SEMANTIC SUPPORT FOR EDUCATIONAL IT SERVICES

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ABSTRACT

Technology enhanced learning is one of the intensively researched domains, because it promises interesting contribution to modern educational processes at various levels, in particular in higher education. This paper presents our approach to design and implementation of semantic structures that are capable to support selected educational processes, e.g. in mathematical and computer science disciplines. The methodology for collaborative ontology development, applied on the analyzed domain of eleven courses, is proposed as a generic approach that can be potentially reused and adapted to create semantic models of other domains (courses, disciplines) for semantically supported technology enhanced learning applications. The resulting structure of developed ontologies is presented as a basis for constructing semantically enhanced electronic services that can be further orchestrated and integrated into complex educational processes. This approach may provide powerful means to educators at universities, namely for (semi-)automated preparation, running, and maintenance of their courses. Added semantics, by enabling an integration of learning services into specified educational processes, is capable to minimize the efforts of educators when preparing and running a new lecture or course, as well as to effectively analyze the whole process and the students' performance.

Keywords: *semantics, ontology, learning processes, technology enhanced learning*

1. INTRODUCTION

Technology-Enhanced Learning (TEL) refers to the support of any learning activity through suitable technological solutions [1]. Typical learning activity can be described by several key aspects as *objectives* of the learning process (learning goals, individual or group), *actors* (student, teacher, facilitator), learning *resources* (their creation, sharing, distribution and editing of digital content), *activities* (communication, collaboration, interaction with environment) and *context* (time, duration, surrounding people and location). Each learning activity can be understood as composition of all these aspects. There are many different information systems available, which usually mediate only some part(s) of the learning processes. When one would like to make use of miscellaneous information systems or services in order to support manifold education e.g. in mathematics and computer science, several problems may arise. One of the main problems is the interoperability between various information systems or services. The other problem arises when changing some part of a course, introducing e.g. some new services, methods, or simply switching to another information system supporting the learning process.

Most of these problems can be solved by incorporating semantics into the learning environment that is actually supported by information systems and services [2]. This is one of the main ideas behind the IT4KT project (Information Technology for Knowledge Transfer), which is being solved at the Faculty of Electrical Engineering and Informatics, Technical University of Kosice. Researchers and educators from three different departments joined together in order to analyze current learning processes and best practices within a set of eleven selected courses of mathematics and computer science. The focus on just mentioned two areas was given just because of limited resources and the ITK4T project focus, not limiting further, possibly much broader exploitation of the project results. given Based on this analysis, most important processes have been identified, modeled and will be supported by various electronic services (either existing, or newly implemented). Finally, these upgraded learning processes will be evaluated in real education of mentioned mathematical and computer science courses. All these activities are based on a common background of semantic technologies, where the shared semantics is modeled by means of an ontology. The TEL ontology created within IT4KT provides a common vocabulary for all modeled and implemented processes, particular electronic services and communication flows between them.

This paper focuses on the TEL ontology, which was designed and developed as a semantic core of the IT4KT platform. Next section describes the related work covering similar approaches used in TEL. Section 3 presents the methodology, mechanisms, and tools that were created and used for the design and collaborative development of the shared TEL ontology. The ontology structure is described in more details in Section 4. In Section 5, the main educational processes that were identified in our analysis are briefly described. The paper closes with a short summary of our contribution in the last section.

2. RELATED WORK

The area of TEL (or e-Learning, in general) as a research and application domain is extremely broad and rapidly expanding in last decade. However, IT4KT is particularly focused on the exploitation of semantic technologies, executable process models, and electronic services that support learning activities in higher education. When looking on the existing research activities in this specific area of the TEL domain, the portfolio of relevant projects, approaches, and/or applications is much smaller, even still quite extensive. Next we present some of the most relevant approaches (most of them are elaborated in respective European research projects) that were analyzed and at least partly utilized in IT4KT.

The PALETTE project aimed to provide an innovative TEL in communities of practice (CoP) [3], based on an expandable set of electronic services. Integration and interoperability between these services was achieved through Cross Awareness Knowledge Base (CAKB) tool, which provided inter-service synchronization and cross-service search. CAKB retrieves and stores any action performed in registered services, making it available for users' and services' awareness. The gathered knowledge is stored in CAKB ontology which describes services, resources and their actions [3]. From more recent work on ontology-based TEL/e-Learning concepts we can mention, for example [4] or [5]. The ontology-enabled service interoperability concept was adopted for IT4KT as well; however, we have decided to handle the service integration by means of a more transparent and flexible approach of semantic process models.

