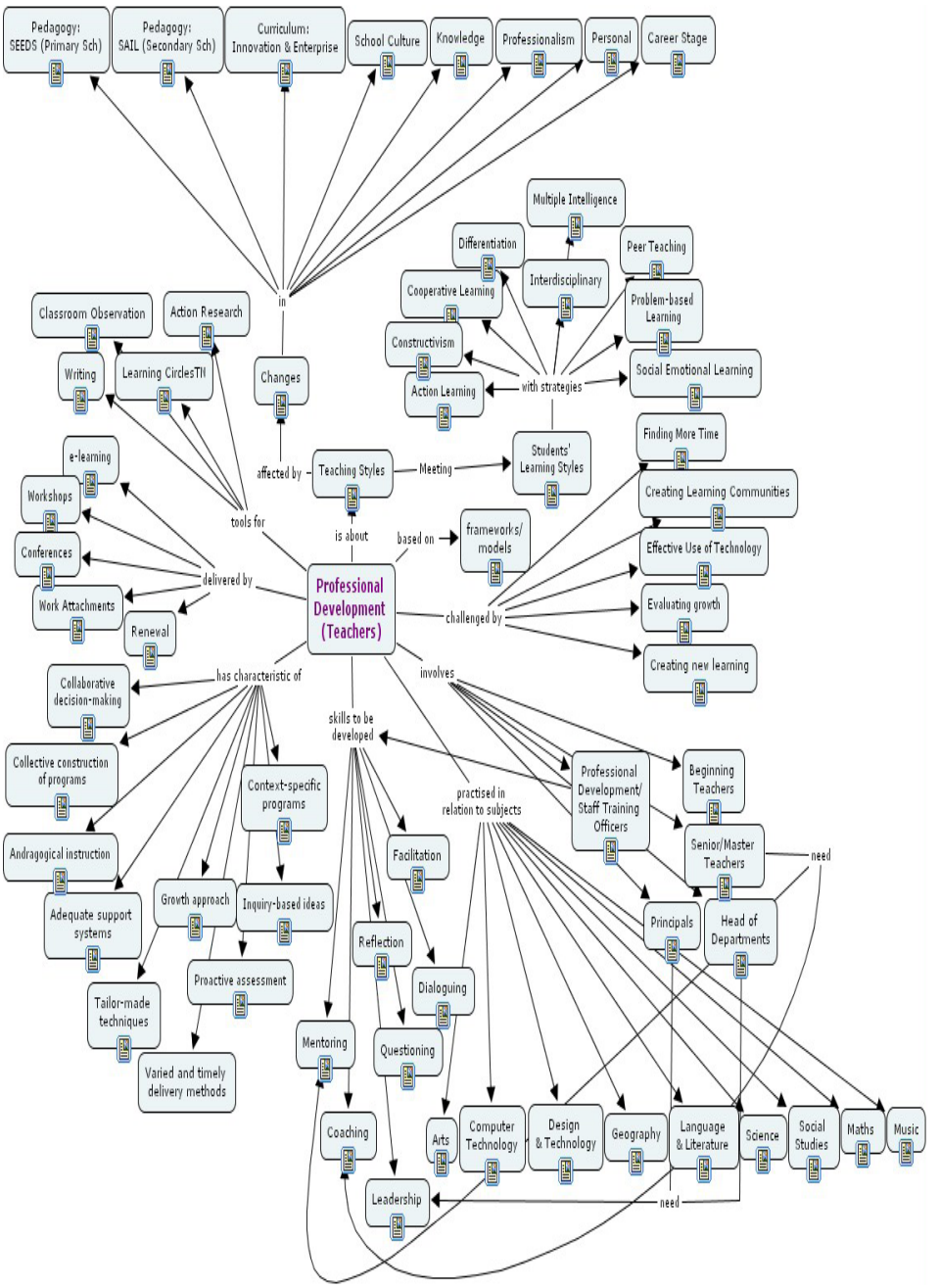


Figure 2. Concept map on teachers' professional development



Research on users' perceptions of concept maps in the knowledge management field is not very prevalent. Much of it deals with knowledge elicitation and knowledge construction. Ford, et al. (1996) described a nuclear cardiology expert system called NUCES in which concept maps were used for knowledge elicitation and navigation. Leaker et al. (2003) described an approach to support experts as they built their own knowledge models of a domain. Mularz and Lyell (2004) explored the integration of concept maps and semantic web technologies for the capture, visualization and navigation of knowledge in support of the lifecycle of knowledge management.

