An XML-Based Tool for Building and Using Conceptual Maps in Education and Training Environments

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Abstract. Conceptual maps have been used in many areas as a means of capturing and representing knowledge. Several authors have explored the use of visual tools to enhance the learning process. *Thinking maps* as well as *frame games* use visual patterns of relationships (learners thinking processes) to structure knowledge. Based on their graphical structure it is possible to recognize the thinking process(es) employed in the map. Several software applications have been created to support different kinds of maps, but they use proprietary files to represent their maps. It makes sharing of knowledge difficult and jeopardizes the widespread use of maps.

This paper proposes XML (Extensible Markup Language) as the language to describe maps. A knowledge construction and navigation tool (KVT- Knowledge Visualization Tool) has been implemented using XML to represent the kinds of maps supported by *thinking maps* and/or *frame games*. This paper describes the uses of KVT in education and training environments.

Keywords: Knowledge Construction and Navigation Systems, Conceptual Maps, Thinking maps, Frame Games, XML, and Learner Models.

1. Introduction

Conceptual maps have been widely used in many disciplines for different purposes. Concept maps have been used in education and training as a means of capturing and representing knowledge. Concept maps are just one of a variety of visual tools employed in schools and corporations. Several authors [2,4,5,6,7,9,10, and 14] have explored the use of conceptual maps to enhance the learning process.

Several authors [1,3,7, and 14] have used map adaptation techniques in hypermedia systems to offer a pertinent group of links to a particular user in a particular situation. Existing map-based navigation systems use different adaptation techniques to change the structure of the map according to the users' goals or preferences.

In this paper, we present KTV (Knowledge Visualization Tool), a knowledge construction and navigation tool that allows students and teachers to create XML-based maps in which they can add different kinds of links to the nodes on the map and navigate throughout the content using their own map. In addition, learners can introduce their own links or use links suggested by the teacher and/or other learners. Students and teachers can remove any unwanted link and define the sequence in which the links will appear. XML-maps are viewed as an important step in the creation of an open representation of maps that facilitates sharing of knowledge and assessment of students' knowledge by comparing their maps.

2. Visual Concept-Mapping Tools.

Visual concept-mapping tools (maps) have been used for constructing knowledge and capturing information about people's thinking processes. Because of the many types of maps available, people may feel confused about what kind of map to choose for a specific problem. Hyerle [4] classifies maps in three categories:

- **Informal representations**, such as *brainstorming webs*, *web maps*, and *mind maps*, which are used mainly to support association and creative processes.

- **Task specific maps or organizers**, such as *life cycle*, *text structures*, and *decision trees*, which are used in specific content areas or tasks.

- **Thinking process maps**, such as *concept maps*, *system thinking maps*, and *thinking maps*, which are used to represent not only content relationships on a specific area, but also the thinking process or kind of reasoning behind the map.

Web maps, *mind maps*, and *brainstorming maps* have been used to support creative processes. Their informal structure is useful in areas, such as: brainstorming sessions, decision making, problem solving, taking notes, public speaking and planning. Figure 1 shows an example of a mind map created using Mind Manager® MindJET, LLC [8].
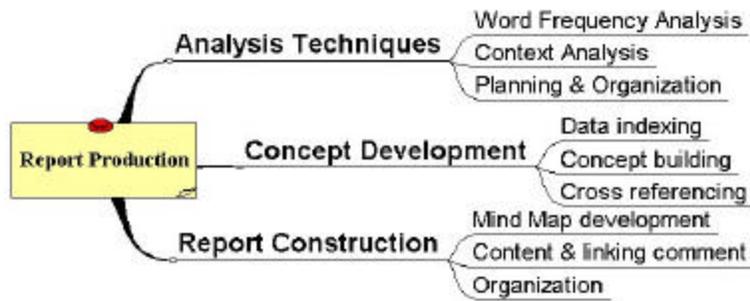

Figure 1. Example of a mind map [8].