Technical University of Kosice participated on the European integrated FP6 project KP-Lab [6]. All co-authors of this paper were actively involved in design and development work. KP-Lab aimed at developing theories, tools, and practical models that facilitate a collaborative creation of knowledge and its transformation to so-called knowledge practices in a learning process. A set of TEL-related ontologies (such as Trialogical Learning Ontology, KP-LAB Reference Model ontology, etc.) was produced to enable a semantic integration of project's tools and services. Collaborative learning environment built on these services was implemented, providing advanced analytical tools for analyzing students' actions throughout the courses [6]. In IT4KT, the KP-Lab outcomes, namely ontologies and related semantic structures, were reused and adapted to the process-oriented TEL solution.

Agre and Dochev [2] proposed an approach for developing a semantic SOA-based framework oriented to e-Learning applications, facilitating namely reusability and repurposing of learning objects. However, they do not provide an actual implementation. Experiments and best practices were presented in [7], where authors discuss outcomes of the FP6 project LOGOS, mainly its "Authoring studio", a subsystem for creation of learning materials from existing digital repositories by means of semantic annotation and access.

Methods and software components developed within the LOGOS project are being adapted and enhanced in the Bulgarian project SINUS [8]. Objectives of this project include a creation of new application-oriented methods and end-user tools for Semantic Web Service descriptions oriented to TEL, development of new methods for dynamic service composition suited for e-Learning, as well as the creation of a new Semantic SOA framework for TEL, which facilitates the learning objects reusability. SINUS currently provides two quite mature ontologies that model basic aspects, types, and technical parameters of learning objects. These ontologies, together with the means of setting up the SOA-based environment for electronic services, are complementary to the proposed IT4KT system in terms of its further extension and adaptation to particular service-based TEL courses. To ensure an extensibility and compatibility with other TEL/e-Learning applications, semantic structures of IT4KT were designed with respect to the available standards. Regarding e-Learning Standards, the IMS Learning Design Information Model (IMS-LD) is currently the most widely used educational modeling language [9]. According to its authors, IMS-LD allows to model any type of learning process irrespective the underlying learning theory. Therefore, it is not concentrating on specific pedagogies but provides a generic and flexible language. The IMS-LD specification is maintained by IMS Global Learning Consortium.

The IEEE LOM standards specify the syntax and semantics of Learning Object Metadata, defined as the attributes required to adequately describe learning objects [10]. The learning object is defined as digital or non-digital entity, which can be used, re-used or referenced during TEL processes. The LOM standards focus on a minimal set of attributes needed to allow these learning objects to be managed, located, and evaluated.

Semantic Web Services methodologies are being developed and standardized in groups such as Web Service Modeling Ontology working group (WSMO WG), Conceptual Models for Services Working Group (CMS WG) and W3C. They integrate the work from various past and present projects, such as European FP6 and FP7 R&D projects SOA4ALL, SUPER, and from standards such as DAML. Other projects together with the most significant outcomes and notable TEL ontologies in WSMO and OWL-S formats (most of them were analyzed and partly also reused in IT4KT) are outlined, for example, in [2].

From a variety of existing TEL/e-Learning tools we can mention LAMS (the Learning Activity Management System) [11], an open source Java-based system for authoring, running, and monitoring online collaborative learning activities. Despite its maturity and quite strong community support, the extensibility and adaptation of LAMS could be an issue that can be namely addressed by the process-oriented and ontology-based architecture adapted in the IT4KT system.

3. METHODOLOGY AND TOOLS

The IT4KT project has an ambition to provide a generic and expandable solution, where the developed semantic structures can be adapted to new application cases (i.e., new courses, disciplines, etc.) in a transparent and straightforward way. It implies a necessity of proper methodology and tools for design, implementation, testing, and deployment of the TEL ontology, which would be capable to support the ontology development process in an iterative and collaborative manner.

3.1. Existing methodologies for ontology creation

In general, the methodology of ontology development includes a set of rules, recommendations, and principles that may be applied to a domain of interest for obtaining its conceptual description. Such methodologies are studied and proposed within the *Ontology Engineering*, a field that belongs to a broader area of Knowledge Engineering. It targets the criteria such as a broad and universal *acceptance* of the created ontology, which should correspond to the reality of the modeled domain, and the *applicability* of the ontology in practice, i.e., in real-world systems and applications.

A survey of methodologies for ontology development, together with user manuals and references, is available, for example, on the SemanticWeb.org portal [12]. Some of the most significant and frequently used methodologies are listed in the following outline.

