

Conceptualising Smart Spaces for Learning

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Abstract:

Selecting appropriate learning services for a learner from the large number of heterogeneous knowledge sources is a complex and challenging task. This paper presents the idea of Smart Spaces for Learning. A Smart Space for Learning is defined as a distributed system (ie “space”) that provides management support for the “smart” retrieval and consumption of heterogeneous learning services via Personal Learning Assistants. Personalisation and system interoperability play an important role for the realisation of a Smart Space for Learning. In this paper we illustrate and discuss how Semantic Web technologies such as RDF, TRIPLE, QEL and ontologies can be applied to create a Smart Space for Learning.

Keywords:

learning management, knowledge management, distributed systems, ontology, educational semantic web, personalisation.

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1. The Corporate Learning Spaces Today

Over the past few years, corporations have made significant progress in linking learning processes with the employee's work environment. Today's knowledge workers are served by Internet access through their desktop and mobile phone, business-unit specific knowledge repositories, e-learning tools, and customized education and training opportunities available through corporate intranets. Leading business organisations are offering its workforce a heterogeneous set of learning resources ranging from traditional seminars to knowledge management activities and e learning content.

While such a sophisticated learning space creates competitive advantage by intellectually empowering a company's workforce, some shortcomings limit the benefits, mainly from the perspectives of decision effectiveness, process administration, and IT infrastructure management. The lack of interoperability of knowledge repositories, for instance, does not allow for a unique view on the learning services offered. As a result, a user's search costs increase and the transparency of learning resources offered is reduced with each repository added to the environment. However, such an environment not only lacks transparency in terms of learning service offerings, but also does not provide a customizable view of the learning processes undertaken by the work force. The latter constitutes important information for personnel developers and other mentors. In many cases, the electronic environments also lack decision and recommendation support. Neither potential learners nor their mentors have all the goal-driven business tools and information available to concisely select the right learning service for closing a particular knowledge gap. On the other hand, a series of wrong decisions (eg not taking a "required" learning service or registering for a "wrong" learning service) can have substantial impact on individual and corporate performance.

Until recently, setting up a corporate learning space consisting of monolithic components such as traditional course offerings, e-learning content (where appropriate), and knowledge management activities has been a major task in corporate work environments. However, this no longer seems to be the main concern. Companies are starting to focus on the integrated management of these heterogeneous components in what can be referred to as "Smart Spaces for Learning". Besides the integrate view on a company's human resources (HR) development process, institutions are now also selectively opening up there knowledge environments to incorporate also resources from other environments (eg book abstracts, courses offered through electronic market places, etc).

In Smart Spaces for Learning, semantic web technologies are used to provide enhanced, customizable and automated learning and administrative services. These include technologies such as the Resource Description Framework (RDF), the Query Exchange Language (QEL), TRIPLE, and ontologies that play a crucial role in achieving interoperability among repositories or recommending appropriate learning services. This paper reports on the ELENA project¹ and investigates and discusses how these technologies can be used to build systems like Smart Spaces for Learning. Smart Spaces for Learning are defined in Section 2, while Section 3 describes relevant design issues. Sections 4 and 5 respectively address two of the design issues mentioned: artefacts interoperability and personalisation. The paper concludes with a presentation of the ELENA Smart Space for Learning and discusses implications for the development of an Educational Semantic Web.

2. “Smart Spaces for Learning” Defined

A Smart Space for Learning is a distributed system, which provides management support for the retrieval and consumption of heterogeneous learning resources. While "Space" is used as a synonym for "Network", "Smart" refers to the 'intelligent' mediation of learning resources (eg courses, e-learning content, etc) based on user profiles and artificial intelligence techniques.

Like any information system also a Smart Space for Learning consists of a human component and a technology component. Smart Spaces for Learning are built for supporting human resources development processes. Hence, learners, educators (eg teachers, instructors, trainers, professors, peers), and learning managers (eg parents, HR developers, team leaders) constitute the primary users of the system.

The two major technology components of Smart Spaces for Learning are the network of interconnected educational nodes (the Learning Management Network) and a Personal Learning Assistant (PLA), which provides a personalised access point to learning resources on the network (see Figure 1). The PLA supports learners in searching for, selecting, contracting with, and evaluating learning resources. It might also assess the learner's pre-existing knowledge to better identify knowledge gaps and learning needs. By using personalisation techniques a PLA is capable of creating a personalised view of a Learning Management Network.