Task-specific maps or *organizers* are designed to structure knowledge on a specific area. Figure 2 shows an example of a simple task-specific map (a classification tree) used in a biology class.
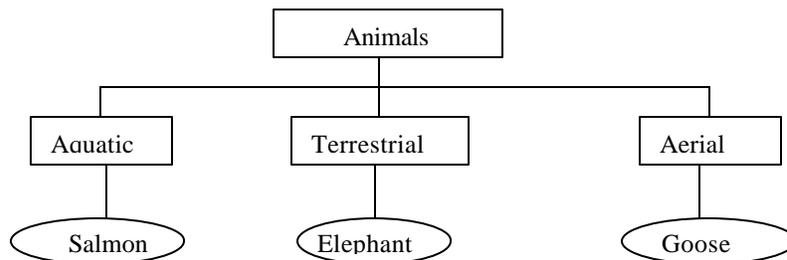

Figure 2. An example of a task-specific map or organizer (classification tree) used in a biology class

Thinking process maps include *concept maps*, *system maps* and *thinking maps. Thinking maps* [4] are similar to *frame games* [6]. They use various kinds of visual patterns to represent information relationships and mental processes such as: sequencing, identifying attributes, cause-effect reasoning, analogical reasoning, part/whole reasoning, and classifying information.

Using *concept maps* [5,6,9, and 10] with different types of links, it is possible to represent more or less the same mental processes that thinking maps represent. The main disadvantage of *concept maps* over *thinking maps* is that their graphical structure does not necessarily reflect the thinking process. Figure 3 shows a simple example of a concept map.
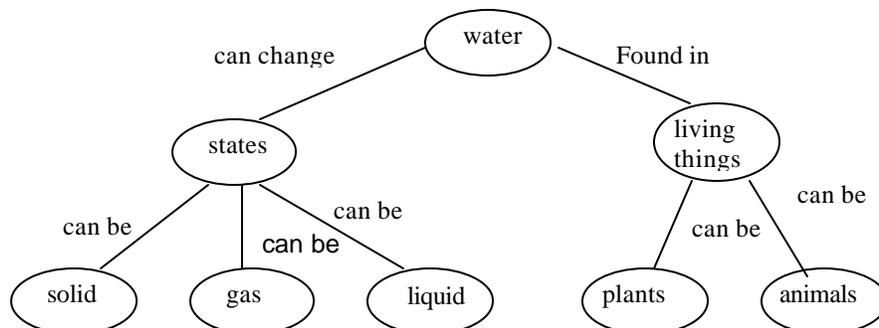

Figure 3. An excerpt of a concept map [10].

Thinking maps and *frame games* integrate knowledge views and make explicit fundamental human cognitive processes. According to Hyerle [1], by using *thinking maps*, it is possible to create any map that can be created using *brainstorming webs* and *task organizers* without being as informal as *brainstorming webs* and less content dependent than *task organizers*. Not only do thinking maps support structuring of content but also thinking processes, meta-cognitive abilities and reflection. Figure 4 shows some of the visual patterns supported by *thinking maps* and/or *frame games*.
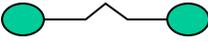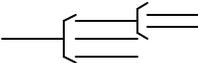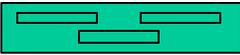
Thinking map	*Frame game*	*Reasoning*
 Bridge	 Analogy	Metaphorical
 Multi-Flow	 Cause-Effect	Systems dynamics
 Brace	 Part/Whole	Inductive and deductive

Figure 4. Some of the maps (visual patterns) supported by thinking maps and/or frame games.

3. Proprietary Map File Formats vs. XML-Maps

Most of the available commercial products (i.e. [8,11, and 13]) support *mind maps* or variations of them for multiple purposes (i.e. brainstorming sessions, decision making, problem solving, taking notes, public speaking, etc.). These products provide links to external applications, to other maps, and to content on the web. Although, ThinkingMaps® [12] is a software tool for the creation of thinking maps in education and training environments, it does not provide links to external applications, to other maps, or to the web. All these products use proprietary map file formats to represent their maps. It makes difficult sharing of knowledge and jeopardizes the general use of maps.

Using XML as the language to represent maps it is possible to eliminate proprietary files. The creation of a DTD file (Document Type Definition) to validate XML-maps should consider the main characteristics of the maps, such as: linking nodes to external applications, to content on the web, and to other maps. The DTD file proposed in this paper ('XMLmaps.dtd') covers all of the eight kinds of maps supported by *thinking maps* [4] and the ten kinds of maps (visual patterns) supported by *frame games* [6]. We have chosen to work with *thinking maps* and/or *frame games* because of their property of providing different visual patterns to represent different thinking processes. Figure 5 shows a fragment of the DTD file created to validate XML-maps.

