INTEGRATING A CONCEPT MAPPING TOOL INTO A VIRTUAL LEARNING ENVIRONMENT: PEDAGOGICAL AND TECHNOLOGICAL CHALLENGES

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Abstract. Interoperability and integration of digital concept mapping tools has not been widely prioritized and supported by software developers. Digital alternatives to paper-based concept mapping (from simple digital whiteboard to dedicated concept mapping software) are increasingly popular among educators, but computer-based concept maps are still difficult to analyze, assess, expand or export to other software platforms. Lack of interoperability and poor integration of concept mapping tools with widely used Learning Management Systems increases workload of teachers, because of poor reusability and automation opportunities.
This paper describes conceptual design and implementation of a concept mapping tool that has been integrated into an open-source virtual learning environment IVA. Despite this concept mapping tool has several unique pedagogical features, interoperability with other stand-alone concept mapping tools has been reached. For instance, concept maps can be exported from IVA to CmapTools or other tools that support XTM specification.

1   Introduction

We are living in the age of learning technology boom: new software systems and tools are appearing too fast to be properly implemented into everyday practices in educational institutions. Stand-alone desktop educational multimedia applications ceased to be the mainstream way of using ICT in education – nowadays everything has to be Web-based. Having an up-to-date virtual learning environment or, as it is often called, Learning Management System (LMS) seem to be a must for every school and college. Due to rapid development of this kind of systems, significant number of organizations are considering to change their existing LMS to a newer, better or cheaper one (Paulsen 2003). Despite of predictions that soon this boom will be over and one killer app will dominate on the learning technology market (just like it happened with office software in mid-90s), the trends are controversial. On one hand, we have seen the recent merger of largest LMS providers (Blackboard and WebCT), but many of their competitors keep the leading position in smaller countries (Norway, Sweden, Finland, the Netherlands) where e-learning has become a normal part of academic life (Paulsen 2003). In the open-source world, the variety of new LMS's is even increasing. Information portal Edutools.info lists as much as 61 Learning Management Systems, each of these are used in large number of institutions. In this situation, considering the increasing needs for re-usability of digital learning materials and virtual mobility of students, interoperability of e-learning systems and tools becomes a crucial factor. Bartlett et al (2003) define interoperability as ,*the ability to transfer and use information in a uniform and efficient manner across different organizations and information technology systems*'. In the context of Learning Management Systems, interoperability means the ability of two different LMS's (or a LMS and a Learning Object Repository) to easily exchange different kinds of information, for instance:

- the digital learning objects and their metadata (using IEEE LOM specification)
- collections of learning objects (using SCORM specification)
- quizzes and self-tests (using IMS QTI specification)
- calendar events and ToDo's (using vCal)
- learner information profile (using IMS LIP specification).

One of the challenges on the way towards interoperable LMS is related to teachers' needs for specific pedagogical tools/modules that are based on widely used active learning methods like Jigsaw groupwork (Aronson & Patnoe 1997), role-play, Progressive Inquiry (Hakkarainen 2003) etc. For the sake of interoperability, most LMSs try avoid too specific modules, thus decreasing the pedagogical affordances of the system. Concept mapping tool can be seen as one of these specific modules that is requested by the teachers but not yet implemented in an interoperable manner in any LMS.

At this point, we would like to specify our approach to concept mapping. We rely on the works of Novak and Gowin (1984) who have defined concept map as a '*schematic device for representing a set of concept meanings embedded in a framework of propositions*'. Concept maps have been used in education in many ways: either as advance organizer made by a teacher, groupwork method or as an instrument for assessing the learning outcomes of

students. An alternative but quite close technique to concept mapping is mind mapping (Buzan 1991): an image-centered radial diagram where concepts or topics are organized as hierarchical branches. In the context of developing our online concept mapping tool, we see mind maps as a more restricted subset of concept maps.