¹ <http://www.elena-project.org/>

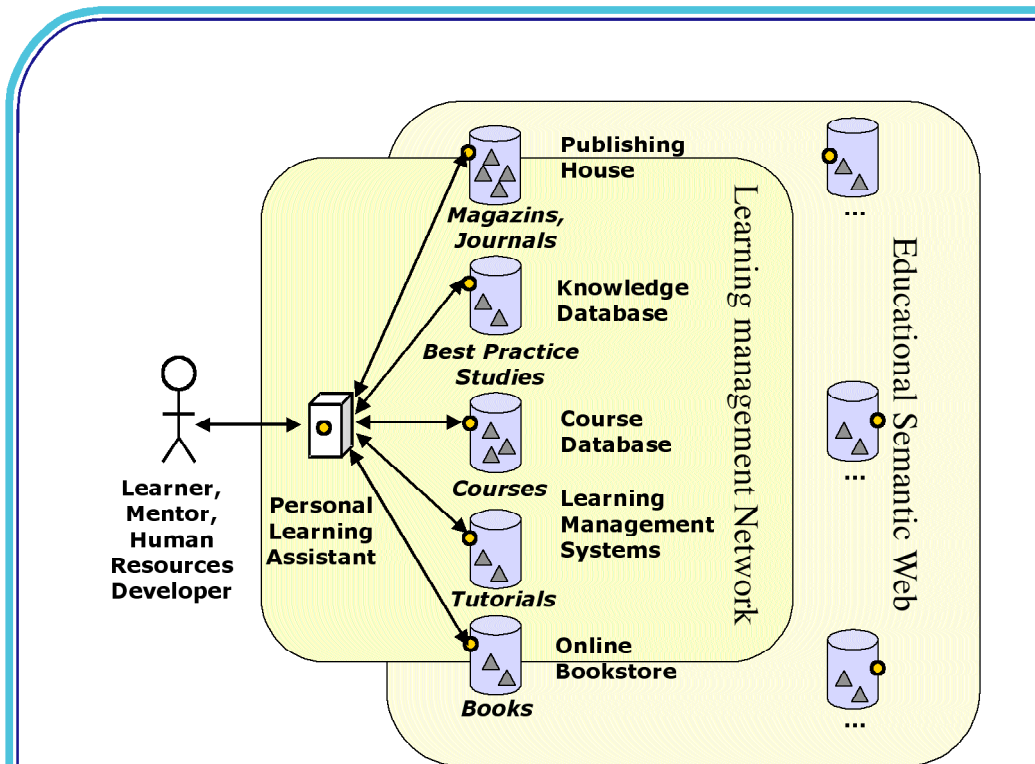


Figure 1: System components of a Smart Space for Learning

In a Learning Management Network, system interfaces provide means for exchanging information on educational artefacts such as courses, offer information and learner profiles. The information on educational artefacts (ie data on data) is commonly referred to as metadata and plays a crucial role for achieving interoperability among the various educational nodes. A Learning Management Network is a “trusted” network in which users and systems are authenticated.

We envision learning management networks as sub-networks of a larger Educational Semantic Web – according to ELENA terminology also referred to as Artefacts and Service Network. The Educational Semantic Web facilitates the identification of educational nodes, both, in terms of network location as well as service types offered. The types of services offered comprise learning services and services that supplement learning services, which facilitate the preparation, generation, control, or evaluation of learning services. For example, a content brokerage service can be used for preparing the delivery of a course or for providing a learner with related information in a particular subject area. Assessment services can be used to identify knowledge

gaps. Evaluation services provide information that helps to gauge the quality of a learning service. Reputation services attempt to quantify the reputation of a learning service provider within the network. Designers of Learning Management Networks can take advantage of the variety of educational services offered in the Educational Semantic Web by integrating external educational nodes into their Smart Space for Learning.

3. Design Issues

The implementation of Smart Spaces for Learning creates a variety of design challenges including the following:

- **Network Design:** Here, issues such as how can a network be set up that provides a flexible framework for the registration of educational nodes need to be addressed. Additionally, the network needs to support a communication framework for exchanging messages between the various educational nodes.
- **Interoperability of Educational Nodes:** Within a smart space for learning, common interfaces need to be created to make educational nodes interoperable (Simon, Retalis, & Brantner, 2003). Basic specifications or standards for exchanging information on educational artefacts and triggering the delivery of learning services and resources need to be defined.
- **Artefacts Interoperability:** Educational artefacts are understood as descriptions of educational service types (eg a course catalogue or an evaluation service) or instances of educational services and resources (eg a particular course, an assessment activity or an online text book). When an educational node forwards an educational artefact to another educational node for further processing, both nodes need to speak a common language. Hence, an ontology needs to be designed to provide a *lingua franca* – common trade language for learning resources - in the Smart Space for Learning.
- **Personalisation:** When a Smart Space for Learning provides access to a vast number of learning resources and services the problem arises of how to find appropriate learning services which satisfy a learner's demand. To solve that problem, intelligent PLAs need to handle learner profiles (Dolog & Nejdil, 2003a) and utilize them to recommend learning services (Dolog & Nejdil, 2003b) and learning paths according to their needs.
- **Support of Human Resources Development Processes:** With the implementation of a PLA, organizations aim at improving the effectiveness of learning

service selection decisions. Hence, the PLA shall support various management techniques that can be combined as a powerful tool supporting the effective selection of learning services and optimising the transfer of knowledge according to corporate goals.

- **Privacy and Security:** Privacy is a major concern when it comes to the design of a Smart Space for Learning. Learners submitting a personalised search request need to be able to control the information they are willing to submit to the learning management network.

In the following sections, we focus on how Semantic Web technologies such as TRIPLE, RDF, QEL, and ontologies can be used to achieve artefacts interoperability and personalisation. Other design issues are not addressed.

4. Artefacts Interoperability

In a Smart Space for Learning several educational nodes that use different schemas for describing educational artefacts need to communicate with each other. A possible approach to tackling the problem of artefacts interoperability is to create pair wise mappings (Aberer, Cudré-Mauroux, & Hauswirth, 2003). This approach is based on an idea that the schema of each system connected maintains mappings to the schemas of “neighbouring” systems.

However, this might require a large number of mappings in case many systems need to be interconnected. Another approach is to use one shared ontology in a particular community as a mediating schema and all local schemata in that community used by the systems interconnected are mapped to this common schema. In other terms, an ontology is terminology consisting of a set of related/associated concepts (Gruber, 1993) that are shared by software such as a Personal Learning Assistant. These concepts are used to describe information in the application domain in a way suitable for machine processing. We recognize two kinds of ontologies. One kind is used to prescribe structures for information about educational artefacts. Another kind is used to prescribe value ranges of particular properties in former ontologies as controlled taxonomies/vocabularies (eg subject ontologies).

The ELENA Smart Space for Learning is also built upon a common ontology describing the educational artefacts subject to exchange. Identifying learning services as special instances of learning resources is for example an important design assumption of the ELENA ontology. In ELENA we assume that learning resources, similar to learning objects as defined by the IEEE Learning Object Metadata (LOM)

Standard (IEEE, 2002) can be seen as any kind of (digital and non-digital) material or person, which facilitates the delivery of learning. Learning materials such as textbooks, lecture notes, computer-based training applications, etc, as well as educators are examples of learning resources. A learning service is defined as an event that is provided by a learning service provider in order to support the accomplishment of a specific learning objective. This is achieved by creating a learning environment consisting of learning resources, communication devices, meeting places, etc. Learning services are primarily concerned with various functions of instruction, such as motivating learners, re-calling learners' pre-existing knowledge, conveying learning content, providing exercises, and learner assessment. They are frequently identified with a specific type of outcome (eg grade, certificate, degree, etc) and sometimes require specific prerequisites to be fulfilled before a learner is allowed or recommended to interact with the service.

