Utilization of Semantic Networks for Education: On the Enhancement of Existing Learning Objects with Topic Maps in <ML>³

Ulrike Lucke, Alke Martens

University of Rostock, Institute for Computer Science
Albert-Einstein-Str. 21, 18059 Rostock, Germany
firstname.lastname@uni-rostock.de

Abstract: Semantic networks represent dependencies between concepts or topics, and thus are well-suited not only for processing by computers but also for knowledge transfer to learners. A challenge is to combine knowledge networks (for self-directed learning) with traditional, hierarchical courseware. The paper presents an approach for integration of both, semantic networks and hierarchical structures, within a single learning object based on the eLearning markup language <ML>³.

1 Educational Benefits of Semantic Networks

Semantic networks are also described as knowledge networks, since they combine isolated facts with associations and meanings to applicable knowledge. That's why an utilization for knowledge transfer and description of learning objects (LOs) stands to reason. Learning and knowledge construction (in the constructivist theory) are related to the idea that each individual has to *re-construct knowledge structures* based on given information in interaction and in relation with the individual's own mental model(s) and prior knowledge. The mental model of a person can best be compared with a knowledge network – i. e. in computer science terms a mental model consists of associations and relations between information parts (e. g. facts). When learners re-construct these facts and relations for other learners, the result is comparable to a semantic network.

Coming from the perspective of instructional design, the traditional structure of courses and training material usually is purely hierarchical (e. g. based on categorizations, top-level/sub-level structures, easy-to-difficult structures and the like). But a closer look reveals that often sub-structures are realized. For example, in the preamble of a book, the author might explain how to use the book – e. g. a beginner should read chapter 1 first and then continue with chapter 3, whereas the advanced learner could start at chapter 2. The index structure, read on a meta-level, often reveals a knowledge network.

When instructional material is developed for computer-based teaching and training settings, the advantages of semantic networks or task models can easily be used in the instructional design: instead of a hierarchical composition of the training material, the content can be developed a) for different levels of expertise (i. e. adaptable), b) in networked relations. The result is a navigation structure where not only the information hidden behind the “information nodes” is relevant and part of the learning, but also the nodes’ interrelation [Ma04]. The relation of facts which currently *should* be learned with those facts the learner *might* additionally be interested in support the construction of knowledge and thus has the potential to facilitate learning. Moreover, the network-like information composition is one of the advantages of computer-based training.

The paper is structured as follows: A short overview on prior work in this area is given in section 2. Next, section 3 presents the concept of combining several didactical models for given content within a single learning object, and the implementation of this concept in the description language <ML>³. Finally, the pro’s and con’s as well as general conditions for the use of semantic networks in eLearning are discussed.

2 Related Work

There are many facets of using semantic technologies in eLearning. Early and widely accepted mechanisms include the description of *metadata* for educational material in order to make it easily accessible. The most common standard for the educational sector is Learning Object Metadata (LOM). It consists of a variety of fields grouped in 9 categories explaining the characteristics of a resource and the conditions of its use. A more complex problem is content interoperability, to be targeted with interchange standards like the Sharable Content Object Reference Model (SCORM). Metadata and content packaging formats are a strong requirement for identification and re-use of LOs.

A more challenging approach is to use metadata in combination with subject ontologies for automated *course generation*. Considering the learner’s specific pre-knowledge, competencies, and needs, the LOs in given repositories can be selected, configured, and combined to individual course material. Evaluation of inter-dependencies between LOs leads to a network structure of the educational content. After a selection of the best suited LOs (regarding topic, didactical approach, technical issues, and so on) and the serialization of the resulting sub-graph, individual material can be generated [Bun03]. Additionally, missing parts of the subject that are not covered by any LO can be identified with the help of a domain ontology [APB03, Bal04, DWC05] and then added manually. These mechanisms make use of semantic technologies *across a set of LOs*.