While paper-based concept mapping is fun, effective and easy to implement, digital tools have their advantages: digital concept maps can be easily archived, copied/multiplied, modified, transported, organized etc. There are various commercial and open-source software packages for working with concept maps. Most of these packages are still not Web-based and prefer the radial and hierarchical approach typical to mind mapping. There are only a few Web-based tools that support concept mapping, the most advanced and well-known of which is IHMC CmapTools (http://cmap.ihmc.us). In the context of Learning Management Systems, concept maps can be drawn using a shared whiteboard tool, which is available in most LMSs. Concept mapping with shared whiteboard has its pros and cons: ease of use and collaboration support are strong points, while reusability and semantics are weak.

This paper provides an overview of the development of an online concept mapping tool that is integrated into a Web-based Learning Management System IVA and is interoperable with other concept mapping software packages that support XTM (XML TopicMaps) as an export-import format for concept maps. First, we are going to demonstrate how poor is the interoperability among current concept mapping tools and how it can be increased with the help of XTM. Then we introduce the pedagogical and technological foundations of IVA LMS and describe the typical scenarios of using the integrated concept mapping tool for individual and group assignments.

2   Interoperability of educational concept mapping software

The dominant approach for describing knowledge structures and associating them with information resources are related to Topic Maps standard. Work on Topic Maps was initiated in the beginning of 1990s by the Davenport Group, in the context of developing the DocBook Data Type Description for interchange of computer documentation. In 2000, Topic Maps were formalized as an ISO International Standard (ISO 13250). Topic map is a semantic network, where different topics are interconnected using associations and instantiated with occurences (information resources related to the topic).
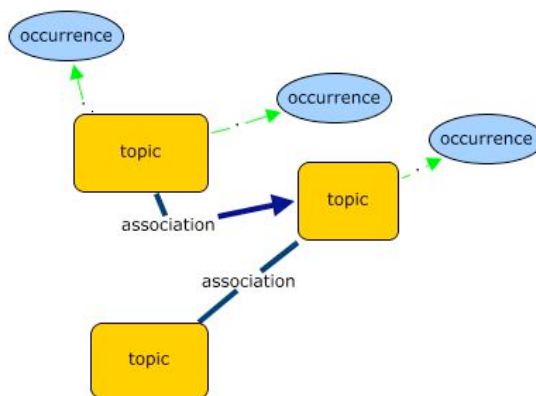
Figure 1. The structure of a Topic Map

Topic maps can be used as a formal description standard for making concept maps interchangeable between different software applications. In this case, the topics represent concepts, the associations represent relations and the occurrences can be interpreted as links to information resources relevant to the associated topic (e.g. external Web pages). In practice, Topic Maps are mostly created using XTM (XML Topic Maps) specification that allows easy interchange of Topic Maps between different Web-based applications.

Of course, XTM is not the only available solution for making concept maps interchangeable: there is also a simplified text-based notation for Topic Maps called Linear Topic Maps (LTM) and an authoring language called AsTMa. Resource Description Framework (RDF) has alternative approach to describing the semantic metadata of

information resources through triples (subject-predicate-object). Despite the fact that RDF and Topic Maps have many things in common, they are not completely compatible and translatable into each other (see Moore 2001). We selected XTM as the format for interchanging concept maps between our concept map tool and other applications mainly because this format is also used by IHMC CmapTools and their repository of re-usable concept maps. Unfortunately, XTM is not yet supported by majority of other concept mapping software providers. We tried to find out empirically, which other formats can be used for interchanging concept maps between the popular concept mapping (and mind mapping) software packages: Mindmanager, OpenMind, SmartIdeas, VisiMap, Inspiration, FreeMind, Cmap and IVA.