Since learning services require also many other learning resources, they are usually quite costly. In a corporate setting also opportunity costs have to be taken into account in addition to course price and accommodation costs. On the other hand, learning material is often freely available on the Internet. In some cases the provision of learning material is combined with a usage license (Quemada & Simon, 2003), so called open content licenses, while sometimes a specific price as to be paid which is usually significantly smaller than the price of a similar learning service.

Educational nodes aiming to share artefacts in a Smart Space for Learning then need to map the local schema to the common ontology. In this section we aim to illustrate what such a mapping can look like. We take the case of a schema developed for the ULI (Universitärer Lehrverbund Informatik) project (ULI, 2001). In ULI courses are described according to the schema presented in Figure 2.

The main concepts used to describe ULI courses are *Resource*, *Course*, and *Module*. All these concepts are described using the same attributes: *creator*, *created*, *subject*, *language*, *description*, *hasPart*, *title*, and *requires*. Prefixes used within the attributes refer to abbreviations of schemas URIs which define the attributes in IEEE LOM RDF bindings (eg dc refers to Dublin Core). The *isa* relations between the *Resource*, the *Module*, and the *Course* indicate that the attributes are inherited from *Resource*. In addition, *Course* and *Module* can have additional attributes like time, location and so on. The main concepts used also refer to other classes such as *W3CDTF* (W3C Date Time Format) for describing date of creation. *W3CDTF* class prescribes a structure of date, time, format. It contains properties for day, month, year, time zone, hour, minute, and fraction of second. LOM schema allows by *lom:entity* to

reference the vCard (Dawson & Howes, 1998) standard for describing persons. In this case it is used for representing a person who created a particular course, module or resource. *FN* is another concept prescribing a structure for full name of the person who created the course, module or resource. A course can have a composite structure. Hence, a course can be composed from other courses, modules and resources (*hasPart** relation together with *hasPart* attribute). Instances of the courses, modules or resources are maintained in the *hasPart* relation.

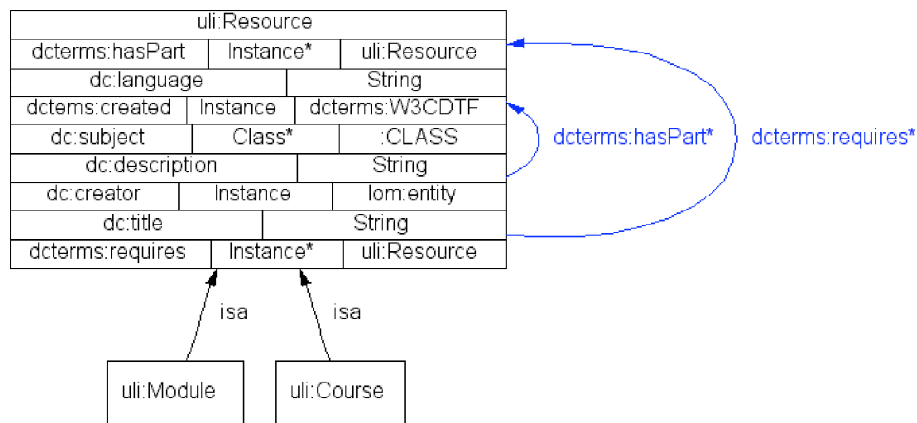


Figure 2: An excerpt of the ULI schema

In ELENA, we have developed a common ontology as a shared conceptualisation. The ontology was created reusing concepts from the IMS Learning Design specification (IMS, 2003) with some specifics required for ELENA. Figure 3 depicts a basic set of concepts used within *LearningService*. The *LearningService* class is a subclass of the *LearningResource* class. There are other subclasses of the Learning Resource which are not depicted in the figure. The *LearningService* can have a *LearningObjective*, and can create a *Certification* if the *LearningObjective* is successfully achieved by the learner.

LearningMaterial is a subclass of *LearningResource*. *Tutorial*, *LectureNote* and *Example* are possible subclasses of *LearningMaterial*. This ontology is described with the TRIPLE model @elenaont and uliont references the ULI schema (<http://triple.semanticweb.org/> provides an introduction into TRIPLE).

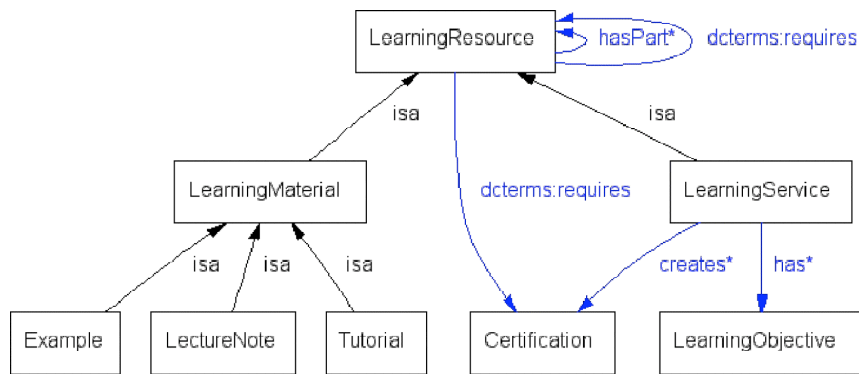


Figure 3: An excerpt of a general learning service ontology

Mapping will help us to achieve a subpart relation between the schemas mentioned. To achieve the interoperability or the possibility of querying ULI schema using ELENA Learning Service ontology), some concepts from the ULI schema have to be aligned by mappings. Our assumption in this context is that *Course* and *Module* can serve as learning services. The simple mapping rule in TRIPLE reflecting that assumption is:

```
FORALL R R[ rdf:type->elenaont:LearningService ] <- R[ rdf:type->
uliont:Course ] OR R[ rdf:type-> uliont:Module ].
```

Using these rules we can create a parameterized model in TRIPLE which allows users to query the ULI resources only in terms of the ELENA ontology. The following rules map *Course* in ULI to *Course* in ELENA and *Modules* in ULI to *Lectures* in ELENA.

```
FORALL R R[ rdf:type-> elenaont:Tutorial ]
<- R[ rdf:type->uliont:Course ].
```

The mapping rules are summarized graphically in Figure 4 at the schemas level.