Another aspect is the utilization of semantic data *inside a learning object*, in terms of a *knowledge network*. The benefits of using relationships between content fragments for visualization of and navigation through a course were shown in several works [DDA04, Hie05]: non-linear knowledge creation, intuitive and memorable visualization of dependencies, synergies by collaboration with other knowledge networks and/or other learners, and starting point for additional semantic and intelligent technologies. Nevertheless, learning objects have to demonstrate their usefulness in traditional educational settings, too. That’s why a hierarchical arrangement of content cannot be missed. This leads to the question how to combine content arrangements in hierarchies and in networks without redundant description of LOs.

3 Flexible Didactical Descriptions with <ML>³

The XML based eLearning Language <ML>³ (Multidimensional LearningObjects and Modular Lectures Markup Language) was developed in 2001 [LTV03]. Recent works include a commercial adaptation and development of authoring tools [GLT09]. This also brought up an advanced didactical conception that makes use of semantic networks.

3.1 General Model of <ML>³

Beyond the *separation of content and layout* (as associated with XML in general) <ML>³ implements a *separation of content and didactics*, too. These aspects are described separately, with references from basic didactical units to main structural elements on content-side. This is depicted in Figure 1.

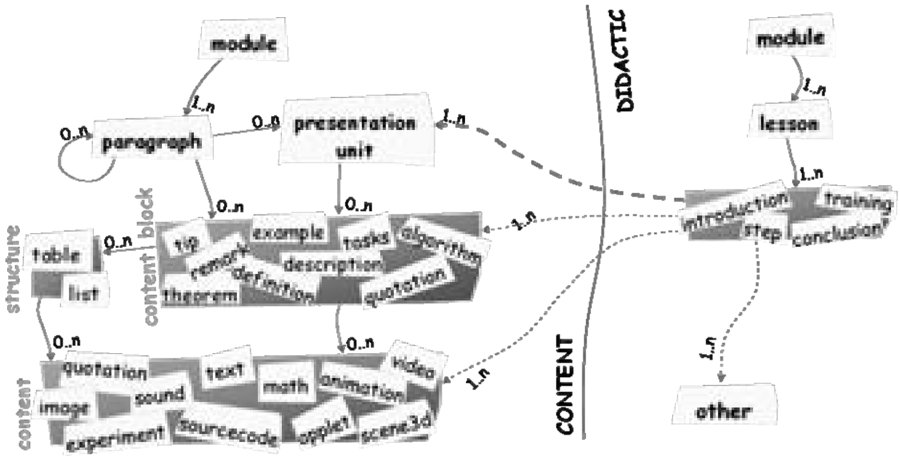

Figure 1: Structural Model of <ML>³ with References from Didactics to Content

Thus, there are the following possibilities to add a didactical description for another educational setting to an existing module:

- additional description based on the same didactical model:
  - re-sorting of existing presentation units
  - re-arrangement of single content elements
  - inclusion of content from external sources
- additional description using a different didactical model

Existing and currently introduced mechanisms for didactical descriptions in <ML>³ are explained in the following sections.

3.2 Traditional Educational Material based on Web Didactics

Most LOs are structured in a hierarchy, applying Meder's concept of Web Didactics [Med06]. Every topic to be communicated is considered as a unit of learning, which again consists of units of knowledge that can be captured as a whole (like a screen). Media units (like text or images) build the basic level.

<ML>³ implements this concept by a didactical structure divided into lessons and typed learning steps, as depicted in the right-hand part of Figure 1. A lesson contains all content that closely belongs together, like a section or chapter. A step equals the amount of content to be placed together, like a screen or slide. Every step keeps a reference to a presentation unit in the content-side of a module.

The similarity to the structure of existing material (books, slides) makes this model easy to author for the teacher. But, the paths of learners through this material are limited (differences appear mainly from omitting a step or lesson), and individual creation of inter-dependencies between knowledge elements is not forced.