Despite the fact that several packages are able to export concept maps as standard text files and popular word processing formats (.txt, .rtf, .doc), the resulting export files have different data structures and they cannot be imported into other software packages. For instance, in some cases an exported MS Word document can include the image of map accompanied with outlined text that demonstrated the hierarchical relations of concepts, while in other cases the MS Word export file contains only outlined text or image file names, which are used to construct the map. In some cases, the exported text file includes outlined text, while in others the text file may be complete with maps, text content and different metadata of levels structure, links, added object information, description etc. This is why VisiMap can not correctly import exported .doc or .rtf files.

	Cmap Tools	OpenMind	Smart Ideas	VisiMap	Inspiration	Mind Manager	Freemind	IVA
CmapTools	XTM, outlined txt, proposition	-	-	-	**Outline txt**	-	-	**XTM 1.0**
OpenMind	-	MS Word, PowerPoint MathWare Mediator	-	-	-	-	-	-
SmartIdeas	-	-	Ideas project .ipr	-	**Inspiration .ins**	-	-	-
VisiMap Professional	-	-	**Plain text**	Map .mmp, Plain text, RTF	**Outline txt**	-	-	-
Inspiration	-	-	-	-	Inspiration .ins, Plain text, RTF	-	-	-
Mind-Manager	-	-	-	-	-	MPX, MS Word	-	-
Freemind	-	-	-	-	-	**MPX**	Branch	-
IVA	XTM 1.0	-	-	-	-	-	-	XTM 1.0, CSV

Table 1: Concept map interchange formats between different software applications.

Plain text files exported from SmartIdeas can be imported perfectly and result with a correct map, whereby the Inspiration software opens such plain text files only as text and do not draw a map. CmapTool is able to import text

files with map outline exported from Inspiration, but not always correctly. Table 1 illustrates the poor interoperability of major commercial and open-source concept/mind mapping software packages.

As CmapTools seemed to have the most open approach to concept map interoperability and they also maintain a repository of downloadable concept maps in XTM format, we decided to choose XTM-based export-import for IVA concept mapping tool. Before we introduce the IVA concept mapping tool, the pedagogical foundations and structure of IVA LMS deserve some attention.

3   Pedagogical foundations of IVA LMS

IVA is a Web-based Learning Management System developed at Tallinn University in order to advocate constructivist approaches and practices in e-learning (IVA 2006). IVA is an adaptation of another open-source Zope product called FLE3 (Future Learning Environment 3, see http://fle3.uiah.fi). Just like FLE3, IVA is released under GNU General Public License (GPL) as free and open-source software. Anyone could download the latest version of IVA source code from home page of the IVA development project at http://www.htk.tlu.ee/iva. IVA is developed as a product of a leading open-source Web application server Zope. The development of IVA was supported (among others) by the Ministry of Education and Research of Estonia, Hansapank and the Tiger University Program of The Estonian Information Technology Foundation. IVA is currently available in Estonian, English, Russian and German.

What does the name IVA mean? On one hand it could be read as an acronym (e.g. Interactive Virtual Academy). On another hand, IVA is a metaphor in Estonian language and means ‚a seed‘ (also ‚point‘ or ‚meaning‘). In 1817, the Reverend Otto Reinhold von Holtz published a series of moralist stories for Estonian peasants under a slogan ‚story is a shell, meaning is a seed‘. Since then this hermeneutic slogan has been widely used among teachers and teacher educators in Estonia, when they want to stress the importance of looking deeper below the surface in order to understand better the meaning, or ‚the point‘ of phenomena. The red dot in IVA logo is symbolizing ‚the point‘ we are trying to make with our new learning management system: e-learning is not about changing just a shell (or media) of learning delivery. In order to make full use of opportunities offered by new powerful learning environments, both teachers and learners should look deeper behind the routine of traditional educational practices and discover new ways of meaning-making. We hope that our system with its intuitive user interface and innovative pedagogical tools helps them in this endeavor.

