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CONCEPT MAPS FOR MANAGING INDIVIDUAL KNOWLEDGE

Abstract. Advanced computer-based concept-mapping tools have the potential to not only represent conceptual knowledge but also content knowledge (self-generated annotations, text, graphics) and knowledge about knowledge resources (e.g. websites, multimedia documents, CBT/WBT programs). Up to now empirical research on concept maps has focused on their potential as teaching, learning and assessment tools. It is suggested that advanced computer-based concept maps may also help students in managing knowledge when they cope in a self-regulated manner with complex cognitive processing tasks. The paper aims at analyzing the potential of computerized concept maps for supporting processes of individual knowledge management in self-regulated resource-based learning scenarios. Perspectives for research on the use of concept maps for individual knowledge management are outlined.

1. INTRODUCTION

Learners studying self-regulated have to cope with a complexity of knowledge and knowledge resources in many domains. Particularly in resource-based learning scenarios (Rakes, 1996) which use the Internet as a tool students are often cognitively overcharged. Information literacy is needed to make effective use of resources (Brevik, 1992; Brevik, & Senn, 1994). Many students, however, have not yet acquired effective strategies of resource-based learning. They suffer from cognitive overload and conceptual and navigational disorientation (Bleakley & Carrigan, 1994). Visualizations are suggested to help learners coping with subject-matter complexity and ill-structuredness (Holley & Dansereau, 1984; Jonassen, Reeves, Hong, Harvey & Peters, 1997). They may help students to elicit, (co-)construct, structure and restructure, elaborate, evaluate, locate and access, communicate, and use ideas and thoughts as well as knowledge about relevant contents and resources (Jonassen, Beissner & Yacci, 1993). Jonassen et al. (1993) have described a variety of visualization methods for representing, conveying, and acquiring structural knowledge. The idea behind all methods is that cognitive processing of complex subject-matter may be enhanced if structures behind ideas and knowledge as well as their relevance for learning and problem solving are made explicit. Helping students to organize their knowledge is as important as the knowledge itself, since knowledge organization is likely to affect student´s intellectual performance (Bransford, Brown, & Cocking, 1999).

2. CHARACTERISTICS OF CONCEPT MAPS

A visualization technique which has a long tradition in the educational context as a cognitive tool for enhancing learning is concept mapping. The technique has been invented by Novak & Gowin (1984) based on the ideas of Ausubel (1963) who advocated that an individual´s subject-matter knowledge is mentally represented in a hierarchy of concepts. A concept map is a spatial array that represents elements of knowledge by means of nodes and links, the nodes representing ideas, concepts, and beliefs and the links relations between them. Multiple linkages between concepts may depict how each concept is related to other concepts. Concept mapping is suggested "to take advantage of the remarkable capabilities of the human visual perception system and the benefits of visual information representation. These benefits include (a) ease of recognition, (b) the possibility to quickly scan a picture and find differences or keywords, (c) compactness of representation, and (d) the observation that it seems to be easier to keep an overview" (Kommers & Lanzing, 1997, 423). Concept mapping is conceived to be essential for a constructivist approach to learning and problem solving. "Constructing concept maps stimulates us to externalize, articulate, and pull together information we already know about a subject and understand new information as we learn". … "It stimulates a learner to find contours of his/her knowledge" (Kommers & Lanzing, 1997, 424).

During the process of learning and problem solving a concept map as an external representation of semantic memory may also help the learner overcoming problems that are due to the limitations of short term memory in both capacity and duration of stored information. Combining visual and verbal modes for cognitive processing reduces the burdon on working memory, expanding the brain´s ability for coping with complex cognitive task requirements. In addition to the potential of concept maps for reducing cognitive load (Sweller, 1988, 1994), they may serve functions more than simple memory extensions. There is a lot of evidence indicating that the use of concept maps has proven to be a valuable strategy for supporting cognitive functions in a variety of learning and instructional settings (a.o. Novak, 1990; Jonassen, 1987; O'Donnell, Dansereau & Hall 2002; Bruillard & Baron, 2000).