3.3 Topic-Maps for Self-directed Learning with Traditional Material

The use of spatial content arrangements in eLearning is not new, e.g. for combining achieved knowledge to a portfolio or for visualization of content dependencies. Semantic networks are a mature mechanism for this idea, since they include several starting points and typed associations between any elements in the network. That's why we extended the specification of <ML>³ by the possibility to describe Topic Maps according to the ISO standard XTM 2.0 (XML topic map syntax) [GM08]. Figure 2 depicts the resulting vocabulary, including topics as core elements and typed associations between topics. Referencing to presentation units of the content-side of a module is realized from topics.

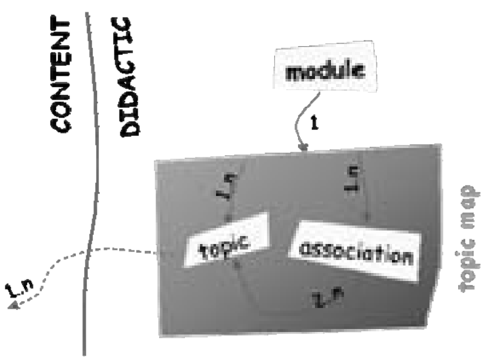

Figure 2: Extended Didactical Model of <ML>³ for the Use of Topic-Maps

An example for a Topic Map is shown in Figure 3, as used in the editors of the XMLeditools [GLT09]. In the project editor, the authors selects between hierarchical or networked structure. Afterwards, the content editor provides mechanisms to edit the topic map as well as the content fragments behind each topic. By clicking on a topic, the corresponding presentation unit is opened. Navigation takes place completely in the network structure. Independently, a classical LO with hierarchical structure may exist that consists of (i. e., references to) the same content fragments. Thus, redundant descriptions during re-use of LOs for different settings are avoided. This offers a higher degree of autonomy, and a self-directed learning experience to the learner. The intentional navigation and arrangement of topics encourage an inter-connection of knowledge, thus achieving a higher cognitive level and learning outcome.

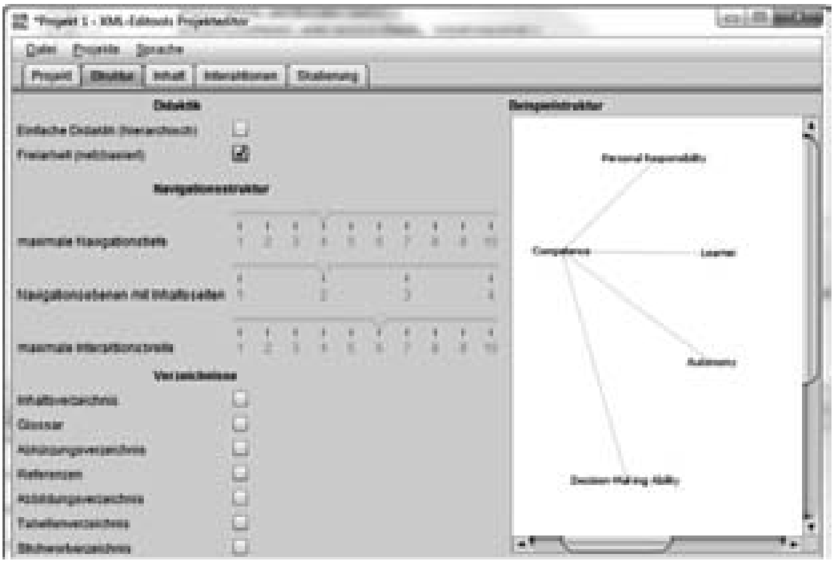

Figure 3: Exemplary Topic-Map from a LO on „Individualized Instruction“ in the XMLeditools

3.4 Discussion

The benefits of the presented approach can be seen in the application of self-directed learning, and of a constructivist learning theory, without having to change existing content. Moreover, hierarchical and networked descriptions of a LO co-exist without the need to change the learners infrastructure (i.e., web browser or learning platform). But, there are also some problems or challenges related to this approach. Basic pre-knowledge on the topic is required from the student in order to navigate through the network. Moreover, development and practical use of such descriptions are not trivial for teachers, and acceptance in conventional educational environments might be reduced. This leads to a set of conditions for this approach. It is useful only for experienced teachers and learners. The most benefit is gained in scenarios with the need to select individually required knowledge out of larger repositories (like learning at work place), best in combination with traditional educational settings.