Some of the benefits of using XML as the language to represent *thinking maps* and/or *frame games* are:

- XML provides an open format to maintain and share maps as opposed to proprietary file formats.

- By using a common vocabulary in conjunction to XML-maps, it is possible to compare maps. That is, maps can be compared to find similarities and differences in the type of structure employed (thinking process used by the learner to analyze the topic), relation among nodes and types of links and documents attached to each node.

- Any XML query language such as XML-QL or XQL can be used to create queries to compare maps. By comparing maps it is possible to assess learners' knowledge and determine possible misconceptions, or gaps on a specific concept or group of them. By analyzing the type of map used to represent the knowledge it is possible to identify possible problems of the learner with a specific kind of reasoning.

- XML permits collaborative viewing of maps. See section 4.3 (KVT- Navigation System).

- By maintaining the student's knowledge information (XML-maps) in the learner model, new interesting opportunities for assessment, collaboration, adaptation, and inspection can be explored.

- Opening visual knowledge representations is an important step towards the goal of capturing, sharing, and using knowledge across disciplines.

Figure 6 shows a fragment of an XML-map used to study Anatomy. This map has been validated using the grammar rules encoded in 'XMLmaps.dtd'. Figure 7 shows the graphical representation of the same XML-map. This map can be classified as a 'brace map' following the notation of *thinking maps* or as a 'parts-whole' pattern using the *frame games* representation. In both cases, they represent part-whole relationships among concepts and inductive/deductive kinds of reasoning.

```
# Author: Juan Diego Zapata Rivera
# Version: XMLmaps.dtd 1.0
<!--*******************************************************************
ELEMENT: XMLmap
COMMENT: thinking maps structures and frame games-->
<!ELEMENT XMLmap  (CircleMap* | BubbleMap* | DBubbleMap* |
BridgeMap* |FlowMap* | BraceMap* | TreeMap* |MultiFlowMap* )
<!ATTLIST XMLmap
<!--*******************************************************************
ELEMENT: BraceMap
COMMENT: Brace map. whole/ part. Inductive and Deductive Thinking-->
<!ELEMENT BraceMap (BraceNode+,Link* )
<!ATTLIST BraceMap
MapId CDATA    #REQUIRED
Type   CDATA    #REQUIRED
Name CDATA   #REQUIRED
Description  CDATA   #REQUIRED
<!--*******************************************************************
ELEMENT: Link
COMMENT: Link description-->
<!ELEMENT Link (FromNode,ToNode,LinkMedia )
<!ATTLIST Link
LinkId CDATA    #REQUIRED
Type   CDATA    #REQUIRED
Name CDATA   #REQUIRED >
```

Figure 5. Fragment of DTD for XML- maps .