This study was aimed at investigating the potential application of concept maps in knowledge discovery. Teachers' professional development was chosen as the central topic for developing a prototype concept map to be used for review. Relevant concepts were derived from selected information repositories and reference questions received by READ@TN (Teachers Network's information resource centre at the Ministry of Education in Singapore). The prototype concept map covered a set of terms and their relationships, which also took references from Educause taxonomy (http://www.educause.edu/Browse/647), ERIC Thesaurus (http://eric.ed.gov/) & Library of Congress Subject Headings (*LCSH)*. Relevant documents were categorised and linked to the established concepts and their associations. User feedback on the usefulness was of the concept map was sought from a group of teachers. This domain-specific concept map was implemented to function as a finding aid.

A framework comprising usability, learnability, usability, and task & technology fit was used for review of concept maps. Based on this framework, several parameters were identified to perform usability analysis by two main groups of stakeholders: teachers and administrators. It served as a map of the knowledge for a community-of-interest in the area of continuing professional development for teachers.

DATA COLLECTION

Original concepts for the map were derived from the writings of Diaz-Maggioli (2004) and Zmuda (2004). These concepts were subsequently presented to a team working on teachers' professional development for comments and amendments. *CmapTools, (*an open source tool by the Institute for Human Machine Cognition (IHMC), University of West Florida) was used to construct the concept map. It allowed easy publishing of knowledge models in concept map servers and enabled concept maps to be linked to related concept maps and to other types of media. Linking phrases were added to the key concepts on the preliminary concept map to express the relationships among concepts. This was followed by adding cross-links to illustrate the inter-relationships between concepts in different areas or sub-domains on the map.

A total of 157 documents housed by READ@TN were linked to the relevant concepts. These included mostly documents in Microsoft Word and PDF format. In-house web pages and quality information from external websites were also linked to the concept map. Most concepts had one or two documents attached to them to give the respondents a flavour of what they could expect on the concept maps. The concept map was subjected to several rounds of reviews by senior education officers. Changes to the structure and contents were made prior to implementing the prototype on a hosting server (http://www.100free.com) at http://leeyf.100free.com. The availability of concept map on the Internet provided ease of access for participants. They could experience the working of the concept map at their convenience. On the basis of their experience they subsequently responded to a questionnaire survey (which was also web-based). Figure 2 show the final concept map constructed.

Thirty education officers and five administrators participated in the online usability survey. The participants were invited to view the concept map after a demo was arranged to introduce the concept map to them. Eighteen participants signed up for the follow-up interview (three senior administrators, nine senior education officers and six junior education officers).

FINDINGS

Usability

Three parameters including ease of use, effect, and satisfaction were used to review the usability aspects. Feedback from participants on these parameters is reported in the following section.

Ease of Use

Ease of use of the concept map encompasses the notion of simplicity and accessibility of finding and discovering information. Seventy-seven % participants reported that the concept map presented to them was easy to use. However, a fair portion of the respondents felt that, when the map was first presented to them, they were overwhelmed by the concept map and had difficulty understanding and using the map.

Twenty-nine % indicated that navigating the concept map was easy. All respondents were able to follow the logic of the navigation. Most participants were able to appreciate the navigational logic of the concept map. A large majority was able to easily navigate the concept maps for relevant information.

Sixty-eight per cent participants supported the proposition that concept maps improve the information searching output; while 14% did not agree that concept maps added value to the information searching experience. Despite the differences in opinion, all participants acknowledged concept map as a useful tool to aid knowledge discovery. They expressed that concept maps could provide guidance and direction to the information search process.