There are other rules we use to map ULI schema to the ELENA ontology, eg to derive environments used in ULI, to classify resources in ULI, to derive *Prerequisites* and *Learning objectives* in ULI, and so on. You can find more complete example on using TRIPLE views for mappings between ontologies in Miklós, Neumann, Zdun, & Sintek, 2003.

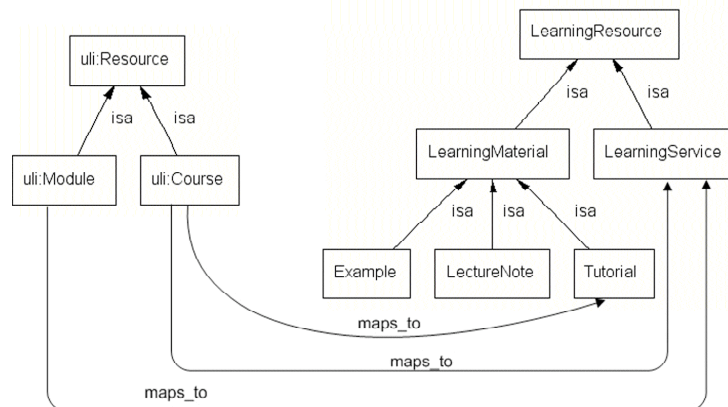


Figure 4: A graphical illustration of mappings at the schema level

Using these rules we can create a parameterized model in TRIPLE which allows users to query the ULI resources only in terms of the ELENA ontology. The following query is an example for such a query, and returns all *Courses* –where the course is meant in the context of the ELENA ontology – while the answer was originally described with the ULI ontology:

```
FORALL R <- R[rdftype->elenaont:Course]@view(uliont,
uliont:resources, elenaont, mappings).
```

After applying the rules on ULI we can reuse the personalisation services, eg recommendation, query rewriting or other services provided in the ELENA network which use the ELENA ontology as a communication language to deal also with ULI *Resources* and *Courses* provide in the ELENA network.

5. Personalisation

Personalisation in a Smart Space for Learning can be based on metadata about learners and metadata about learning resources. By matching a learner profile with the descriptions of the resources available, a personalised view on a Learning Management Network can be provided. The matching process is performed by using inference rules, which determine whether a service or resource is recommended or filtered. Inferring can also be used to identify related resources or to create a suitable learning path (Dolog, Gavrioloaie, Nejd, & Brase, 2003).

5.1 Representing Learner Profiles

In recent years there have been some efforts to standardise learner profiles. The two most important initiatives in this context are the IEEE Personal and Private Information (PAPI) (IEEE, 2000) and IMS Learner Information Package (LIP) (IMS, 2001). Concepts introduced by these initiatives can be used to personalise a learner's view in a learning management network.

IEEE PAPI, for example, provides a comprehensive and well developed structure for managing a learner's **learning performance**. Besides other information, one can store competencies gained in that structure. The competency or concepts learned were usually acquired during the consumption of a learning service or a resource. This information can be stored in such a structure as well. In addition, the competency level of a particular topic can be maintained using that structure. An example of the performance category using a TRIPLE representation of RDF is shown below.

```
student:student1[rdf:type -> elena:Learner].
student:student1[papi:has -> student:performance_1].
student:performance_1[rdf:type->papi:Performance].
student:performance_1[papi:performance_value -> '0.6'].
student:performance_1[papi:performance_metric -> '0-1'].
student:performance_1[papi:performance_coding -> 'number'].
student:performance_1[papi:granularity -> topic].
student:performance_1[papi:learning_experience_identifier ->
raw3:'Praedikatenlogik3.pdf'].
student:performance_1[papi:learning_competency ->
acm_ccs:'I.2.4.2.1'].
student:performance_1[papi:issued_from_identifier ->
raw3:'Test_Praedikatenlogik3.pdf'].
```

The example depicts a performance record of a learner “student1”. He knows about *Skolem Functions* at the level of 0.6. This level of knowledge has been derived from an appropriate annotation for the (already read) *Praedikatenlogik3.pdf* resource and evaluated by the test *Test_Praedikatenlogik3.pdf*. For the topic we use the competence field from the PAPI profile. To indicate the level of knowledge, we use *granularity* (ie we measure the level of knowledge for each topic), *performance coding* (in numbers), *performance metric* (from 0 to 1) and *performance value* (0.6). We also use *bucket* to specify the time, which was required for performing the test.

Preferences of a learner can, for example, be split into those for language, communication devices, location and concepts. The IMS LIP accessibility category has four main parts: language, preference, eligibility, and disability. The attributes of all four parts can be unified by using a type ontology. Then, the language preferences can for example have a language type or the communication devices can have a device preference type and so on. The preferences of learners can be used to recommend learning services and resources constrained with a certain type and value of the preference (language, device type used for delivery, etc) or to restrict a query with the values from preference records.

A learner's **role and aspirations within a company** is also very important information that can be used to help recommend and customise learning services. The information can be combined with the learner's career goals and his business objectives. The basic scenario in the corporate environment can be to extend competencies of learners at certain positions to satisfy needs to expand in a particular area. This might include acquiring knowledge about new selling strategies, new competencies in new technologies, etc.