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="XMLmaps.xsl"?>
<!DOCTYPE XMLmap SYSTEM " XMLmaps.dtd">
<XMLmap>
    <BraceMap Type="'BraceMap'" Description="'Example of an XML-map'" Name="'The human body'"
    MapId="'Map001">
        <BraceNode NodeId="02" Type="'BraceMap'" Name="'head'" XMLthinkingMapLink="'">
            <LinkMedia XMLConcept="'head'" Text="'" Application="'" URL="'l'" Sound="'"/>
            <Chlidren>05</Chlidren>
            <Chlidren>06</Chlidren>
            <Parents>01</Parents>
        </BraceNode>
        <BraceNode XMLthinkingMapLink="'" Name="'ears'" Type="'BraceMap'" NodeId="05">
            <LinkMedia XMLConcept="'ears'" Text="'" Application="'" URL="'www.body.xml'" Sound="'"/>
            <Parents>02</Parents>
        </BraceNode>
        <BraceNode XMLthinkingMapLink="'" Name="'eyes'" Type="'BraceMap'" NodeId="06">
            <LinkMedia XMLConcept="'face'" Text="'" Application="'" URL="'www.body.xml'" Sound="'"/>
            <Parents>02</Parents>
        </BraceNode>
        <BraceNode XMLthinkingMapLink="'" Name="'torso'" Type="'BraceMap'" NodeId="03">
            <LinkMedia XMLConcept="'trunk'" Text="'" Application="'" URL="'l'" Sound="'"/>
            <Parents>01</Parents>
        </BraceNode>
```
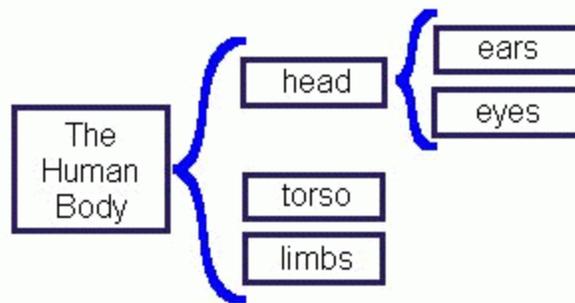
Figure 6. Fragment of an XML-map about 'Anatomy'

Figure 7. Graphical representation of an XML-map about 'Anatomy'.

4. *KVT* (Knowledge Visualization Tool)

KVT is a map construction and navigation system that allows not only the creation of XML-based *thinking maps* or *frame games*. KVT provides the possibility to link different kinds of resources to specific nodes. In this way, KVT supports personalized navigation throughout the class content. Students can create their own knowledge structure using a set of predefined concepts (*common vocabulary* given by the teacher) and use their own map to access class resources. These resources are suggested by the teacher (*initial links*) or by his/her classmates during the creation of their maps (*collaborative browsing using XML-based maps*).

The class content is not limited to a specific group of pages, videos, sounds, etc. On the contrary, any student or teacher in the class can navigate through the map via the WWW, can add links, and can add new resources. Every participant has access to all of the resources that are associated with the nodes in his/her map. The list of resources attached to a node can be ordered arbitrarily by the learner.

4.1 KVT's Architecture

KVT (see figure 8) is composed of the following modules:

- *Map Construction Tool*. KVT supports the ten kinds of maps identified in the context of *frame games* [6] and the eight types of thinking maps proposed by Hyerle [4,12]. Students select concepts from a predefined list and create their own structure. Having a predefined list of concepts (*common vocabulary*) makes it easier to share, compare, analyze and evaluate maps. Students can link different resources (course materials, web pages, documents stored on different applications, etc) to their map. They can even include other maps in a recursive manner. Students' maps are stored in the learner model for further modification, analysis and evaluation.

- *The Browser.* This is the main interface to visualize one's map and its associated class content. Students can navigate throughout the content by clicking on any node of the map and selecting one of the links/documents that are available for this node. Furthermore, students can navigate freely and add links and documents to any of the nodes in the map. Students can navigate using links suggested by other students/teachers in a hyperspace created collaboratively for a particular topic and encoded on the map.

- *The Learner Model*. The Learner module maintains basic learner information as well as their XML-maps (XML files including map structure, links, and order preferences). Students can add, order, modify, or remove links and nodes. Students and teachers contribute to populate each node with different sort of resources, but it is up to each person to remove unwanted resources and define the sequence in which he/she prefers to see the resources.

- *Course Materials.* Class resources are classified into three main categories: web content, XML content, and general documents (text, sound, images, videos, etc.). They comprise an open range of materials that are organized first by the teacher. Using KVT, students and teachers can create different representations of the knowledge, and as a result of their contributions a highly refined subset of useful documents will be attached to each of the nodes. KVT supports the cooperative creation of information spaces to be used in educational contexts.

- *Learners and Teachers Share Maps.* Learners and teachers can use KVT in a number of ways. For example, Teachers and learners can visualize maps using different levels of granularity. Learners can

use an existing map as a guide to study the content, or use this system as a learning tool to facilitate remembering, create maps collaboratively, share their maps, and engage in interesting discussions about a particular topic. Teachers can create maps to serve as 'guided tours', which can be used by students to navigate throughout the content. Teachers can use XML-maps to assess the student's knowledge. This can be done by comparing different maps (visually or through queries) to determine problems in the learning process for a particular student or groups of them. Finally, teachers can use this system as an adequate environment to promote reflection among students on a specific topic (map structure and content).
