Semantic Technologies and Learning

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Semantic Technologies and Learning

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Synonyms

Knowledge representation and reasoning and learning; Linked data and learning; Semantic web and learning

Definition

Semantic technologies provide for the expression of meaning of resources such as content, software, systems, people, and communities in machine processable formats with the help of ontologies. Ontologies provide the vocabulary for describing resources and their relationships (Gruber 1993; Musen 1992). Based on the meaning of resources, semantic technologies can draw conclusions and enable better resource discovery and matching.

In a learning context, the potential of semantic technologies translates to a number of affordances. The types of resources involved in formal or informal learning environments could include learners, teachers, software, services and content. Given the description (or annotation) of these resources with the help of ontologies, it is possible to support more efficient discovery of learning resources, sequencing of relevant learning material, adaptation of learning experiences to match learner profiles, formation of groups for teaching learning activities, collaborative construction of knowledge, recommendation of learning resources and activities, and assessment. A number of ontologies are developed in the learning domain in order to support these applications with the help of reasoning software.

Theoretical Background

Semantic technologies for learning draw from work in Knowledge Representation and Reasoning and have been significantly influenced by developments in the Semantic Web community (Berners-Lee et al. 2001). The Semantic Web vision has been considered "inevitable" and its impact on education significant (Ohler 2008).

With the help of ontologies, semantic technologies can support knowledge representation and reasoning. There are a number of ontology languages to address the tradeoff between how expressive an ontology language is and the performance of reasoning based on resources annotated with this ontology language. Resource descriptions in more expressive ontology languages could potentially let us perform advanced reasoning and draw more conclusions about resources, at the cost, however, of increased computation and potentially reduced performance.

For example, some ontology languages let us use *transitive* properties when describing how resources relate to each other, which can provide for more powerful reasoning. Consider an ontology for the domain of language education. We could identify concepts such as *student* and *class* and relationships that express that a student *attends* one class *only* or that a student *is a classmate of* another student; one could also specify that the relationship *is a classmate of* its *transitive* (i.e., if A *is a classmate of* B and B *is a classmate of* C then A *is a classmate of* C). Given this ontology, one can *annotate* (mark up) specific resources as instances of ontology concepts. For example, one could mark up each of "*Alice*," "*Bob*," and "*Eve*" as instances of a *student* and "*French*" as an instance of a *class;* one could also state that "*Alice*" *is a classmate of* "*Bob*,"that "*Bob*" *is a classmate of* "*Eve*," and that "*Eve*" *attends* "*French*." Given this annotation and the ontology, it is possible to *draw conclusions* with the help of software; in this example, software could *infer* that "*Alice*" *attends* "*French*" and that "*Alice*" *is a classmate of* "*Eve*" even if this information is not explicitly stated in the annotation.

The power of knowledge representation and reasoning bears significant promise for learning. In addition, the well-formed description of resources with the use of lightweight or more expressive ontologies bears potential for interoperability and data integration. This has led to

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research on the use of semantic technologies in a number of areas related to learning.

Semantic Technology Affordances

The promise of semantic technologies in learning has been identified as an important aspect of Technology Enhanced Learning (TEL) in both formal and informal learning settings. The ability of semantic technologies to match people, content, and communities that are involved in learning processes is central in all these areas.

Matching learners to learning resources has led to work on the integration of semantic technologies Learning Management Systems (LMS), Learning Content Management Systems (LCMS), or Virtual Learning Environments (VLE). The role of semantic technologies in these domains is on discovering, sequencing, or adapting learning material based on the learner profile and learning outcomes. Semantic technologies have been considered in the context of collaborative building of knowledge and learning material by means of collaborative ontology building, topic maps and semantic wikis. Collaborative ontology building tools have also been developed to that end.

The use of semantic technologies to match learners to other learners or teachers has been considered in group-formation systems in formal learning and informal learning settings. In vocational training, semantic technologies have been proposed to form groups of learners with similar or supplementary competencies. In informal learning, successfully matching learners based on their profiles and their learning objectives using semantic technologies has been pursued.