As opposed to many commercial Learning Management Systems, IVA is not ‚pedagogically neutral‘. The structure and functionalities of IVA system advocate constructivist approaches to learning and teaching (Laanpere et al 2005). For constructivists, learning is not merely transmission of objective knowledge - each learner constructs actively his/her own ‚picture of the world‘, associating new meanings with previous experiences and communicating with others. According to D.H.Jonassen (1994), the three most important conceptual pillars for designing a truly constructivist learning environment are three C-s:

1. Meaningful and authentic **Context** for learning,
2. Tools, support, time and space for personal knowledge **Construction**
3. Support for **Collaboration** and group reflection and production.

The structure of IVA user interface contains three sections that are directly based on Jonassen's three C-s: there is the shared Bookshelf with learning resources that provide domain-specific context for learning, each learner has his/her own personal Webtop (Web-desktop) for knowledge construction and reflection, and there are various Workshops for collaborative learning. One of the most important features of IVA are various types of individual and group assignments that can be given by a teacher to learners: essays, quizzes, peer reviews, readings, discussions (based on Progressive Inquiry or E. de Bono's Six Thinking Hats templates), role-plays, group projects and more. When a teacher creates an assignment, a dedicated submission folder will be created in the learner's personal portfolio or in the group portfolio (if this is a group task).

While developing a new concept mapping tool, we had to find pedagogically meaningful ways to integrate this tool into existing conceptual framework of IVA. As a result of participatory design sessions with potential users, we decided that concept mapping should be used in IVA for both individual and group assignments on two levels: simple (with limited functionalities) and advanced (with few or no restrictions). Another important feature of the

new tool that was decided to be implemented was dedicated to automating the assessment of concept maps according to the framework provided by Fischler et al. (2001). The next chapter illustrates functionalities of IVA concept mapping tool through descriptive usage scenarios.

4   Scenarios of using the integrated concept mapping tool within IVA LMS

There are two ways to use concept mapping tool within IVA LMS: individual and collaborative. In case of individual use, every learner will build his/her personal map instance from scratch or modify the template prepared by the teacher. In case of the collaborative use, each small sub-group of students will create and edit a sub-version of a concept map template given them by the teacher. Yet, collaborative concept mapping exercise cannot be performed simultaneously – only one user can change the map at the time and other users are able to observe the changes. The next group member will be granted permission to edit the group's concept map after the current user completes the operation (which in most cases happens within a few seconds), or after her/his session expires (after two minutes of idle status).