5.2 Representing Learning Resources

Personalised access means that resources are recommended based on some relevant aspects of the user. Which aspects of the user are important or not depends on the personalization domain. For educational scenarios it is important to take into account aspects such as the level of expertise of the learner in a specific field, whether she wants to obtain a certain qualification, has specific language preferences, etc. Learner Preferences can be easily exploited, especially when they coincide directly with the metadata and metadata values used for describing a learning service or resource. Some specific examples are provided below.

One can, for example, employ an approach where the subject value of the learning service description is a URI pointing to a subject, topic or competence ontology. This allows for the identification of the subject that this learning resource deals with. The classification scheme can be encoded by using *classification* category and *taxon* feature of RDF bindings of the LOM RDF Binding Guide (Draft Version) (Nilsson, 2001). Examples of subject ontologies are the ACM computing classification system (ACM, 1998) or eclass (ECLASS, 2003). The latter provides a service classification for the education and training industry under the subclass 25-25.

IEEE LOM (IEEE, 2002] allows us to describe also learning service prerequisites in terms of either topic; other learning resources; competencies; or certificates. The RDF bindings of LOM uses *requires* concept for these purposes.

The prerequisites can be seen as constraints which determine what competencies a certificate learner should have to be eligible to participate in a service which has the prerequisites in its metadata. This is another example of using information for constraining resources in the ELENA network.

LOM provides the classification category with the *purpose* element. The *purpose* element has several sub-elements: *prerequisite*, *educational*, *objective*, *accessibility restrictions*, *educational level*, *skill level*, *security level*, or *competency*. The *accessibility restriction* sub-element can be used to define constraints for accessing the learning object or service (see below). All required learner profiles to partake of such a learning service can be encoded into the accessibility restrictions.

```
Resource1[lom-cls:accessibilityRestrictions ->
student:performance_1].
student:performance_1[rdf:type->papi:Performance].
student:performance_1[papi:performance_value ->
greater_than('0.5')].
student:performance_1[papi:performance_metric -> '0-1'].
student:performance_1[papi:performance_coding -> 'number'].
student:performance_1[papi:granularity -> topic].
student:performance_1[papi:learning_experience_identifier ->
unihann:'Praedikatenlogik3.pdf'].
student:performance_1[papi:learning_competency ->
acm_ccs:'I.2.4.2.1'].
```

Directly using the user model fields (PAPI) allows us to directly search for resources, which conform to the user profile. For example, the resource with the restricted access specified in the previous example is intended for a user whose level of knowledge about the *skolem functions* topic from ACM CCS is greater than 0.5.

5.3 Query Transformation based on Learner Profiles

At an educational node, a query for learning services submitted via a user interface is first translated into a formal query language, for example SQL. This formal query can then be rewritten using information stored in a learner profile using, for

example, TRIPLE. Such a rewritten query contains additional restrictions on resources and services matching the query. The following example demonstrates how such transformations can be implemented. Consider for example a query in the Query Exchange Language (QEL) (Nilsson & Siberski, 2003) and represented in TRIPLE as depicted below.

The query looks for resources which describe a competence on “Intelligence Agents”. This is represented by the identifier “I.2.11.1” in “dc:subject”. The identifier points to the entry in ontology available at the URI abbreviated by “acmcSS”. The identifiers for ontology entries are prescribed by the ACM Computer Classification System (ACM, 1998)

```
// original QEL query in TRIPLE
@edu:q1 {
  edu:X[rdf:type -> edu:Variable;
        rdfs:label -> "X"].
  edu:st0[rdf:type -> edu:RDFReifiedStatement;
          rdf:subject -> edu:X;
          rdf:predicate -> dc:subject;
          rdf:object -> acmcSS:'I.2.11.1'].
  edu:genQuery[rdf:type -> edu:QEL3Query;
               edu:hasQueryLiteral -> edu:st0;
               edu:hasResultType -> edu:TupleResult].
}
```

The rules which can add restrictions to the QEL query are depicted below. The rules are created according to learner’s preference. The first rule in the personal preferences indicates that the learner is interested in query results in German. With the second type of rules a learner can express related interests, if he issues a query to find learning services in a specific area, additional query conditions will be added. In this case, when the original user query contains a restriction on “Intelligent Agents”, the rules will generate additional restrictions on “dc:subject” to the query with identifiers “I.2.11” and “I.2” respectively. Other preferences of this type can easily be added to the personal learning profile.

```

// user profile
@edu:p1 {
  // we want only German resources, so add "dc:lang ->
  lang:de"
  edu:add1[rdf:type -> edu:AddSimpleRestriction;
    rdf:predicate -> dc:lang;
    rdf:object -> lang:de].
  // add topic restriction:
  // "if topic is restricted to I.2.11.1, add additional
  // topic restrictions I.3.12.2 and I.4.13.3"
  edu:add2[rdf:type -> edu:AddTopicRestriction;
    edu:topic -> acmcss:'I.2.11.1';
    edu:topic -> acmcss:'I.2.11';
    edu:addTopic -> acmcss:'I.2'].

```

Based on this user profile the following modified query is derived:

```

ns001:genQuery[rdf:type -> edu:QEL3Query;
  edu:hasResultType -> edu:TupleResult;
  edu:hasQueryLiteral -> ns001:st0;
  edu:hasQueryLiteral -> edu:genid0;
  edu:hasQueryLiteral -> edu:genid1;
  edu:hasQueryLiteral -> edu:genid2].
edu:genid0[rdf:type -> edu:RDFReifiedStatement;
  rdf:subject -> ns001:X;
  rdf:predicate -> dc:language;
  rdf:object -> ulang:de].
edu:genid2[rdf:type -> edu:RDFReifiedStatement;
  rdf:subject -> ns001:X;
  rdf:predicate -> dc:subject;
  rdf:object -> acmcss:'I.2.11'].
ns001:X[rdf:type -> edu:Variable;
  rdfs:label -> "X"].
ns001:st0[rdf:type -> edu:RDFReifiedStatement;
  rdf:object -> acmcss:'I.2.11.1';
  rdf:predicate -> dc:subject;
  rdf:subject -> ns001:X].
edu:genid1[rdf:type -> edu:RDFReifiedStatement;
  rdf:subject -> ns001:X;

```

```

rdf:predicate -> dc:subject;
rdf:object -> acmcss:'I.2'].