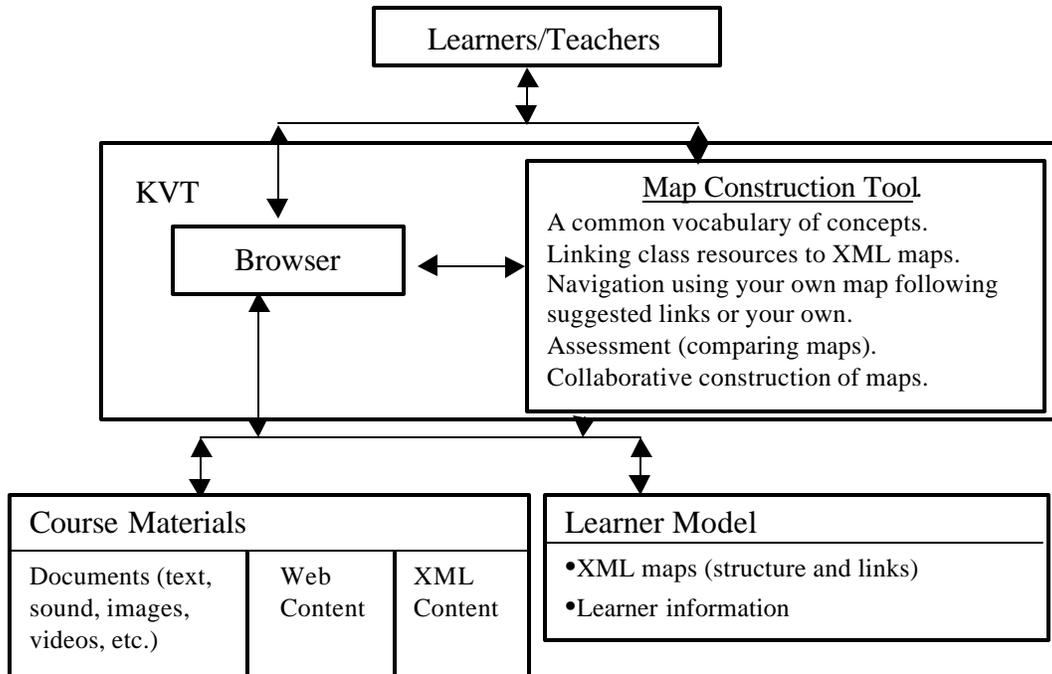

Figure 8. KVT- System Architecture

4.2. KVT- Linking Documents to Nodes.

Using KVT it is possible to add different kinds of documents to the nodes of the map. Figure 9 depicts the user interface provided by KVT to add, modify and remove documents. This interface allows students/teacher to attach a web page, XML document, video, sound, or image to any node on the map. KVT also provides the option to test any of the documents, edit the description and document fields and remove any unwanted link from the map. By clicking the headers on the grid it is possible to change the order in which the links will be presented to the student when navigating using the map. Order preferences are stored in the learner model for further use.

New links/documents for a particular node are automatically shared with all of the maps that contain such a node. This can affect maps of several students/teachers in the system. However, individual sequencing or removal of resources affects only the student's own map. Maps are stored as XML files in the learner model. The example on figure 9 shows a Brace-map that is used to organize information related to Anatomy. The grid of current documents shows the currently available links for the concept 'ears'. It is possible to visualize who included each link (user type/user), the document type location and description.

4.3. KVT- Navigation System.

Figure 10 shows how students and teachers can navigate on the web using their own maps and their own links or the ones suggested by others. Just by clicking the concept, a list of current links/documents appears to be selected. If the student has not chosen any particular sequence of resource presentation, this list is initially ordered by type of user (teacher/student). In this environment, it is also possible to navigate freely on the web by entering a URL or just following the links on the current page. When an interesting page is found, it can be attached to any concept on the map by selecting the target concept and pressing the button 'Add Link' located at the bottom of the window.

The example in Figure 10 shows how the student uses the map to navigate by the links related to the concept 'ears'. The current web page corresponds to the first link suggested by the teacher 'Anatomical Tour of the Ear'.
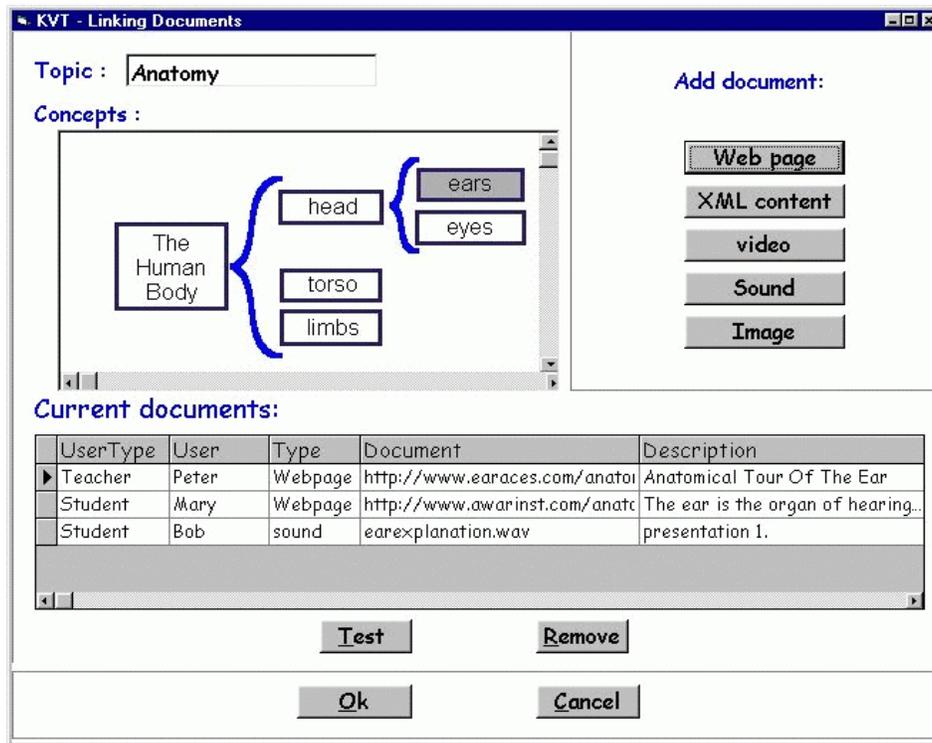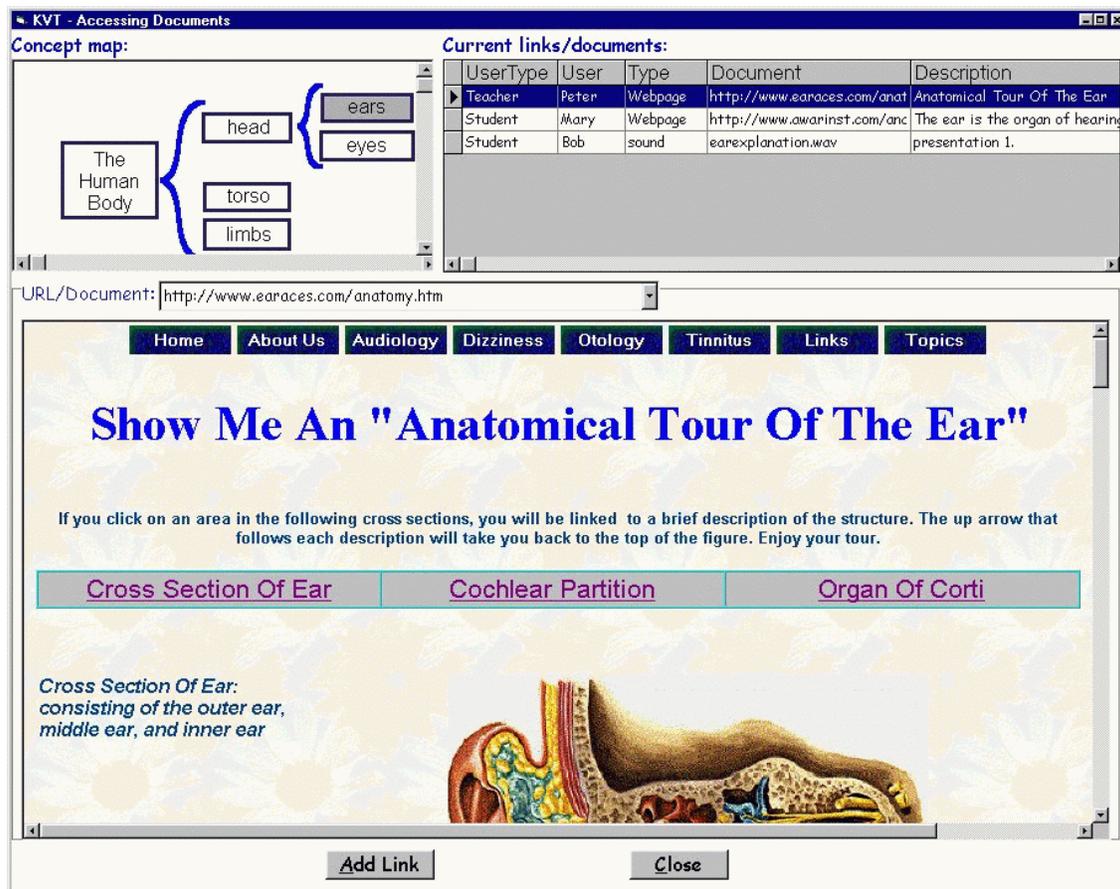

Figure 9. KVT - Managing links.

Figure 10. KVT- Navigating on the web using XML-maps and suggested links/documents.

5. Conclusions and Future Work

XML offers an excellent language to represent maps. Using XML maps, it is possible to support knowledge sharing without the problems of having proprietary files. By using a common vocabulary for the content and XML maps, it is possible to compare map structures.