For each concept mapping assignment, the teacher can specify a set of conditions like the deadline for submission, the default color scheme and other layout properties of concept map, the type of assignment, the level of restriction (either none, restricted or full concept mapping menu can be made available for students).
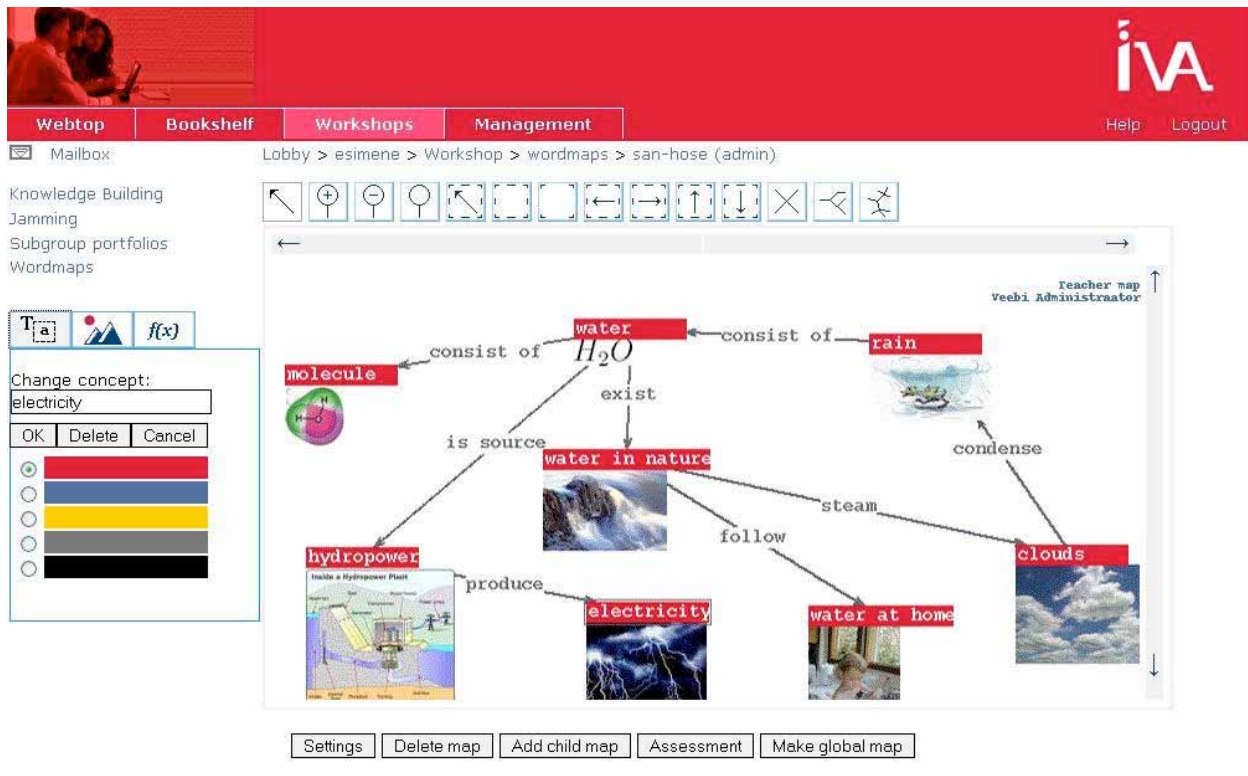

Figure 2. Adding images to a concept map.

Both individual and collaborative concept mapping tasks could have three different assignment types:

- **Allocate and connect** assignment is the simplest version of concept mapping exercise, suitable for younger students, but also for people with poor computer skills or without previous experience of concept mapping. In this case, learners do not see the concept mapping menu at all – the only thing they can do is to rearrange preset concepts and connect any two concepts using preset relation types. If the teacher decides so, learners may be allowed to add new concepts and relation types.

- **Create and design** is a more advanced type of assignment where learners start building a concept map from scratch and are able to manipulate the map to a large extent using concept mapping menu. The default menu type is ‚minimal‘, but it can be changed by the teacher to ‚extended‘. The minimal menu allows to add images, change the color scheme, customize line shapes (thickness, arrowheads). The extended menu allows to work with maps that are larger than the computer screen area. Learners can upload new images needed for their concept map into a common ClipArt folder which is accessible for all participants of this course. Learners can, if needed, replace a concept with an image (see Figure 2 above).
- **Custom type** is defined by the teacher by setting different assignment properties.

4.1   Creating a new concept mapping assignment

While creating a new assignment, teacher goes first to Workshops section and adds a new Teacher's Map. The next step is specifying the properties for the map. For example, younger students would need more simple type task and less functionalities. Here the some of properties that can be edited by teacher:

- **Default color scheme**. Each color can be associated with semantic value.
- **Versioning**. If versioning is allowed, each student can make one or more copies of the Teacher's Map. By default, versioning is allowed. Learners will be able to practice before they design their final concept map.
- **Formula editor**. If formula editor is switched on, a student can add mathematical symbols to a concept map. Mathematical formulae and symbols will be associated either with concepts or relations just like ordinary image files (see Figure 3 below).
- **Access properties**. Students can be granted the right to change the map properties by themselves.
- **Public map**. Sometimes it is important to hide the concept map from other learners (e.g. in order to avoid blind copying from faster learners).
- **Editable map**. By default this property is not checked, then students can only see the Teacher's Map without being able to edit it. But if you want to engage learners in collaborative concept mapping, map should be made editable.
- **Hyperlinks, attachments**. Allowing students to add hyperlinks and file attachments to concepts.
- **Maximum number of concepts**. Teacher may need to limit the quantity of concepts that can be used on the map.
- **Maximum number of relations**. Sometimes it could be important to let the learners decide, which relations are more important than others – then this feature might become handy.
- **Fixed number of relation types**. Students can be permitted to use only limited number of relation types.
- **Fixed set of concepts**. Teacher may list the set of concepts, which are required for concept mapping. Again, concept maps with fixed set of concepts are more easy to compare and evaluate.
- **Fixed set of relation names**. Some concept mapping tasks may require only fixed set of relation types (e.g. Universal Language Modeling task that has relations: part of, context for, instance of, generalization for etc.). Concept maps with fixed set of relations are more easy to compare and evaluate.

After defining the properties for the new Teacher's Map, teacher goes to the Management section which is not accessible by students – otherwise the User Interface of IVA LMS looks the same for teacher and learner. Under the Management section, teacher can add a new concept mapping assignment that uses the Teacher's Map as a starting point. Learners will see the assignment description in their personal Portfolio on their next logon. When a learner clicks on the link ‚Start working on the assignment‘ in his/her Portfolio, a personal instance of the Teacher's Map will be created for the learner.

Figure 3. Using the Formula Editor within a concept map.

4.2   Working on a concept map

While designing the concept mapping tool for IVA LMS, we wanted to avoid heavy add-in frameworks like Java that would complicate the installation process of IVA (which is already quite challenging to most of server administrators). As we wanted to provide collaborative concept mapping opportunities (that imply server-side drawing solution), we also decided not to use Flash-based drawing of concept maps. These decisions left us with the native imaging framework for Zope-based products: we used Python Imaging Library (PIL) and JavaScript for drawing the concept maps, thus sacrificing the drag-and-drop feature. Many advanced computer users complain in the beginning when they have to re-learn to use point-and-click instead of drag-and-drop, but in most cases the learners will get used to draw concept maps 'the IVA way' quite quickly. A click on an unoccupied spot within the area of map will create a new concept. If the new concept will not be given a name at once, it will be deleted after the next mouse click. Click on an existing concept selects this concept, after which the user can either to rename, delete or connect it with other concept. The usability testing on users from different age groups showed that this way of drawing the concept maps is intuitive and easy to learn.

4.3   Assessing the concept maps

IVA concept mapping tool has powerful, but yet only prototypical functionalities dedicated to comparing and analyzing the concept maps by teacher. When the learners have created a large number of maps, it could be a challenging task for a teacher to analyze all these maps and give feedback to students. IVA concept mapping tool can automate this task to some extent by transforming all student maps that are associated with the same assignment into one Global Map. This map can be used then for evaluation discussion with whole group or by a single student for comparing his/her concept map with all others at once. Teacher rates the validity of each proposition (consisting of two associated concepts and relation that connects them) in the Global Map using the scale from 0 to 3. Value ‚0' means that the proposition is not valid and ‚3': that the proposition is strongly valid. When the Global map is created and propositions rated, each learner's map will be assessed automatically against the Global Map. While assessing the single learner's map, teacher can change globally given „validity rate" for some propositions, but this is rarely

needed. Automated assessment of concept maps is working better when students are allowed to use only fixed sets of concepts and relation types.

5   Summary

This paper discussed the technological and pedagogical challenges related to development of an interoperable concept mapping tool that is integrated into an open-source Learning Management System IVA. Poor interoperability of popular concept mapping tools (both commercial and open-source) was demonstrated in empirical test. Further, the advantages of XTM as the preferred format for interchanging concept maps between different software packages were explained. Through the descriptive scenarios we tried to explain the design decisions related to the development of IVA concept mapping tool.

6   Acknowledgements

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