```

The rewritten query depicted above will now look for resources and services which are annotated also with the more general ACM categories “Distributed artificial intelligence” and “Artificial intelligence”. The additional concepts are referenced using the ACM Computer Classification System identifiers “I.2.11” and “I.2” for the categories mentioned above. The query will also specifically look for results in German.

5.4 Personalization on Query Results

Recommendation and filtering based on the level of competence acquired is one example of personalisation which can be performed on the query results. The competence level is maintained in the performance category of the learner profile. With this as a starting point several different rules can be used to derive recommendations. We can, for example, assume that a resource is recommended when for all prerequisites of all covered concepts have at least one performance record can be found in the learner profile.

The rule can be realised in TRIPLE as follows:

```

FORALL U, S recommended (U, S) <-
  learner(U) AND service(S) AND
  FORALL S1 (prereq(S, S1) ->
    (FORALL C (concept(S1, C) -> (EXISTS P
      (U[papi:has->P]@uli:learner AND
        performance(P) AND
        P[papi:learning_competency ->
          C]@uli:learner)))))).

```

Other rules are needed to define for example what is a service (service(S)) or who is a learner (learner(U)) and so on. In well defined metadata we can assume that resources are classified using types (e.g. LearningService) from ontologies. These types can then be used to check for appropriate resources within predicates like service(S) or learner(U). If these types classification are not available heuristics can be used (e.g. service is everything which is described by attributes from a certain schema). The rules can conclude not only with information that a service or resource is recommended.

6. Prototyping Smart Spaces for Learning

6.1 The ELENA Smart Space for Learning

Within the ELENA project a prototypical Smart Space for Learning has been realized by September 2003. The prototype builds upon EDUTELLA (Nejdl et al., 2002), a schema-based P2P networking infrastructure using RDF and the JXTA Framework (Sun, 2003). EDUTELLA provides a search service where a node is able to submit a query to the network specifying supported metadata schemas. This query is expressed in the QEL language (Nilsson & Siberski, 2003), a query language based on Datalog, and forwarded to the nodes with related content in the network. The results of the query are sent back to the requester in the form of RDF statements. Since the educational nodes do not use the same kind of metadata schema our network provides several integration possibilities to them in order to facilitate the task. EDUTELLA adopts an approach based on wrappers. A wrapper can be defined as a mediation application. In our context, a wrapper is in charge of translating between the mediating language used by EDUTELLA (QEL) and a specific repository language (eg SQL). Currently different wrappers are adapted to different kinds of repositories like relational databases, RDF repositories, concept databases or file based sources.

EDUTELLA is used for connecting educational nodes such as ULI and Educanext. Clix, Arel, and ITeachYou connect to the Learning Management Network via the Educanext portal. Figure 5 depicts the current implementation of the ELENA network and the different educational nodes already integrated into it::

- **Educanext:** Educanext is a web-based platform which supports the creation and sharing of knowledge (<http://www.educanext.org/>). The portal is based on the Universal Brokerage Platform (UBP), which enables collaboration among educators by providing a full range of services to support the exchange of Learning Resources (Law, Maillet, Quemada, & Simon, 2003).
- **ULI:** The ULI (Universitärer Lehrverbund Informatik) project, a University teaching network, tries to establish an exchange of course material, courses and certificates in the area of computer science (see also Section 4). Eleven German universities with eighteen different professors have agreed to exchange their courses and to allow students from one university to attend courses at another university, using advanced e-learning technologies (ULI, 2001). Figure 5 shows file based providers for three concrete courses. Other

courses are omitted for space limitation and are represented by file based provider marked with "...". However, each of the courses is provided via its own file-based provider in the network.

- **IMC CLIX:** CLIX is a standard Learning Management System (LMS) developed by the German software vendor IMC. Like any other LMS, CLIX supports the administration of learning services. CLIX stands for Corporate Learning and Information Exchange.
- **ITeachYou:** ITeachYou is an independent multimedia learning environment, which is designed for use in the internet or intranets. It can be considered as a presentation template for the library of highly structured content in field of information technology.
- **Arel:** Arel offers a unique training solution for corporations, distance learning institutions and large organizations. The Arel system enables experts to deliver live and on-demand interactive broadcast sessions from a centre to a large number of participants in virtual class sites and so called “spotlight desktops”.

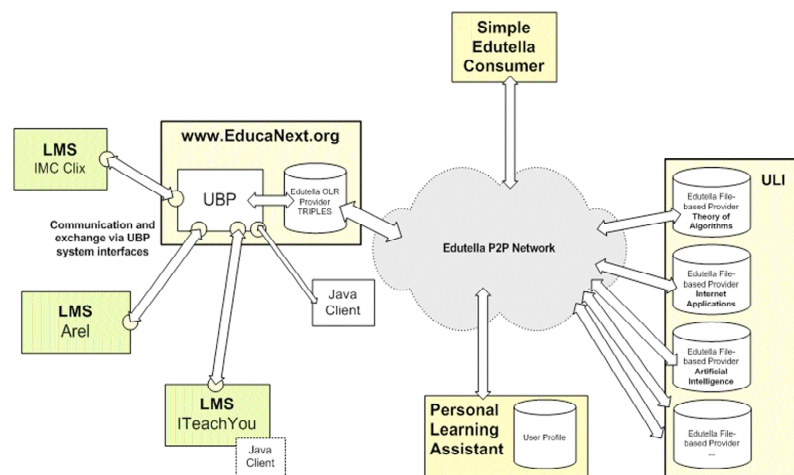


Figure 5: The ELENA Smart Space for Learning

The ELENA PLA provides a personalised search service, which implements the rule-based personalization approach for query transformation as described in Section 5. Figure 6 depicts the PLA’s user interface for formulating a query for a particular

concept or competence a user would like to acquire. Users can type the concept or concepts into three provided fields or can select the concepts from an ontology provided. The PLA integrates recommendation, query transformation, ontology mappings and other functionalities provided as web services. The details about the integration/orchestration of services by PLA can be found in Dolog, Henze, Nejd, & Sintek, 2004.