The Uschold / King methodology [13], targeting the ontology creation from scratch, is one of the first attempts to systematically describe the steps of design, development, and implementation of ontologies. It recommends the steps as (1) identification of a goal and target of the ontology, (2) development of the ontology by specifying keywords, their definitions, attributes and relationships, encoding of concepts onto a proper formal representation, and combining them with other existing ontologies, (3) release and evaluation, and (4) creation of supportive documentation materials and usage manuals. In contrast to most of other methodologies, Uschold / King do not propose the ontology development to be held in iterative cycles, but as one shot process.

The OTK methodology [14], formulated within the On-To-Knowledge project, defines five phases of the iterative ontology development process: (1) feasibility study, which includes the analysis of the modeled domain, (2) kickoff, initial conceptualization, (3) refinement, transformation of conceptual structures to a formal semantic representation, (4) evaluation, comparison of the resulting ontology with the goals, and (5) application & evolution, i.e. the release, operation, and updates of the implemented ontology.

Collaborative creation of shared ontologies in a distributed environment is supported by DILIGENT or HCOME methodologies [12]. Finally, the Rapid Ontology Development [15] is one of the newest approaches, which emphasizes the processes after implementing and releasing ontologies to the Semantic Web environment. It includes the monitoring, continuous evaluation, and content adjustment with respect to the evolving requirements.

3.2. Steps in the ontology development

The development of ontologies is typically proposed on the level of general processes and activities that should be accomplished in a sequence or cycle. Methodologies, including these mentioned above, are not dependent on particular domain, tool, or semantic formalism. However, there are exceptions as, for example, the Ontology Development 101 [16], which is an user-oriented guide describing the ontology construction in the Protégé editor. Similar steps, but even more focused on gathering the information on the modeled domain from users, are proposed in the so-called *Requirement-Driven Approach* (RDA) [17]. This methodology was successfully applied in European FP6-7 R&D projects Access-eGov and SPIKE, where Technical University of Košice participated as coordinator and development partner, respectively. RDA defines the following steps:

1. *Identification of information needs*. A group of potential ontology users is analyzed and their requirements are identified.
2. *Identification of required information quality*. The users provide materials (usually textual documents) that describe the domain of interest. The materials are analyzed and a set of requirements on scope, structure, level of details, and topics is produced.
3. *Creation of a glossary of topics and terms*. Keywords that characterize the domain with respect to the required information needs and quality are extracted from the materials and are provided in a form of glossary. In this step, available external ontologies describing the domain can be analyzed and concepts that match the information needs are included into the glossary.
4. *Creation of a controlled vocabulary*. The glossary is further processed - each keyword is enhanced by its definition, related concepts and attributes, and type (e.g. "class" or "instance" type).
5. *Grouping and relating terms*. Keywords in the vocabulary are clustered into groups, based on the meaning similarity. Relations between the groups and keywords (terms, concepts) are specified.
6. *Designing an ontology*. The structure of grouped terms is transformed into a formal ontology representation (e.g., OWL, RDF, WSML).
7. *Implementing semantics*. Based on the selected implementation platform, the formal ontology is enhanced by constructs such as logical rules, axioms, constraints, data types, etc.

The methodology was originally designed in these seven steps only [17]; however, another step was added later from practical reasons [18]. The goal of this additional step is to validate the implemented ontology and ensure its conformity with the user requirements:

8. *Verification*. Users verify the required scope and quality of the information stored in the ontology. A suitable verification method could be to use the created ontology for a semantic annotation of materials describing the modeled domain.

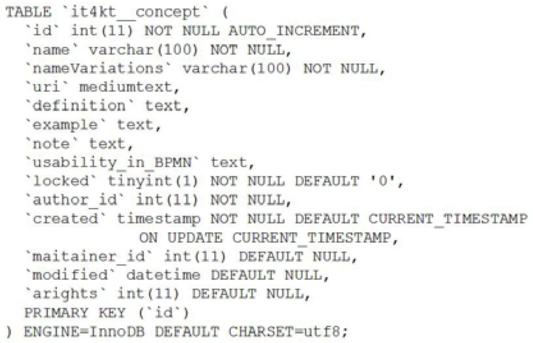
This step may result with a set of requirements for extension, modification, or refinement of the semantic information modeled by the ontology. It can re-invoke the first step of the procedure and initiate the next iteration cycle of ontology update.

3.3. Methodology for building the TEL ontology

RDA was taken as the main methodology for the TEL ontology construction in IT4KT. The TEL-specific concepts were adopted from the KP-LAB Reference Model ontology, as it is described in the next section. User requirements on the information needs and quality were gathered from textual descriptions of the selected eleven subjects in areas of mathematics and computer science.