Another significant advantage of semantic technologies is in matching content and people involved in learning processes on a large scale: a larger pool of people and content increases the chances of accurate matching. In this respect, the semantic description of resources available in repositories of reference material has been used for advanced content discovery. Semantic applications to support critical thinking and argumentation by enabling the discovery of material in support or against a certain argument are also being explored. At the same time, aggregating and processing information about people and their activity using semantic technologies has led to work on expert matching tools and query answering. Ontologies for describing relationships among people such as the Friend-of-a-Friend (FOAF) ontology enable additional tools on discovering people and supporting informal learning processes.

Semantic technologies can support a number of processes in formal education institutions such as assessment. In the environment of assessment semantic technologies can help in preparing appropriate assessment material that matches certain assessment criteria or in the analysis of text that is submitted as part of assessment; there are examples of use of semantic technologies for both summative and formative assessment.

Semantic technologies can also support well-formed description of resources in a formal education environment and address interoperability and data integration requirements inside and across education institutions. In the context of formal education, the data interoperability and integration affordances of semantic technologies can support efficient systems for curriculum design, development of learning material, and collaboration among the people involved in teaching and learning activities.

Building Semantic Technologies

Different approaches can be followed when it comes to developing semantic technologies in a specific domain. One can consider a top-down approach where the use of an ontology or a set of ontologies are agreed first before the annotation of resources and the deployment of applications. An alternative approach gives priority to exposing data sources using lightweight vocabularies first, in order to enable data interoperability and integration before considering more complex ontologies in the context of specific applications. The latter view is central in the linked data movement (http://linkeddata.org/), which proposes practices for exposing and connecting structured data on the Web (Bizer et al. 2009). The Linked Data movement supports the exposure of data sources in lightweight vocabularies such as RDF (http://www.w3.org/RDF/) in order to allow for the emergence of intelligent applications that will make use of the exposed data.

The value of semantic technologies and linked data in terms of well-formed description of resources, data interoperability, and data integration in the UK higher education sector has been highlighted in a number of reports (Tiropanis et al. 2009). The types of semantic technologies that are related to learning and which can benefit from the linked data approach include:

- Collaborative authoring and annotation tools
- Searching and matching tools based on linked data resources (e.g., expert finders)
- Repositories and VLEs that import or export their data in linked data formats to support learning resource discovery

In parallel to the Semantic Web vision, there are proposals for a *Pragmatic Web* (http://www.pragmaticweb.info), in which the description of the meaning of resources is based not just on the semantic constructs and their relations as defined in ontologies, but also on the context in which resources are found and used. This contextual information could provide for more accurate mechanisms for learning resource discovery and use.

Important Scientific Research and Open Questions

Research on semantic technologies in learning has been developing in several directions. A non-exhaustive list of such directions and open research questions includes:

- Collaborative knowledge representation and maintenance in learning environments
- Supporting personal and group knowledge construction with semantic technologies
- Establishing the underpinning pedagogy of semantic applications or introducing pedagogy in semantic applications
- Knowledge extraction on resources related to learning
- Transition from taxonomies and hierarchies to more expressive ontologies for learning
- Semantic applications for critical thinking and argumentation
- Exploring the potential of semantic technologies for exploratory learning and problem-based learning
- Investigating the potential of sharing and combining linked data inside or across educational institutions
- Semantic technologies to capture and enhance informal learning processes

There are of systems that can support personal or collaborative knowledge construction, which are often Wiki-based or Topic-map based. In many cases, the constructed knowledge is not available in machine processable formats or formats that are appropriate for integration with other relevant applications. This opens siginificant questions on the feasibility, scalability, and efficiency of semantic technology based approaches to learning resource authoring and to data interoperability and integration for learning systems. In addition, the potential of semantic technologies to support pedagogy in technology-enhanced learning requires further research. Semantic applications seem promising in supporting critical thinking and argumentation given the availability of relevant resources and applications. Applications that combine resources described using lightweight vocabularies on a large scale, across educational institutions and organizations, could potentially support novel processes for formal, informal, exploratory, and problem-based learning.

Cross-References

- ► Collaborative Knowledge Building
- ► Knowledge Acquisition: Constructing Meaning from Multiple Information Sources
- ► Knowledge Organization
- ► Knowledge Representation
- ► Ontology and Semantic Web
- ► Ontology Development and Learning
- ► Ontology of Learning Objects Repository for Knowledge Sharing
- ► Semantic Networks to Support Learning

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