The Personal Learning Assistant then creates an EDUTELLA QEL query. The query is extended with restrictions by query rewriting using preferences of the learner profile. Then the query is submitted to the EDUTELLA network. After receiving results, the Personal Learning Assistant takes advantage of a recommendation service to filter the results. For example, a learning resource or service is only recommended if all its prerequisite concepts are understood. It is not recommended when no prerequisite concepts are understood. If some prerequisite concepts are understood, a document is partially recommended.

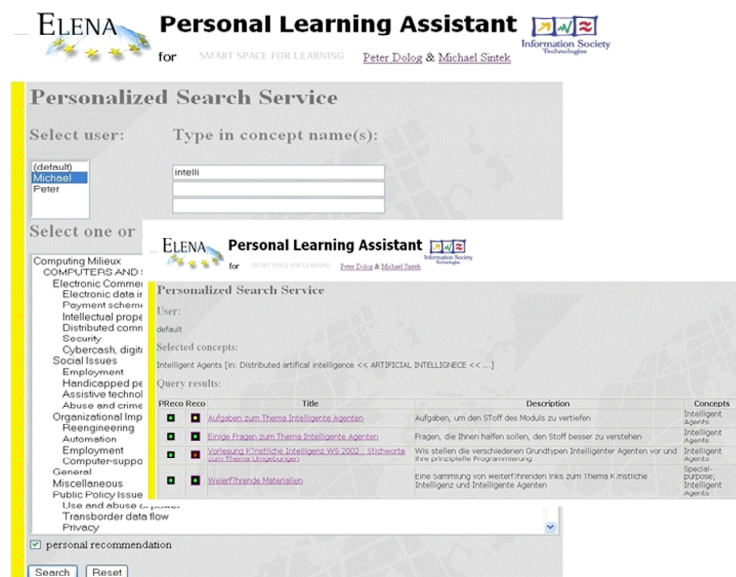


Figure 6: Personalised search interface of ELENA PLA with search results

Figure 6 depicts a user interface for personalised search results. As you can see, we use a traffic light metaphor to annotate resources with recommendation information.

A green light marks the recommended resources, a red light is shown next to not recommended resources and a yellow light stands for a partial recommendation. The personal recommendation is depicted in the first column (PReco). There is a second column (Reco), which provides learners with a group-based recommendation. The group-based recommendation is calculated according to recommendations of learners from the same group.

6.2 Evaluation and Outlook

The implementation of our research prototype has helped us to identify a number of open research questions when it comes to the realization of the Educational Semantic Web in general, and the implementation of Smart Spaces for Learning in particular. Below the identified issues are presented according to the structure of Section 3:

- **Interoperability of Educational Nodes:** In order to achieve service interoperability we have used a semi-automated provision interface as well as query interface directly connecting to a predefined database table in our prototype. The experience gained so far suggests that an interface fulfilling the following requirements is needed:
 - o The interface needs to abstract from authentication and access control mechanisms. Learning Management Networks can be based on different authentication mechanisms. Once authentication is established the similar query methods shall be used.
 - o The interface needs to abstract from concrete database implementations. Queries for learning resources shall be defined via query languages.
 - o The query interface needs to provide means for communicating target schemas, so that an educational node can map the query results accordingly.

With the Simple Query Interface (Simon, Duval, & Van Asche, 2004) an international group of researchers on educational technology aims to contribute a specification that meets these requirements.

- **Artefacts Interoperability:** We have observed that authors of educational artefact descriptions rather do metatagging only from a local perspective. While some aspects are general enough to be considered for any context, some aspects like competencies covered, prerequisites and others are heavily context dependent. To abstract from the context often requires an additional

(co-ordination) effort many metadata authors are not willing to go through. Metadata authors are in general reluctant to input data for a complex metadata structure because it requires a significant effort. This is especially an issue when it comes to “small” educational artefacts with low value. It means that in open systems you can find metadata without prerequisites or all subjects covered and so on. This makes the re-use of this metadata difficult because no assumptions can be made on the usage of specific concepts. This category of problems can be labelled as an “incomplete metadata problem” or a “quality of metadata problem”. Investigators researching these types of problems should focus on the heuristics of how to find information which is not exposed by metadata. Developers should work on developing metadata authoring tools, which are capable of deriving metadata directly from the content. The quality of the metadata has profound implications on the precision of search and personalisation capabilities.

- **Personalisation:** We described some steps towards such as “rule-based” personalisation methods based on semantic web description formats, subject ontologies and the logical layer of the semantic web tower represented by TRIPLE reasoning, querying, and transformation language for the semantic web. This area however still requires further study and research.

Another problem connected with personalisation is the state of the art of learner profile standards and learner models for open systems. We have mentioned some features of a learner profile that we use for personalisation. However, a commonly agreed representation of learner profiles is still missing.

Last but not least, advanced personalisation methods have not gained high acceptance in current industry practice. There are personalisation approaches implemented in Google or Amazon. These approaches, however, should be improved and adapted for learning services.