These descriptions were provided by teachers leading the respective courses on the Technical University of Kosice.

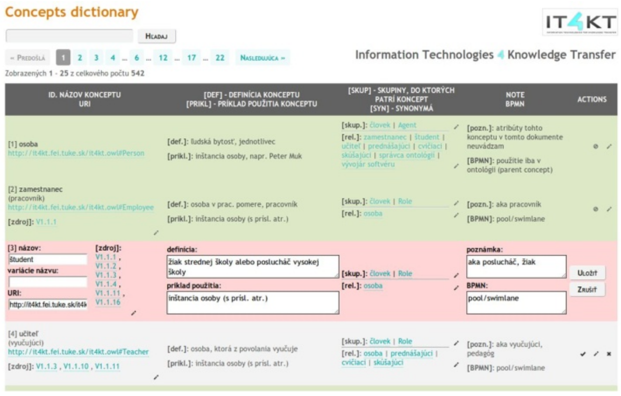
The glossary and controlled vocabulary was developed from the provided texts during several iteration cycles, in a tight collaboration of teachers and ontology engineers. Resulting vocabulary contains about 500 identified concepts, both classes and instances, which were divided into 12 basic categories. Each concept in the vocabulary is described by its definition, attributes, relations, references to the occurrences in texts, and usage examples. The controlled vocabulary, in its prototype presented as complex Excel sheet, was transformed into the respective database representation, as it is depicted in Figure 1.



```
TABLE `it4kt__concept` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `name` varchar(100) NOT NULL,
  `nameVariations` varchar(100) NOT NULL,
  `uri` mediumtext,
  `definition` text,
  `example` text,
  `note` text,
  `usability_in_BPMN` text,
  `locked` tinyint(1) NOT NULL DEFAULT '0',
  `author_id` int(11) NOT NULL,
  `created` timestamp NOT NULL DEFAULT CURRENT_TIMESTAMP
              ON UPDATE CURRENT_TIMESTAMP,
  `maitainer_id` int(11) DEFAULT NULL,
  `modified` datetime DEFAULT NULL,
  `arights` int(11) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8;
```

Fig. 1 Attributes of a concept from controlled vocabulary in its SQL representation

Web-based tools enabling the browsing, retrieval, collaborative updates, and export of the vocabulary were developed to ease the transformation of concepts into the corresponding formal ontology representation - in our case, into the OWL format. The interface of one of the tools, a web-based browser and editor of the structure of concepts and relations, is presented in Figure 2. The tool, accessible at http://studentweb.fei.tuke.sk/it4kt/, provides vocabulary browsing facilities in its default "view" mode, including features such as keyword and similarity search, reference browsing, ordering, and filtering of the list of concepts. In the "edit" mode (for authorized users only), all parameters of a concept can be collaboratively updated in a transactional way.



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ID. NÁZOV KONCEPTU URI	[DEF] - DEFINÍCIA KONCEPTU [PRIKL] - PRÍKLAD POUŽITIA KONCEPTU	[SKUP] - SKUPINY, DO KTORÝCH PATRÍ KONCEPT [SYN] - SYNONYMÁ	NOTE BPMN	ACTIONS
[1] osoba http://it4kt.fei.tuke.sk/it4kt.owl#Person	[def.]: ľudská bytosť, jednotlivec [prikl.]: inštancia osoby, napr. Peter Muk	[skup.]: človek | Agent [rel.]: zamestnanec | študent | učiteľ | prednášajúci | cvičiaci | skúšajúci | správca ontológií | vývojár softvéru	[pozn.]: atribúty tohto konceptu v tomto dokumente neuvádzam [BPMN]: použitie iba v ontológii (parent concept)	
[2] zamestnanec (pracovník) http://it4kt.fei.tuke.sk/it4kt.owl#Employee [zdroj]: V1.1.1	[def.]: osoba v prac. pomere, pracovník [prikl.]: inštancia osoby (s prísl. atr.)	[skup.]: človek | Role [rel.]: osoba	[pozn.]: aka pracovník [BPMN]: pool/swimlane	
[3] názov: študent variácie názvu: URI: http://it4kt.fei.tuke.sk/it4k [zdroj]: V1.1.1 , V1.1.2 , V1.1.3 , V1.1.4 , V1.1.11 , V1.1.16	definícia: žiak strednej školy alebo poslucháč vysokej školy príklad použitia: inštancia osoby (s prísl. atr.)	[skup.]: človek | Role [rel.]: osoba	poznámka: aka poslucháč, žiak BPMN: pool/swimlane	Uložiť Zrušiť
[4] učiteľ (vyučujúci) http://it4kt.fei.tuke.sk/it4kt.owl#Teacher [zdroj]: V1.1.3 , V1.1.10 , V1.1.11	[def.]: osoba, ktorá z povolania vyučuje [prikl.]: inštancia osoby (s prísl. atr.)	[skup.]: človek | Role [rel.]: osoba | prednášajúci | cvičiaci | skúšajúci	[pozn.]: aka vyučujúci, pedagóg [BPMN]: pool/swimlane	✓ ✕