In the past concept mapping has been used in the instructional context primarily for purposes of fostering knowledge elicitation, knowledge acquisition, and knowledge assessment (Kommers & Lanzing, 1997). The approach was restricted to a mapping of concepts and relations between concepts. Recently this conception of concept mapping has been criticized as too narrow and not appropriate for capturing in a comprehensive manner an individual´s knowledge about a subject-matter (Alpert & Gruenenberg, 2000). The maps tend to represent the conceptual macrostructure of a domain only, leaving the knowledge about contents and resources to which the conceptual structure refers unrepresented. Unlike traditional tools advanced computer-based concept mapping tools

(e.g. Knowledge Manager, http://www.knowledgemanager.us/; Mind Manager, http://www.mindjet.com/; Inspiration, http://inspiration.com/productinfo/inspiration/features/index.cfm; Cmap Tools, http://cmap.ihmc.us/; SMART Ideas, http://www.smarttech.com/products/smartideas /index.asp) provide additional representational capabilities. They allow to express knowledge more fully by incorporating the representation of content and resource knowledge using multiple coding formats (text, sound, picture, video) and interactive links. Thus, not only semantic knowledge of a subject-matter domain in terms of abstract concepts and their semantic relationships may be represented but also in a more comprehensive manner content knowledge as represented by self-generated annotations and elaborations of the conceptual knowledge like notes, short-texts, web-logs, graphics. Additionally resource knowledge to which the concepts refer and which is relevant for a further elaboration of the conceptual knowledge may be represented by means of linking concept nodes to files stored locally or to web-pages available in the Internet. These are e.g. multimedia resources, websites, programs, cognitive tools (Coffey, Hoffmann, Cañas, & Ford, 2002). Whereas traditional concept mapping tools only allow for two-dimensional static representations advanced computer-based tools also provide free interactive access to content and resource knowledge linked to the conceptual knowledge by means of hyperlinks. Concept maps in this way may be used as a cognitive tool for providing knowledge-based access to individual repositories of resource knowledge.

In addition advanced computerized concept-mapping tools provide typical office-software facilities, e.g. free editing facilities to be used for (re)constructing, (re)organizing, and (re)representing mapped knowledge. They also provide facilities for storing, printing, representation in different formats (outline, graphic), e-mailing and web-implementation in html format. Functions for interactive access to linked knowledge elements on the basis of the conceptual structure of a domain may be used to enhance the localization and use of individual conceptual elaborations as well as knowledge resources. Some of these tools in addition provide functions for reviewing the creation process of a map, e.g. by means of backtracking and provide functions for web-conferencing (e.g. Smart Ideas). Most of the tools also support ways for a collaborative construction of concept maps enabling distributed teams to collectively develop and access maps (see Cañas, Lake & Wilson, 1999). Because of the enhanced functions computer-based concept maps may be particularly helpful as cognitive tools for students studying self-regulated in open resource-based e-learning scenarios designed toward a constructivist design rationale. These scenarios leave students a high amount of freedom for self-evaluating the appropriateness of existing knowledge, searching for additional information, assembling ideas, (co)constructing and representing knowledge and knowledge resources, sharing and communicating it to others, as well as for using knowledge and knowledge resources in a flexible manner for creative problem solutions.

This conception of using concept-mapping technology for managing knowledge and knowledge resources is quite concordant with a conception of individual knowledge management as part of advanced self-regulated resource-based learning, which is gradually fading into the field of e-learning (Maurer & Sapper, 2001). A framework for analyzing the potentials of computerized concept mapping for different process categories of individual knowledge management is suggested. The framework is oriented toward a model of basic knowledge management processes as described by Probst, Raub and Romhardt (1999). The processes focused are cognitive as well as meta-cognitive processes framed into categories which are relevant for knowledge management processes in advanced e-learning and resource-based learning. It is suggested that the framework may be used for analyzing and tailoring empirical research on concept mapping used for supporting processes of individual knowledge management.

3. CONCEPT MAPPING FOR FOSTERING PROCESSES OF KNOWLEDGE MANAGEMENT

How can mapping tools add to fostering processes of individual knowledge management? According to Malhotra (2000) the focus of knowledge management is on an interaction of technology-based tools and the people using these tools in a task-appropriate manner for coping with cognitive requirements of managing both mental and external representations of knowledge. Based on the model of Probst et al. (1999) (see also Reinmann-Rothmeier and Mandl, 2000 for a revised version of the model) several highly interdependent process categories of knowledge management may be identified. The categories are: knowledge identification/evaluation, information search, knowledge generation, knowledge representation, knowledge communication, knowledge use.