Satisfaction

Satisfaction is derived when a user is able to perform his/her information search task successfully. About one-third participants strongly supported the acceptance of concept maps while almost two-third expressed continuing interest to use concept maps in the future. When asked which group of Internet users could effectively use concept maps to search for information, 69% felt that concept maps would be accepted in all strata of Internet users; 71% felt that concept maps could only be accepted by novice Internet users while an astonishing 94% agreed that seasoned Internet users were capable to effectively use this finding aid. Forty-nine % felt comfortable using the concept maps. A further 31% were confident; only 17% experienced some stress while using concept maps to find information. The findings revealed a moderately high level of satisfaction and acceptance to the use of concept map in the context of teachers' professional development. The fact that participants had indicated strongly their desire to use concept maps shows a high level of confidence within them in this information search tool.

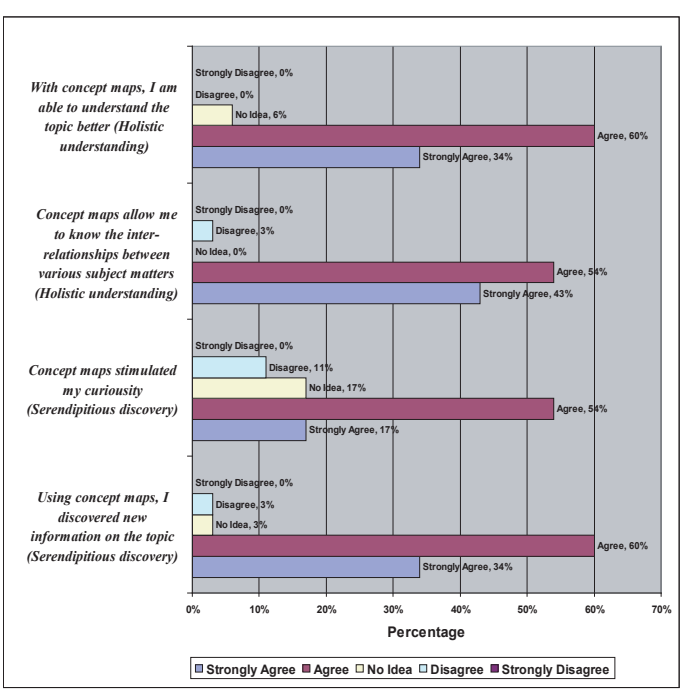
Effect

The effect of concept maps is tied to performance and outcome of the information searching exercise. There is a good spread of responses on the effectiveness of concept maps compared with other online search tools such as Internet search engines, Internet directories, library online catalogue. Forty-two % participants maintained that concept maps were more effective while 32% felt otherwise. More than three-quarter (77%) either agreed or strongly agreed that their overall experience with concept maps was successful and positive. All respondents felt that concept maps were able to guide them in their information search. They expressed full confidence in concept maps reflecting that concept maps provide a sense of purpose in finding information. However, statistical analysis suggested that concept map alone was not able to replace the role of other search tools like Internet search engines (e.g. Google, MSN Search) and search directories (e.g. Yahoo Directory), as less than half believed it could do so.

Learnability

Learnability refers to the ease of learning the system's functionality and gaining proficiency to complete the search for information. Our analysis attempted to review whether the concept map as an information search system encouraged holistic understanding and supported serendipitous discovery. We also reviewed if the concept map was able to enhance a broader understanding of concerning concepts surrounding each topic. When the concept map was developed, we expected that with the inter-relationships between various sub-topics (concepts) teachers would be able to gain breadth in their subject of interest. In the review, we wanted to

Figure 3. Learnability aspects of use of concept maps



find out whether the concept map demonstrated the ability to arouse interest on related concepts to facilitate the discovery of new information domains. Figure 3 displays the trends among participants on these learnability aspects.

Analysis of responses of participants indicated a good potential of concept maps on the various learnability aspects. In terms of holistic understanding, 94% participants agreed that concept maps provided them an overview of the topic and helped them understand the topic better. All respondents either agreed or strongly agreed that concept maps allowed them to explore the inter-relationships between various subject matters. In terms of serendipitous discovery, 71% of the respondents indicated that concept maps stimulated their curiosity. Almost all respondents asserted that they were able to discover new knowledge through the use of concept maps.