Fig. 2 User interface of the web-based vocabulary editor

To support a seamless transformation of the vocabulary to the OWL ontology, the concepts were grouped and organized into hierarchical categories. URI attributes and relations such as synonyms, parent and child concepts were specified for each concept. To trace the usage of concepts in process models of learning activities, the "usability in BPMN" attribute was filled in with a recommended type of process element for a given concept (e.g., task, event, pool/lane, etc.). The controlled vocabulary has been revised in several iterations by all involved participants, i.e., developers of vocabulary or ontology editing tools, ontology engineers, and teachers of the analyzed courses. Finally, the vocabulary in its agreed final version was transformed into the TEL ontology in its OWL format. The next section describes an inner structure of the resulting TEL ontology, namely the distribution of sub-ontologies that model particular TEL aspects.

4. TEL ONTOLOGY STRUCTURE

The core of the TEL ontology, a semantic model of the IT4KT platform, is based on the previous work done on the KP-LAB Reference Model ontology [6]. In accordance with the KP-LAB approach, the IT4KT model follows the trialogical learning theory, which is based on so-called knowledge artifacts - abstract entities that are created, manipulated, and exchanged by actors during learning activities. Based on this approach, the top-most general concepts of the designed TEL ontology correspond to the *Activity*, *Actor/Agent*, *Role*, *Knowledge Artefact*, and *Tool* elements with the trialogical semantics, which can be generally described using the following statement: the Actor of a given Role is using the Tool to create/manipulate a Knowledge Object, where the whole act of the creation/manipulation of the Knowledge Object is formalized as the Activity. Moreover, *Event* and *Condition* concepts were introduced to represent specific characteristics for learning activities such as start/end conditions, prerequisites, and event types such as Lecture, Seminar, Lecture, etc. The resulting structure of top level ontology concepts is presented in Figure 3.

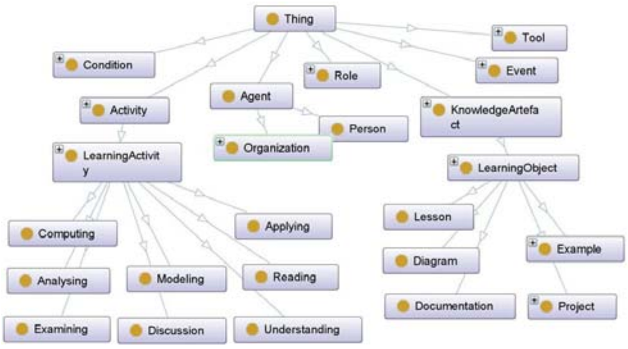

Fig. 3 Upper-level structure of the TEL ontology

Top-level concepts determine the hierarchy and inner structure of seven sub-ontologies that are described in more details in the following sections.

4.1. Agent and Role sub-ontologies

The *Agent* sub-ontology models all human agents and/or organization units participating on a learning process. This division is reflected by *Person* and *Organization* classes on the first hierarchical level. The *Organization* concept is further divided on *University*, *Faculty*, *Department*, and *Institute* classes, which represent the most basic units of higher education system. To model other levels of education (e.g. for references to some learning materials from secondary schools), sub-classes such as *Secondary School* or *Elementary School* can be included here as well. The structure of human actors, modeled by the *Person* class, is more complex and that is why it is specified in a separate *Role* sub-ontology. Based on the analysis of provided textual descriptions that resulted in the controlled vocabulary, the main roles of *Teacher*, *Employee*, *Administrator*, *SoftwareDeveloper*, *Student*, and *GroupOfStudents* were specified as classes on the upper level of the *Role* sub-ontology.

Concepts in the *Agent* sub-ontology contain mutual relations between the agents (e.g., a department belongs to a faculty, etc.). Other relations of agents to knowledge objects and tools can be inferred from the instantiation of the *Activity* sub-ontology (see below in Section 4.4). An actor can possess different roles within the scope of one or many activities of the process. Role assignment can be time limited - for example, one teacher can teach some subject only during some terms, etc.

