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ConceptMapWiki – a collaborative framework for agglomerating pedagogical knowledge

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***Abstract*—We propose a new educational framework, ConceptMapWiki, that is a wiki representing pedagogical knowledge with a collection of concept maps which is collaboratively created, edited and browsed. The learners and educators provide complementing contribution to evolving shared knowledge structures that are stored in a relational database forming together inter-connected overlapping ontologies. Every contribution is stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria. Pedagogically motivated learning paths can be collaboratively defined and evaluated, and educational games can be incorporated based on browsing and editing concept maps. The proposed framework is believed to be the first wiki architecture of it's kind, designed for personalized learning with an evolving knowledge repository relying on adaptive visual representations and sound pedagogical motivation. Initial experiments with a functional online prototype indicate promising educational gain and suggest further research.**

Keywords—intelligent tutoring systems, wiki, concept map, ontology, knowledge maturing

I. INTRODUCTION

There is a need for frameworks to support personalized adoption of new knowledge that matures along the learners in a synthesizing way [1] and collaborative construction of knowledge resources [2] supplied with sufficiently converging free exploration and recommending connections that are currently most potential for the learner's needs. *Wikis* are collaboratively created and edited interlinked websites with simplified markup language and full browsable edit history. Wikis have opened useful approach for asynchronous generation and editing of knowledge as well as a fascinating research domain concerning collaborative knowledge maturing process, inspired by the rise of the Wikipedia online encyclopedia. To manage knowledge structures, *ontologies* try to offer formal explicit specification of a shared conceptualization. Knowledge structures can be intuitively visualized with c*oncept maps* typically consisting of nodes labeled with concepts connected with labeled directed arcs depicting their relationship. We propose a new educational framework, ConceptMapWiki, to generate reusable evolving knowledge resources for education based on an inter-connected diverse collection of partially overlapping concept maps, thus forming shared ontologies. ConceptMapWiki is a wiki based on a method representing knowledge with adaptive concept maps that are collaboratively created, edited and browsed according to various learner-driven criteria for many educational purposes, supplied with collaboratively defined and evaluated learning paths.

II. METHOD

The method relies on contributions from individual learners and educators generating educational content by drawing concept maps into a graphic Java-driven user interface with an aim to capture some core semantic meanings of the learning topic relatively intuitively and spontaneously. Each step of creating, editing or browsing a concept map are recorded via Java Database Connectivity (JDBC) interface in a compact text format into a relational MySQL database as *concept map objects* with time stamps and a user profile, containing background information about the contributor's role, gender, age, educational level and experience in current topic. All the concept map objects together form a *concept map collection* that cumulatively matures due to collaborative editing and can be explored and exploited by the learners in various personalized guided learning activities addressing various perspectives and levels of detail.

Learning activities offered by the method rely on two basic modes of browsing. In *topological view* the learner browses conceptual relationships in a certain concept map or between a group of related concept maps in a frozen time frame chosen by the learner, often the latest version. In *temporal view* the learner browses temporal versions of a concept map or a group of related concept maps in sequential time frames showing how the maps gradually evolve and get edited. These two views are generated by querying the database of concept map objects with edit histories. In addition, the method enables creating and editing user-defined learning paths based on certain parts of the conceptual relationship network in the concept map collection. A *learning path* for a desired learning topic primarily consists of a set of concepts and relationships considered pedagogically valuable to be explored to support adoption of knowledge about the topic. The creation, editing and browsing of learning paths by the learners and educators is performed and recorded similarly as done with concept maps, supplied with recommendations about useful order and priority of exploring conceptual relationships supported by various sequential, branching and looping constellations.

As the learner browses the concept maps and learning paths from concept to concept about learning topic she aims to adopt, she becomes fruitfully exposed to various complementing perspectives. To enable diverse alternative perspectives the connectivity between concepts can be

generated and adjusted based on various *relatedness criteria* concerning shared concepts and arcs, including high occurrence in concept maps or collaborative edit histories, popularity of being explored or included in learning paths, as well as quality of ratings or annotations given by the user community. In respect to collaborative edit history, a special priority is given to those occurrences supplied with a long duration and high frequency of contributions and involvement of learners with user profiles indicating high educational level and experience in current topic. The learner can freely adjust connectivity of concepts to display desired perspectives and the constantly updated view focuses to show local connectivity of concepts in respect to desired features of the conceptual network to be highlighted. To optimize cognitive load, the learner can adjust the number and type of concepts and arcs shown simultaneously and stay informed about already visited parts of concept maps.

To ensure and cumulatively enhance quality, each concept map and learning path submitted to the database is collaboratively evaluated by other learners assigning an overall quality rating on five-point Likert scale and more detailed ratings for each concept and relationship separately. Each concept map and learning path can be also annotated with comments concerning their reliability and usefulness. A learner can also publish a request to others about creating or editing concept maps or learning paths about a desired topic. To facilitate identifying related earlier submissions and then to explore or refine them, a search function enables learners to find most matching occurrences for a given set of key words, considering title, user profile, concepts, relationships, annotations and ratings.

III. EXPERIMENT

We asked 151 university students of introductory Java programming course to draw with our method concept maps representing their knowledge about topic "programming", thus gaining 895 unique concepts and 1616 unique relationships between them. The most frequent concepts were Java/C/Python, program, method, object, class and variable, and the most frequent relations were object -> method, language -> Java/C/Python, class -> object, Java -> object, program -> class, and class -> method.