Task & Technology Fit

As the study looks into the learner's ability to interface with concept maps to find information, the issues on Task and Technology Fit (TTF) comes into play. Various elements of TTF were of concern in this study. These included the following parameters:

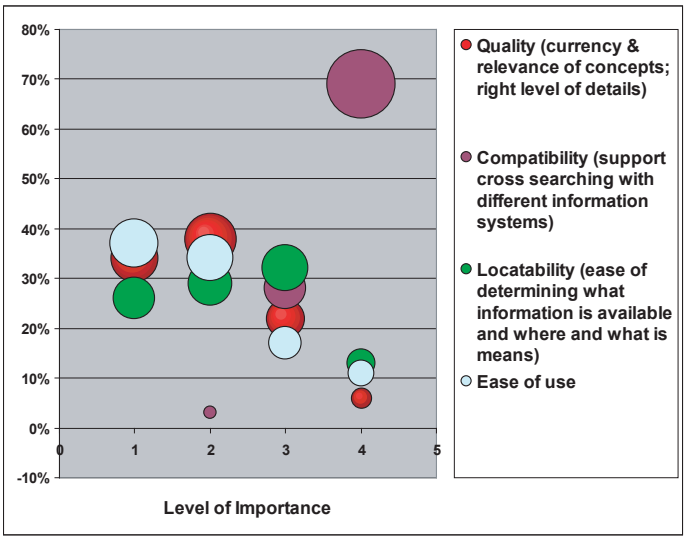
- Quality of concept maps
- Ability to locate information
- Compatibility with other information searching system
- Ease of use

The participants provided input on the importance of the various parameters. Ease of use and quality were viewed as the most critical elements, ability to locate information was ranked third, and majority viewed compatibility as least important. The issue of compatibility was not a serious concern to the respondents in their information finding. Figure 4 shows the level of importance attached to concept maps.

The study highlighted several interesting points in terms of TTF. Most participants pointed out that the quality and the ease of use of finding aids take precedence over other considerations. It is therefore vital that concept maps be designed taking these understandings in view. Despite concept maps' ability to enhance the searching experience and facilitate knowledge discovery, they are not widely used among educators in Singapore to find information, as discovered in this study.

In terms of human-computer interactivity, concept maps provided good interactivity between the system and the users. This was supported by more than half of the respondents. Again, with strong evidence from respondents that there was considerable interactivity between concept maps and the user, one could infer that concept maps are useful tool to facilitate knowledge discovery. In terms of functions, most of the respondents felt that concept maps were most suitable to search for well defined items. About one- third also recognized that concept maps were able to perform accidental discovery of useful information. Sixty-two % felt that concept maps made information finding easier, while only 6% disagree. About 45% agreed or strongly agreed that they could save time looking for information using concept maps, compared to occasions where they had to use Internet search engines and directories. About 30% disagreed with the earlier group. On the basis of these findings one can safely conclude that concept maps could complement other web-based search tools in providing users with a complete information finding abilities.

Figure 4. Task & technology fit



DISCUSSION

One of the strengths of concept maps is their facility to provide meaningful orientation and visual bearings to support information search through the use of nodes, labelled-links and cross-links. The participants of this study were able to appreciate this. An interviewee quoted *"What I liked about concept maps was that it gave me a birds' eye view of the information I was looking for. I get a good macro perspective of the topic and associated ones"*. Another said "*the links are especially helpful to let us know relationship between various subjects. I could never get such things from Google or Yahoo. The cross links added another useful dimension on the information, which is very valuable when I need to explain the subject to my course participants."*

The cross links value-add to the information finding process. They support the users in navigating the concept map. All participants agreed that the links contributed to their smooth accessing of relevant information. However, placing links on concept maps is a double-edge sword. Some interviewees have cautioned not to over-cluster and impair the smooth navigation of the concept maps by inserting excessive links.

More than 80 % participants claimed that concept maps had stimulated their curiosity; and almost all indicated that they were able to understand the topic better and discovered new information on the topic. As one interviewee cited *"Until I see your concept map, I didn't know I know so little about professional development"*. Another said *"What pleasant surprise! I learnt so much on professional development in just a few minutes."*

The source of purposeful learning is context stimulated by genuine interest and curiosity (Sylvie, Andrew & Jacques, 2001). While involving themselves in this study, many participants gained practical insights into teachers' professional development, which allowed them to view their profession in a wider perspective. A significant number of participants also pointed out that they experienced unanticipated findings of worthy information. In fact, one could see concept maps as a valuable platform for individuals to mine for concepts and ideas to further their understanding on specific topics.