4.2. Tool sub-ontology

The *Tool* sub-ontology can be seen as an interface to the tools and applications that are utilized in learning processes and could be potentially orchestrated in a semi-automatic way. As it is depicted in Figure 4, the concepts in the *Tool* sub-ontology are divided to *physical tools*, i.e., any physical objects used in a learning process for demonstration, explanation, modeling, exercise, etc., and *non-physical tools* covering various software and on-line learning toolkits.

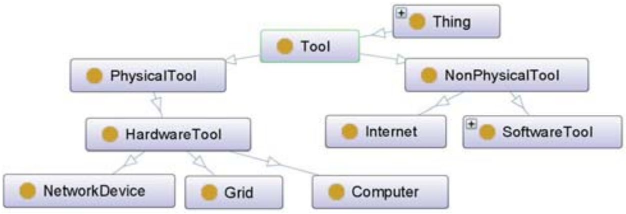

Fig. 4 A structure of the *Tool* sub-ontology

Software tools are subsequently divided to *applications* providing means for direct interaction with human actors, and *web services* that are invoked and used by other software components in an automated process. Both types of tools are described in the sub-ontology by a set of operations, which can be performed on the knowledge artifacts. Each operation is specified by the IOPE characteristics (inputs, outputs, pre-conditions, and effects), which have to be fulfilled before and after the operation is applied.

4.3. Knowledge Artefact and Event sub-ontologies

The aim of the *Knowledge Artefact* sub-ontology is to model all data artifacts and other physical or information objects, which enter or are created and/or modified during a learning process. Covered objects include for example structured learning materials, specification of tests, artifacts generated for student projects or home works, etc.

On its upper level, the sub-ontology contains four concepts, namely the *Subject* class that represents the learning subject types, the *Container* class for a storage space of learning materials, the *Resource* class for types of learning objects, and the *LearningObject* class defining all characteristics of artifacts created and exchanged between actors during a learning process.

The *LearningObject* class is an abstract concept with a rather complex inner structure (see in Figure 5). It defines various parts and types of learning materials such as *Diagram*, *Text*, *Example*, *Textbook*, and similar concepts. In addition, processes of applying a given set of learning materials in a lesson or similar learning unit are modeled by the *LearningScenario* class, which is specified as a subclass of the *LearningObject* parent. Instantiated learning scenarios, together with respective instances of supportive learning materials, define so-called *learning events* - reusable learning units that could be included into a broader learning process; for example, into courses running in a semester.

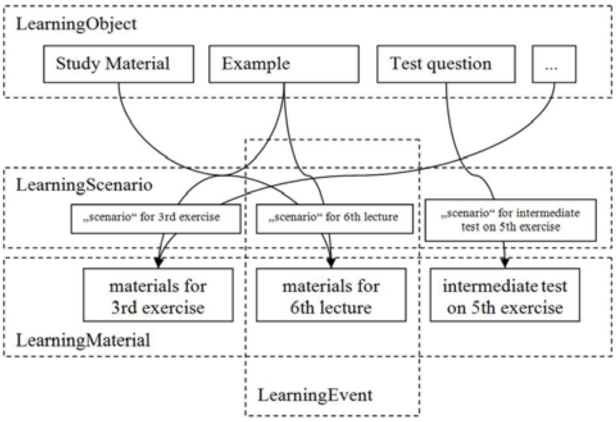

Fig. 5 Inclusion of learning objects into scenarios

Semantic models of learning events are defined separately, in the *Event* sub-ontology. Again, based on the produced vocabulary of terms, the *Seminar*, *Lecture*, *Exercise*, and *Course* classes were identified as the main types of learning events. These events can be seen as a process-oriented environment for running particular learning activities.

4.4. Activity and Condition sub-ontologies

Concepts of the *Activity* sub-ontology model the means of applying the tools on knowledge artifacts from the perspective of the whole pedagogical process. Each modeled activity points to the associated actor with respect to his/her role, together with the tools used for accomplishing the activity. Associated tools constrain permissible knowledge artifacts entering the activity or being produced by the activity as its outputs.

Figure 6 presents a structure of upper level concepts of the *Activity* sub-ontology. In principle, particular activities were identified in the controlled vocabulary as verbs describing some actions, functions, or operations. Specific types of activities are defined in the sub-ontology by classes such as *LearningActivity* describing sequences of learning processes, *TeachingActivity* that models processes required for teaching, etc. The basic division of activity types is specified by means of *AtomicActivity* and *ComplexActivity* concepts. It implies that instances of complex activities can be organized into hierarchies by means of the recursive *hasSubActivity* relation.