4 Conclusion and Further Work

Some educational settings may require the use of courseware without pre-defined learning paths. The benefits of such a self-directed learning can be achieved with the help of semantic networks that visualize the structure of the learning content and allow for individual navigation. The eLearning language <ML>[3] can be used to consistently describe different didactical models (i. e., hierarchies and networks) on the same content. An integration of Topic Maps into <ML>³ and LOs was presented. It leads to a degree of didactical flexibility that cannot be achieved by existing approaches without redundant descriptions of content.

An open question in the existing language specification is how to deal with different amounts of knowledge associated to a topic. Currently, a topic is linked to a single presentation unit, but the capacity of a slide or screen is limited. Complex topics might require an author to break down the content into a set of presentation units, or even into a hierarchical sub-structure of presentation units (and sections). This is not yet covered by the <ML>³ specification and will be subject of further studies.

Moreover, first experiences with teachers and students brought up the need for a more guided navigation through the semantic network, e. g. pre-defined learning paths. This can be achieved by labelling associations between topics as mandatory, recommended, or optional. Thus, a multi-level description of possible paths through the learning object can be achieved. Though this would require a schema modification away from the existing XTM standard, it might be of certain benefit to Learning.

References

[APB03] Aroyo, L; Pokraev, S; Brussee, R.: "Preparing SCORM for the Semantic Web", in *On The Move to Meaningful Internet Systems*, LNCS 2888, pp. 621-634, Springer 2003.

[Bal04] Baldoni, M.; Baroglio, C.; Patti, V.; Torasso, L.: "Reasoning about learning object metadata for adapting scorm courseware", in Proc. of *Int. Workshop on Engineering the Adaptive Web* (EAW), pp. 4-13, 2004.

[Bun03] Bunschkowski, M.; Lucke, U.; Röser, M.; Tavangarian, D.: "The role of metadata for the automated generation of educational material", in *Proc. of 2nd European Conference on E-Learning (ECEL)*, Glasgow/UK, November 2003.

[DDA04] Dichev, C.; Dicheva, D.; Aroyo, L.: "Topic Maps for E-Learning", in *International Journal on Advanced Technology for Learning*, 1(1), 2004, pp. 1-7.

[DWC05] Dagger, D.; Wade, V.; Conlan, O.: "Personalisation for All: Making Adaptive Course Composition Easy", in *Educational Technology & Society*, 8 (3), pp. 9-25, 2005.

[GLT09] Gries, V.; Lucke, U.; Tavangarian, D.: „Werkzeuge zur Spezialisierung von XML-Sprachen für die vereinfachte, didaktisch unterstützte Erstellung von eLearning-Inhalten", in Proc. of *Die 7. e-Learning Fachtagung Informatik (DeLFI)*, Berlin, September 2009.

[GM08] Garshol, L. M.; Moore, G.: „*ISO 13250-2: Topic Maps — Data Model*", http://www.isotopicmaps.org/sam/ (published in June 2008)

[Hie05] Hierl, S.: „*Die Eignung des Einsatzes von Topic Maps für e-Learning*", Churer Schriften zur Informationswissenschaft, Nr. 4, Hochschule Chur, 2005.

[LTV03] Lucke, U.; Tavangarian, D.; Voigt, D.: „Multidimensional Educational Multimedia with <ML>³", in Proc. of *Conference on E-Learning in Corporate, Government, Healthcare & Higher Education* (E-Learn), Phoenix/AZ/USA, November 2003.

[Ma04] Martens, A.: „*Ein Tutoring Prozess Modell für fallbasierte Intelligente Tutoring-systeme*". DISKI 281. Akademische Verlagsgesellschaft AKA, infix, Berlin 2004.

[Med06] N. Meder (Hrsg.): „*Web-Didaktik. Eine neue Didaktik webbasierten, vernetzten Lernens*", wbv – Wissen und Bildung im Internet, Band 2, Bertelsmann 2006.