To analyze pedagogical value of the method we compared evolution of drawn concept maps to an extensive narrative from 28 lectures of introductory Java programming course by evaluating co-occurring words in 18653 unique sentences [3]. The high-frequency lists of concepts and relations well matched between the drawn concept maps and the pedagogical narrative. For example, ten highest-ranking concepts had overlap of about 65 % and ten highest-ranking relations had overlap of about 50 %. We think that this result indicates that the proposed relatively self-guided method can assist learners to generate and process knowledge in a pedagogically rewarding way, even challenging the knowledge evolution process suggested by a professional teacher.

We analyzed the drawn concept maps in respect to the learner's self-evaluation about amount of earlier programming experience, difficulty of learning programming and the complexity of the concept map she had drawn, measured with five-point Likert scale. We observed surprisingly coherent concept maps to be drawn irrespective of the responses given in self-evaluation. For example, for ten highest-ranking concepts as well as relations there was overlap of about 50 % between experienced and non-experienced learners, between learners considering learning difficult and learners considering it easy, and between learners who drew complex concept maps and learners who drew simple concept maps. We think that these results indicate that the method can assist learners to generate and process knowledge in such a way that lets even challenged learners to reach same knowledge qualities in their concept maps as the less-challenged learners can.

Figure 1 shows an example how concept maps and learning paths can be represented to the learner in browsing. Size of concepts and width of arcs indicate the collaboratively defined ranking, in decreasing order of significance.. More details are given at the author's web site (http://www.cs.hut.fi/u/llahti/publ/lahti_2011_data.pdf).

IV. RELATED WORK

Collaborative construction of concept maps has been shown to assist learning knowledge structures [4] and efficient graph-theoretic reasoning algorithms enable relating general problem solving processes to fundamental problems in computer science [5]. Also graph-based clustering schemes have been used to identify groups of related tags in folksonomies [6]. Since emerging in both social networks and the world's largest wiki, the Wikipedia online encyclopedia [7], small world networks are a promising structure for representing educational knowledge. Methods developed to model and explore knowledge in the Wikipedia give inspiration for developing pedagogically motivated knowledge repositories based on resembling wiki frameworks to support collaboratively various personalized learning tasks [8]. Having over 3 million articles in English, more than concepts in a typical human vocabulary [9], the full content of Wikipedia cannot be effectively evaluated all the time [10] and thus it seems reasonable to generate guidance for exploration by evaluating only few steps further in the knowledge network.

Learners should be enabled to retrieve personalized information with semantically enriched models [11]. When different parties provide mappings with typed links between data, semantic cohesion can increase thus enabling data integration on global scale [12]. For example, Semantic MediaWiki enables annotating wikis with semantic data and OntoWiki offers intuitive authoring and navigating of RDF-based knowledge bases. 24 basic and compound evolution patterns of the knowledge engineering process have been identified for knowledge bases in the semantic web [13]. Ontology evolution has been guided by pattern modeling and quality evaluation [14] and ontology mapping has been used for open-corpus personalization in students' knowledge assessments [15]. Ontologies can be used for modeling educational modules [16] and a collaborative environment using shared ontologies can be explored with concept maps [17]. Standardized concept map representation Topic Maps

can address knowledge resources on multiple levels [18] and enable forming an ontology for acquired knowledge in a lifelong learning perspective [19]. Using a wiki visualized with Topic Maps test users went through significantly less irrelevant information and pages than with a traditional wiki [20]. An interactive workspace can integrate real-time synchronized wiki collaboration in knowledge-building activities based on concept mapping [21]. There are many semi-automatic approaches to build concept maps [22].

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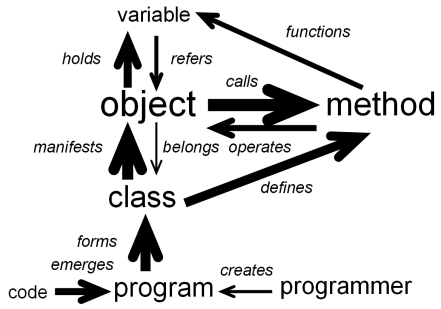

Figure 1. Example of representation of concept maps and learning paths.

V. DISCUSSION AND FUTURE WORK

We do not know any previous similar proposal for a concept map based wiki. We aim to augment traditional wiki techniques for creating, editing and applying knowledge in learning based on a diverse database of collaborative contributions supplied with user profiles. Initial experiments indicate promising pedagogical value and various educational games can be incorporated based on browsing and editing concept maps which can be agglomerated to maturing entities and ontologies that get gradually refined and provide complementing alternative conceptualizations. We think that knowledge structures and user logs gathered with the method can be exploited in daily educational work for evaluating students' learning progress, modeling collaborative learning processes and identifying patterns of successful learning. The method could be easily augmented with components resembling those that have been developed for traditional wikis, data mining and clustering algorithms. The method could automatically suggest which concept maps most urgently need refinement and recommend promising learning paths based on concept maps having popular browsing patterns and active edit histories. Simple tentative concept maps and supplementing hyperlinks could be automatically generated based on hyperlink network of the Wikipedia. In addition, the method might help in curriculum planning and developing semantic analysis and building ontology models. There is a need for comparative research to evaluate benefits of alternative wiki technologies and ontology models and to synthesize their methodologies to develop general theory for creative problem solving and pedagogical guidance in computer-assisted learning.

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