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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* is *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

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

### 83 **Semantic Technology Affordances**

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

90 Matching learners to learning resources has led to  
91 work on the integration of semantic technologies Learning  
92 Management Systems (LMS), Learning Content Manage-  
93 ment Systems (LCMS), or Virtual Learning Environments  
94 (VLE). The role of semantic technologies in these domains  
95 is on discovering, sequencing, or adapting learning materi-  
96 al based on the learner profile and learning outcomes.  
97 Semantic technologies have been considered in the context  
98 of collaborative building of knowledge and learning materi-  
99 al by means of collaborative ontology building, topic  
100 maps and semantic wikis. Collaborative ontology building  
101 tools have also been developed to that end.

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

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

128 Semantic technologies can support a number of pro-  
129 cesses in formal education institutions such as assessment.  
130 In the environment of assessment semantic technologies

can help in preparing appropriate assessment material 131  
that matches certain assessment criteria or in the analysis 132  
of text that is submitted as part of assessment; there are 133  
examples of use of semantic technologies for both sum- 134  
mative and formative assessment. 135

Semantic technologies can also support well-formed 136  
description of resources in a formal education environ- 137  
ment and address interoperability and data integration 138  
requirements inside and across education institutions. In 139  
the context of formal education, the data interoperability 140  
and integration affordances of semantic technologies can 141  
support efficient systems for curriculum design, develop- 142  
ment of learning material, and collaboration among the 143  
people involved in teaching and learning activities. 144

### Building Semantic Technologies 145

Different approaches can be followed when it comes to 146  
developing semantic technologies in a specific domain. 147  
One can consider a top-down approach where the use of 148  
an ontology or a set of ontologies are agreed first before 149  
the annotation of resources and the deployment of applica- 150  
tions. An alternative approach gives priority to exposing 151  
data sources using lightweight vocabularies first, in order 152  
to enable data interoperability and integration before 153  
considering more complex ontologies in the context of 154  
specific applications. The latter view is central in the 155  
linked data movement (<http://linkeddata.org/>), which 156  
proposes practices for exposing and connecting structured 157  
data on the Web (Bizer et al. 2009). The Linked Data 158  
movement supports the exposure of data sources in light- 159  
weight vocabularies such as RDF ([http://www.w3.org/](http://www.w3.org/RDF/)  
160 [RDF/](http://www.w3.org/RDF/)) in order to allow for the emergence of intelligent  
161 applications that will make use of the exposed data. 162

The value of semantic technologies and linked data in 163  
terms of well-formed description of resources, data 164  
interoperability, and data integration in the UK higher 165  
education sector has been highlighted in a number of 166  
reports (Tiropanis et al. 2009). The types of semantic 167  
technologies that are related to learning and which can 168  
benefit from the linked data approach include: 169

- Collaborative authoring and annotation tools 170
- Searching and matching tools based on linked data 171  
resources (e.g., expert finders) 172
- Repositories and VLEs that import or export their data 173  
in linked data formats to support learning resource 174  
discovery 175

In parallel to the Semantic Web vision, there are propos- 176  
als for a *Pragmatic Web* ([http://www.pragmaticweb.](http://www.pragmaticweb.info/)  
177 [info](http://www.pragmaticweb.info/)), in which the description of the meaning of resources 178  
is based not just on the semantic constructs and their 179

180 relations as defined in ontologies, but also on the context  
181 in which resources are found and used. This contextual  
182 information could provide for more accurate mechanisms  
183 for learning resource discovery and use.

### 184 **Important Scientific Research and Open** 185 **Questions**

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

- 189 ● Collaborative knowledge representation and mainte-  
190 nance in learning environments
- 191 ● Supporting personal and group knowledge construc-  
192 tion with semantic technologies
- 193 ● Establishing the underpinning pedagogy of semantic  
194 applications or introducing pedagogy in semantic  
195 applications
- 196 ● Knowledge extraction on resources related to learning
- 197 ● Transition from taxonomies and hierarchies to more  
198 expressive ontologies for learning
- 199 ● Semantic applications for critical thinking and  
200 argumentation
- 201 ● Exploring the potential of semantic technologies for  
202 exploratory learning and problem-based learning
- 203 ● Investigating the potential of sharing and combining  
204 linked data inside or across educational institutions
- 205 ● Semantic technologies to capture and enhance infor-  
206 mal learning processes

207 There are of systems that can support personal or  
208 collaborative knowledge construction, which are often  
209 Wiki-based or Topic-map based. In many cases, the  
210 constructed knowledge is not available in machine  
211 processable formats or formats that are appropriate for  
212 integration with other relevant applications. This opens  
213 significant questions on the feasibility, scalability, and  
214 efficiency of semantic technology based approaches to  
215 learning resource authoring and to data interoperability

and integration for learning systems. In addition, the  
216 potential of semantic technologies to support pedagogy  
217 in technology-enhanced learning requires further  
218 research. Semantic applications seem promising in  
219 supporting critical thinking and argumentation given the  
220 availability of relevant resources and applications.  
221 Applications that combine resources described using  
222 lightweight vocabularies on a large scale, across educa-  
223 tional institutions and organizations, could potentially  
224 support novel processes for formal, informal, exploratory,  
225 and problem-based learning. 226

### 227 **Cross-References**

- ▶ Collaborative Knowledge Building 228
- ▶ Knowledge Acquisition: Constructing Meaning from  
Multiple Information Sources 229
- ▶ Knowledge Organization 231
- ▶ Knowledge Representation 232
- ▶ Ontology and Semantic Web 233
- ▶ Ontology Development and Learning 234
- ▶ Ontology of Learning Objects Repository for  
Knowledge Sharing 235
- ▶ Semantic Networks to Support Learning 237

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