When asked to rank factors most important to them in using concept maps to find information, the quality of concept maps came in second, behind ease-of-use. Users demand for prevalent and high-relevant concepts; and constantly updated information. Currently, concept maps are not able to match the vast amount of information one could access via Google or Yahoo. It is therefore advisable to look into the integration of concept maps with other common search tools to optimise the search outcomes.

Participants repeatedly stated that the noteworthy information search results were obtained through using both concept maps and search engine complementarily. For instance, they used the key words on the concept maps as search phrases on the search engines. They also used the articles available on the concept maps to trace other relevant documents on search directories. The challenge, as a result, is to establish a meaningful integration between concept maps and the various search tools to offer the best finding experience to users. It is with such an agenda that the greater potential of concept maps can be unleashed to support information discovery.

Functional design quality, or ease-of-use, was voted by the online survey participants as the most important characteristic of concept maps. This study surfaced three important areas of users' concern in the design of concept maps, namely over-crowding, interactivity and customisation. Over-crowding was flagged as a concerning issue when 37% of the online respondent felt that they were overwhelmed when first exposed to the concept map. Subsequently, the study found that a small group of individuals might need certain mental orientation to effectively comprehend the working of the map.

Some participants recommended implementing a "maps-within-maps" design concept and avoiding excessive cross-links as resolutions to avoid over-crowding.

But when discussed during the interview sessions, some interviewees warned that "maps-within-maps" would not be appealing to people who wanted fast information and it might put these users off. They added that it was good to be able to see all concepts at one glance. A suggestion was also made to technically code the concept map such that it allows scaffolding and hide details not needed. It might be appropriate for the concept maps designer to further conduct a design acceptance testing and seek feedback from intended users to arrive at an optimal design.

There is also a need to enhance the interactivity of the concept maps with users to increase the effectiveness of the map on information discovery. Many valuable suggestions were received from participants regarding this aspect. Among the suggestions are facilitating manipulation to the design by authorized users, providing templates and instructions to perform the manipulation, forwarding online comments and clarifications to concept maps designer/administrator and setting up communities of practice via online chat-room. In fact, more can be done to make concept maps even more dynamic, for example, allowing users, instead of just authorised personnel, to create concept maps. This is a "collaboration" feature which can be supported by using appropriate tools.

An important factor influencing the acceptance of concept maps is users' *competence* to handle their search. For instance, online chats may be included to enhance interactivity; font and colour setting may be made available to provide a higher level of customisation; and integration with other search tools may be developed to produce better search outcomes. There are also some concerns over who would be responsible for creating the maps, how the maps and related resources would be maintained and at what cost. These are all valid and practical concerns which are seldom dealt with in research papers.

Managing users' *expectation* is perhaps one of the most important considerations in gaining their acceptance to concept maps. An interesting feedback from a survey respondent reads *"there is a need to establish the link between what the concept maps could provide, and what each user actually needs. I feel that concept maps provided the "generally targeted" information (that caters to general needs) but not the "specifically targeted" information (that caters to each individual)."* Indeed, specific features and finding capabilities must be clearly demonstrated and communicated to users to ensure a full appreciation of what concept maps can genuinely offer.

CONCLUSION

This study has indicated that teachers are impressed with the simplicity, user-friendliness and usefulness of concept maps as an information finding tool. They seemed to be enthusiastic to adopt the tool in furthering their knowledge discovery efforts and to recommend it to their colleagues. However, concerns expressed by participants of the study did suggest that concept maps cannot be used in isolation. Drawing on their unique capabilities, there should be meaningful integration with other search tools to bring about higher search outcomes and richer resource discovery experience. The ongoing focus is therefore not to compare concept maps with other search tools but explore avenues to marry them. The study also indicated that while concept maps are generally accepted as useful information search tools, there are still many areas for improvement. To attract mass uses of concepts, the functional design needs enhancements and content quality of concept maps need to be constantly updated. Concept maps as knowledge discovery tools are desired to be promoted among different communities of practice through easy to use infrastructure support.

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