XML-maps (thinking maps, frame games) are very useful in education and training environments because they support content structure and make explicit fundamental human cognitive processes.

KVT offers an attractive tool for the creation of maps and supports collaborative navigation throughout the content. By using XML-maps, KVT provides a better support to education or training setups that uses maps to create, share and assess knowledge. By including XML-maps into the learner model, new possibilities for visualization and inspection of XML-maps can be exploited in order to improve the learning process.

References

[1] Brusilovsky, P. "Methods and Techniques of Adaptive Hypermedia". In Adaptive Hypertext and Hypermedia. Brusilovsky, P., Kobsa, A., and Vassileva, J. (eds.) Kluwer Academic Publishers, pp. 1-41 (1998).

[2] Buzan, T. "Use both sides of Your Brain". Ed. Dutton. New York (1979).

[3] Gaines, B. R. and Shaw, M.L.G. "Web Map: Concept Mapping on the Web". (1995). Available on-line:http://ksi.cpsc.ucalgary.ca/articles/WWW/WWW4WM/WWW4WM.html

[4] Hyerle, D. "Visual Tools for constructing knowledge", ASCD press. Alexandria, Virginia, (1996).

[5] Jonassen, D., Wilson, B., and Cole. P. "Cognitive Approaches to Instructional Design". G.M. Piskurich (ed). The ASTD handbook of instructional technology. McGraw–Hill. New York, pp. 21.1-21.22. (1993). Also available on-line:http://www.cudenver.edu/~bwilson

[6] Jonassen, D., Beissner, K., and M., Yacci. "STRUCTURAL KNOWLEDGE. Technique for Representing, Conveying, and Acquiring Structural Knowledge". Lawrence Erlbaum Associates, Publishers. Hillsdale, NJ (1993).

[7] Micarelli, A., and Sciarrone, F. "A case-based toolbox for guided hypermedia navigation". In Proceedings of the Fifth International Conference on User Modeling, pp. 129-136 (1996).

[8] MindManager® by MindJET LLC. Test version V3.5.5.SP2. Apr 8, (1999).

[9] Novak., J. D.. Learning, Creating, and using Knowledge. Concept Maps as Facilitative Tools in Schools and Coorporations". Lawrence ErlbaumAssociates, Publishers. Mahwah, NJ (1998).

[10] Novak., J. D., and B. D., Gowinn. "Learning how to Learn". Cambridge University Press. Cambridge, England (1984).

[11] THE BRAIN® by Natrificial Software Technologies. Free version 1.73. 9/1/99, (1999).

[12] ThinkingMaps® by Innovative Learning Group. Trial version 1.0.1, (1998).

[13] VisiMap® by CoCo Systems Ltd. Trial version 2.5 c. Nov 1999.

[14] Zyryanov, M. "Adaptive local maps in the hypermedia components of intelligent learning environments"'. In: P. Brusilovsky, P. Kommers and N. Streitz (eds.): Multimedia, Hypermedia and Virtual Reality: Models, Systems, and Applications. Lecture Notes in Computer Science, Berlin: Springer-Verlag, pp. 306-310 (1996).