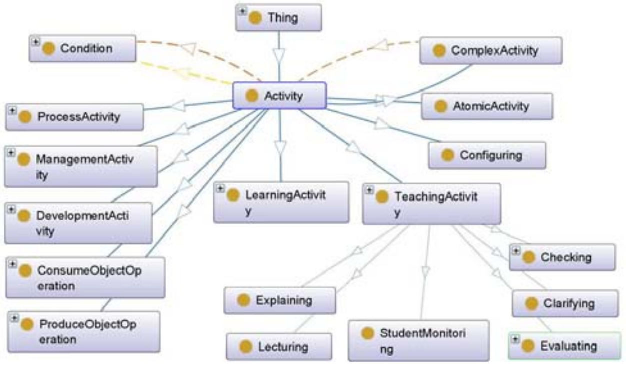

Fig. 6 Top-level concepts of the *Activity* sub-ontology

Activities may require specific conditions on their inputs and/or after producing an output. Types of these conditions are defined in the *Condition* sub-ontology, as it is presented in Figure 7. In process models of activities, these conditions can be utilized as rules or constrains on input pre-conditions or output effects. For example, the *Integration* activity requires a prior activity of *Analysis*, the *Study* activity requires availability of proper learning materials and the respective *Explaining* activity, etc.

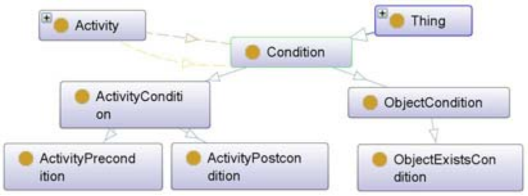

Fig. 7 A structure of the *Condition* sub-ontology

Proposed semantic representation of activities, which are driven by conditions and organized into complex sequences of learning events, enables a specification of corresponding semantically enriched process models, which was actually the main objective and purpose for developing the TEL ontology.

4.5. Implementation of the TEL ontology

The design and incremental implementation of the TEL ontology were accomplished in a collaborative way, similarly as it was for the controlled vocabulary development. The requirement of compatibility with other existing semantic resources, typically available in RDF/RDF-S or OWL/XML formats, was reflected by selecting OWL as the most appropriate language for the formal representation of the TEL ontology. This decision was supported by the fact that OWL 2 already supports business processes and their semantic annotations.

After a detailed analysis of several available ontology editors, the Collaborative Protégé [19] was selected as a tool for iterative development, maintenance, and validation of the TEL ontology. The development was driven by ontology engineers; ontology releases were checked and updated by educators of all analyzed courses of mathematics and computer science.

Initial version of the TEL ontology was produced as a simple conversion of the controlled vocabulary into the OWL format. Vocabulary concepts were clustered into hierarchies and combined with the KP-LAB Reference Model ontology [6]. Resulting structure of seven above-presented sub-ontologies was provided for discussion and further collaborative enhancements in iterative cycles. In parallel, a set of conventions on terminology, ontology update procedures, naming of concepts, relations, quantifiers, and other ontology elements, was agreed. Following the methodology for ontology engineering, elaborated within the development of CIDOC ontology [20], the design principles of monotony, minimality, expandability, generality, granularity, precision, and functional completeness were specified and provided to the involved stakeholders in a form of user manual.

The TEL ontology was implemented under the namespace of http://it4kt.fei.tuke.sk/it4kt.owl, where URI of all the concepts is composed of the namespace and the name of a particular concept. Due to the compatibility with open standards and other semantic resources, TEL ontology concepts are labeled by English names, using the CamelCase notation [21]. Slovak name equivalents and references to the controlled vocabulary are expressed as "title" attributes of the Dublin Core metadata schema [22], for example:

http://it4kt.fei.tuke.sk/it4kt.owl#KnowledgeArtefact,
dc:title "znalostný artefakt".

In addition, all concepts are annotated by dc:identifier and dc:description attributes as well as by subclass and superclass relations. Altogether the TEL ontology in its current version (September 2012) contains 223 classes in 5 hierarchical levels.

Besides the ontology source code, which is maintained by the Collaborative Protégé tool, two additional tools were implemented within IT4KT, namely:

- IT4KT Ontology Explorer, a web-based tool that enables the namespace browsing and download of the TEL ontology in the OWL format, available at: http://kplab.tuke.sk:8080/it4kt-explorer/;
- An export of the TEL ontology, which includes a generated OWLDoc application and a graphical visualization of the main class hierarchies, is available at http://studentweb.fei.tuke.sk/it4kt/v1.2.4/.

The resulting TEL ontology in the OWL format is available for download at http://kplab.tuke.sk:8080/it4kt-explorer/it4kt.owl.