Knowledge identification / knowledge evaluation. Knowledge identification and evaluation are closely related meta-cognitive processes performed by an individual. After an initial process of task analysis and goal setting a student coping with a complex cognitive task has at first to identify task-relevant knowledge and to evaluate it with respect to the knowledge available or not available for coping effectively with a particular task situation. Self-evaluation of individual knowledge may be done on a map-based representation of one´s knowledge. For example, if the task is to acquire expert knowledge, the structure of an individuals' knowledge as represented in an individual knowledge map may be compared with the knowledge structure of an expert as represented in an expert map. The potential of knowledge maps as means for diagnosing individual structures of knowledge has been shown in a variety of empirical studies (a.o. Jonassen et al., 1997). In self-regulated learning scenarios the particular contribution of computer-based concept maps is that they may support self-assessment (Shavelson, Lang, & Lewin, 1994; Kommers & Lanzing, 1997).

Information search. When individual knowledge has been evaluated as inappropriate for effectively coping with a cognitive task situation and knowledge gaps have been identified it is necessary to look for task-relevant content and resource knowledge to fill the gaps and acquire appropriate knowledge. Learners in virtual learning scenarios may, for example, get access to subject matter content knowledge as represented in texts or multimedia documents, which are stored in repositories provided by the learning environment on CD-ROM or they may access knowledge resources available in the World Wide Web. Concept maps have been used as a navigation device for students who need orientation while they explore wide information domains like hypermedia documents available on CD-ROM or in the World Wide Web (Kommers & Lanzig, 1997; Potelle & Rouet, 2003). They "serve to provide learners with navigational clues, in order to facilitate navigation through the materials and ... the construction of new knowledge" (Bruillard & Baron, 2000). For example McDonald and Stevenson (1998) and Carnot, Dunn, Cañas, Gram & Muldoon (http://www.ihmc.us/users/acanas/Publications/CmapsVSWebPagesExp1/CMapsVSWebPagesExp1.htm) found that concept maps may provide an efficient access to web-based information resources. This effect is more pronounced with low knowledge level students than with high knowledge level students and when students are meaningful learners compared to rote learners. An innovative use of concept maps for enhancing web searches has recently presented by Carvalho, Hewett and Cañas (2001). Concept maps combined with filtering and ranking algorithms of the results of search engines (Google, Altavista, Yahoo, Excite) were found to enhance identifying pages that the subjects considered are relevant to the context of the map.

Knowledge generation. New knowledge is generated by constructive cognitive processes like integrating, elaborating, reorganizing, reformatting existing knowledge structures and linking knowledge elements (concept knowledge, content knowledge, resource knowledge) with contexts and situations. Concept mapping has been used effectively in instructional settings to foster processes of knowledge generation (e.g. Wallace, West, Ware & Dansereau, 1998; O'Donnell et al., 2002). For example, Gaines and Shaw (1995) describe the rationale of a prototype Learning Web implementation as well as tools such as concept-maps and repertory grids used within the web for knowledge generation.

Advanced mapping tools also provide functions to annotate nodes as a means for the elaboration of knowledge. Knowledge generation is supported by providing functions for reorganizing and reformatting existing knowledge maps.

Knowledge organization / representation. The process of knowledge representation is in the center of all knowledge management processes. It is closely related to the process of knowledge generation. In order to make generated knowledge accessible for future use

it must be mentally organized according to some semantic or pragmatic rationale, represented in a format mirroring the cognitive affordances for coping with a particular task situation. It must also be adaptable dynamically according to changes in task affordances. In complex and knowledge-rich cognitive processing tasks it is necessary not only to represent the conceptual knowledge of a domain but also content knowledge (stored in local files) and resource knowledge (represented in the Internet) by means of linking the respective knowledge elements. When individual knowledge is externalized in a map, the map can provide easy access to them, e.g. in situations when an argument during a discussion has to be referenced to a particular content or knowledge resource or when a content has to be reviewed in the course of a writing process.

Computer-based mapping tools provide functions for externalizing mental representations of knowledge in arbitrary formats. Computer-based maps are no longer two-dimensional spatial arrays that represent concept knowledge in the form of a node-link-node diagram. In addition to traditional tools computer-based tools also allow for mappings in a hypertext-like format by using sub-maps and links (e.g. Alpert & Gruenenberg, 2000). By means of linking concept knowledge, content knowledge and resource knowledge may be represented in a coherent representational format. When maps are used for representing individual knowledge they serve as cognitive tools to augment capacities of human memory (Jonassen, Carr & Yueh, 1998).