5. EXPERIMENTS ON SEMANTIC SUPPORT FOR GENERIC EDUCATIONAL PROCESSES

The produced TEL ontology provides a reusable semantic knowledge on the domain of higher education in the scope of eleven analyzed courses. This formalized knowledge could be applied in practice in various ways; however, IT4KT targets to exploit the TEL ontology in a support of improved (i.e., more efficient, automated, transparent) learning processes and their subparts represented by particular electronic services.

In line with this goal, the courses were further analyzed to identify candidates for semantic-based electronic services, as well as the underlying educational processes that could be generalized even to other courses, subjects, or education types. The experimental analysis was focused on best practices and possible process enhancements with respect to the utilization of the semantic information provided by the TEL ontology.

Small groups consisting of lecturers, experts for process modeling, and ontology designers were formed together to create BPMN 2.0 models for identified crucial activities. After this phase, that lasted about two months, more than 50 top- and second-level processes were created. During this phase the common vocabulary (as the first step towards ontology design, cf. Section 3) helped to discover possible overlaps and unify the description of processes, actors, roles, activities, events, data objects and messages to exchange.

In the next phase, which was accomplished in parallel with the development and implementation of the TEL ontology, all created processes were analyzed in detail and groups of processes were identified in order to make the experiences, skills and practices of individual processes as generic as possible. The analysis resulted in the proposal of three groups of generic educational processes, namely:

A. *Preparing study materials for a course*. It includes sub-processes such as preparing, publishing, and use of lecture materials. Partial sub-processes include a preparation of questionnaires, controlled self-study, commenting of study scenarios, etc.

B. *Support for students' assignments*. The generic process unifies sub-processes that model individual or team work of students on term projects, incremental work of students on assignments, storage and maintenance of assignment solutions, etc.

C. *Generation, development, and evaluation of tests including programming tasks*. It summarizes sub-processes of validation and evaluation of students' skills and knowledge, which includes entry tests, self testing, dynamic tests of practical skills, automated verification of programming tasks, support for programming assignment variations, and paper equivalents of electronic tests.

Hierarchical BPMN 2.0 models were created for each of generic processes and particular sub-processes. This phase of process modeling was taken as an experimental evaluation and verification of the TEL ontology, since the ontology concepts were applied not only to the activity names, but for processed data and occurred events as well. In addition, executable services were specified for process activities, where their inputs and outputs were again modeled by means of ontology concepts. Thanks to the adopted methodology and incremental development, no further changes on the class hierarchy were required during these experiments. The process agents, activities, and knowledge artifacts were specified as sub-classes and instances that semantically describe each of generic processes and respective web services in terms of their orchestration and interoperability. Concepts were applied on generic processes proportionally as follows: process A employs 42 concepts (i.e., 18,8% of all classes and 24,1% of leaf classes), process B uses 36 concepts (16,1% of all and 20,7% of leaf classes), process C applies 58 concepts (26% of all and 33,3% of leaf classes). Average overlap of concepts applied on these processes is 42%. These results indicate that the TEL ontology is designed in a proper way, well balanced and suitable to serve as a knowledge resource for semantic annotation and orchestration of both process models and web services in the IT4KT system, as well as in semantic e-Learning applications in general, enabling an automation of educational processes and activities in accordance with TEL principles.

6. CONCLUSIONS

The produced TEL ontology, presented in this paper, could be considered as an intermediate but essential step towards the objectives of IT4KT on automation and improvement of educational processes. It already provides a consistent semantic knowledge base for process-oriented TEL applications, as it was proven by experiments on semantic modeling and annotation of selected pedagogical processes. Within the IT4KT project, the ontology is applied on the annotation and semantic reasoning of web services orchestrated in three basic types of generic pedagogical processes. Implementation of such a solution started in autumn 2012, the first prototype of the integrated IT4KT system should be available for testing and deployment in spring 2013.

Since the TEL ontology was constructed in accordance with the trialogical learning theory, it could be seen as a general semantic model of teaching and learning processes that are capable to be progressive, focused on innovations and collaborative production of knowledge artifacts. Thanks to the transparent methodology, the TEL ontology can be further refined and adapted to other domains such as new subjects or university courses, as well as to other types of education in secondary or primary schools, distance learning, self-study, or training in various areas.

ACKNOWLEDGMENT

This work is the result of the project implementation: IT4KT – Information technology for knowledge transfer (ITMS project code: 26220220123) supported by the Research & Development Operational Program funded by the ERDF.

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Received June 5, 2012, accepted December 28, 2012

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