Knowledge communication. Knowledge communication, as a knowledge management process, may serve different purposes, for example, to disseminate knowledge from a tutor to students, between peers of students, and from a student to a tutor. Students working together in a cooperative instructional setting communicate and share knowledge in order to contribute to the construction of shared knowledge or to the design and development of a common cognitive artifact. Computer-based mapping tools may contribute to foster processes of knowledge communication in several ways. They may, for example, be used to communicate the concept structure of a subject matter and enhance knowledge acquisition (McAleese, Grabinger & Fisher, 1999; Fischer & Mandl, 2001). They may also be used as a basis for fostering cooperative work (Jacobson & Levin, 1995). Mapping tools may be particularly useful in fostering coping with a task situation that requires knowledge which is too comprehensive and conceptual views which is too diverse for a single person to manage successfully. During the construction phase concept maps may contribute to foster grounding processes (a.o. Coffey, Hoffmann, Cañas & Ford, 2002; McAleese et al., 1999; Fischer & Mandl, 2001).

Knowledge use. In order to facilitate knowledge use mental representations of knowledge have to be structured and represented task-appropriately. Knowledge representations must easily be restructured and adaptable to different situations, tasks, individual interests and contexts of use (Spiro, Feltovich, Jacobson & Coulson, 1991). It

has been suggested that concept mapping may enhance the processing capacities of the human brain. A necessary precondition for this is that the knowledge must be represented explicitly and knowledge elements must be accessible freely and trackable easily. Map-based visualizations of ideas and individual knowledge representations match these conditions. Concept mapping has proven to be a valuable cognitive tool for supporting cognitive functions in a variety of learning and instructional settings, among them scaffolding cognitive processing in knowledge acquisition and problem solving (Jonassen, 1992; Fischer & Mandl, 2001; O'Donnell et al., 2002), and designing hypermedia products (see Kommers & Lanzig, 1997). Concept maps used to manage individual resource knowledge may be particular useful in resource-based learning scenarios like WebQuest (http://webquest.sdsu.edu/). Concept maps in WebQuest scenarios may help the learners maximizing the use of information obtained from online resources when the resources are made accessible by a concept map (Carvalho et al., 2001).

4. PERSPECTIVES FOR APPLICATION AND RESEARCH

It is important to develop conceptions of how to use strategies and tools for knowledge management for the purposes of coping with knowledge-rich task situations more effectively (Malhotra, 2000). Up to now there are only isolated approaches aiming at bringing together mapping tools for knowledge management and e-learning (e.g. Gaines & Shaw, 2002). It is the task of educational information technology to develop systems and tools for individual knowledge management and to integrate them into platforms for web-based e-learning. Concept mapping has proven to be a valuable technique for enhancing aspects of cognitive processing of conceptual knowledge. Advanced concept mapping tools meet the demands of coping effectively with managing conceptual, content and resource knowledge in one coherent visual representation. They have a high potential to support learners in self-regulated learning and knowledge management. The task of instruction is to develop learner-centered instructional scenarios and integrate the use of knowledge management systems and tools. Research on the effective use of mapping tools for supporting the management of conceptual, content and resource knowledge in e-learning scenarios has to be initiated. Past research has shown that concept mapping is rarely used spontaneously by students, because it is difficult and that the process of map modification sometimes may be messy and cumbersome. Concept mapping used for individual knowledge management requires skills in generating appropriate maps and using them efficiently. The kind of task, map characteristics, the amount of subject-matter knowledge, the tendency for rote or meaningful learning are variables that may effect the effective use of concept maps in learning scenarios (Lambiotte & Dansereau, 1992; Wiegman, Dansereau, McCagg, Rewey & Pitre, 1992; O'Donnell, Dansereau & Hall, 2002; Bruillard & Baron, 2000). In order to evaluate the potential of concept mapping for knowledge management in advanced learning research

has to focus on the individual and situational conditions of effective use of mapping tools for knowledge managing and on how managing-processes may be fostered by technical features and instructional measures.

A rationale for a research program on studying the conditions of effective individual managing of knowledge with computerized concept mapping tools has been presented by Tergan, Gräber & Reinmann-Rothmeier (2003) at the 10th biennial conference of the European Association for Research on Learning and Instruction (EARLI) in Padova (Italy. A further impetus on research on the potential of concept maps for organizing large bodies of individual knowledge has been provided by the International Workshop on Visual Artifacts for the Organization of Information and Knowledge" held at Tübingen (Germany) in May 2004 (http://www.kmrc.de/workshops/visual_artifacts/?go=right).

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