- **Support of Human Resources Development Processes:** While a lot of investigations are carried out on issues such as how to deliver courses effectively on-line, little research on how learning management and training control can be supported using information technology does exist. At the same time, new business standards such as ISO9000 (2000) or Basel II stress the importance of a well-managed corporate learning space. As a result

learning processes in companies have to become more effective. The ELENA project is recently released a study focusing on the requirements on the IT support of corporate HR development process (see (Gunnarsdóttir, 2004 #616}). However, additional investigations need to be carried out in order to design systems that are able to learn from successful cases and apply critical success factors (semi-)automatically in future scenarios

7. Conclusion

From prototyping Smart Spaces for Learning we have identified the following challenges for the evolution of the Educational Semantic Web.

First, Interoperability is a major issue that needs to be resolved. In order to make learning resources and educational nodes interoperable a comprehensive educational ontology covering all important aspects of learning management and learning delivery would be beneficial. Our little experiments have already shown that existing standards in that field such as IEEE LOM or IMS Learning Design are not expressive enough to serve the needs of designers of the Educational Semantic Web. At the same time tool support is required in order to map local learning resource description with the centralized-maintained. The tools need to become an instructional environment by themselves in order to teach annotators the concepts introduced by the ontology. Mapping tools and services are also of paramount importance, since we envision that multiple ontologies will exist in the Educational Semantic Web. Second, a “plug and play” interface for querying, harvesting, contracting and delivering learning resources needs to be established in the field and a significant penetration of this specification is crucial. This interface shall abstract from authentication and access control issues, whereas it also needs to be independent from query languages and ontologies.

Third, the real user value of the all the metatagging and interfacing needs to be demonstrated by applications such as Smart Space for Learning, which aim at improve the effectiveness of HR development processes. The semantic relationships of educational artefacts with learner’s needs, preferences, abilities, cultural backgrounds and development goals need to be established and methods for identifying them have to be studied to be able to increase learner’s satisfaction with semantic educational services. Educational Semantic Web show cases, which prove that going beyond the (semantic) boundaries of monolithic applications helps to significantly improve the capabilities of learner’s tools, are considered crucial for the further evolution of the field.

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References

- Aberer, K., Cudré-Mauroux, P., & Hauswirth, M. (2003). The Chatty Web: Emergent Semantics through Gossiping. In *Proceedings of the 13th World Wide Web Conference*. Budapest, Hungary: ACM.
- ACM. (1998). *The ACM Computer Classification System*: <http://www.acm.org/class/1998/>.
- Dawson, F., & Howes, T. (1998). *vCard MIME Directory Profile*. The Internet Society: <http://www.ietf.org/rfc/rfc2426.txt>.
- Dolog, P., Gavriiloaie, R., Nejdl, W., & Brase, J. (2003). Integrating Adaptive Hypermedia Techniques and Open RDF-based Environments. In *Proceedings of Twelfth International World Wide Web Conference*. Budapest, Hungary: ACM.
- Dolog, P., Henze, N., Nejdl, W., & Sintek, M. (2004). Personalization in Distributed e-Learning Environments. In *Proceedings of 13th World Wide Web Conference*. New York, USA.
- Dolog, P., & Nejdl, W. (2003a). Challenges and Benefits of the Semantic Web for User Modelling. In P. D. Bra (Ed.), *Proceedings of the AH2003 workshop*. Budapest, Hungary.
- Dolog, P., & Nejdl, W. (2003b). Personalisation in Elena: How to cope with personalisation in distributed eLearning Networks. In *Proceedings of the Conference on Worldwide Coherent Workforce, Satisfied Users - New Services for Scientific Information*. Oldenburg, Germany.

ECLASS. (2003). eClass - Standardized Material and Service Classification, Version 5.0: Institut der deutschen Wirtschaft Köln, <http://www.eclass-online.com/>.

Gruber, T. R. (1993). Towards Principles for the Design of Ontologies Used for Knowledge Sharing. In N. Guarino & R. Poli (Ed.), *Formal Ontology in Conceptual Analysis and Knowledge Representation*. Deventer, The Netherlands: Kluwer Academic Publishers.

Gunnarsdóttir, S., Heimerl, U., Kieslinger, B., Simon, B., & Tsiortou, S. (2004). *Current Issues of Training Management in European Enterprises: ELENA Whitepaper*, available at <http://nm.wu-wien.ac.at/hr-dev/issues-in-training-management-v4.pdf>.

IEEE. (2000). *IEEE P1484.2/D7, 2000-11-28. Draft Standard for Learning Technology. Public and Private Information (PAPI) for Learners*.

IEEE. (2002). *1484.12.1 - 2002 Learning Object Metadata (LOM) Standard*.

IMS. (2001). Learner Information Package (LIP) Specification v. 1.0. 2001.

IMS. (2003). *IMS Learning Design Specification*: <http://www.imsglobal.org/learningdesign/index.cfm>.

Law, E., Maillet, K., Quemada, J., & Simon, B. (2003). EducaNext: A Service for Knowledge Sharing. In *Proceedings of the 3rd Annual Ariadne Conference*. Leuven: ARIADNE Foundation.

Miklós, Z., Neumann, G., Zdun, U., & Sintek, M. (2003). Querying Semantic Web Resources Using TRIPLE Views. In *Proceedings of the 2nd International Semantic Web Conference (ISWC2003)*. Sundial Resort, USA.

Nejdl, W., Wolf, B., Qu, C., Decker, S., Sintek, M., Ambjörn, N., et al. (2002). EDUTELLA: A P2P Networking Infrastructure Based on RDF. In *Proceedings of the 11th International World Wide Web Conference*. Hawaii, USA.

Nilsson, M. (2001). *IMS Metadata RDF Binding Guide*: <http://kmr.nada.kth.se/el/ims/metadata.html>.

Nilsson, M., & Siberski, W. (2003). *RDF Query Exchange Language (QEL) - Concepts, Semantics and RDF Syntax*: <http://edutella.jxta.org/spec/qel.html>.

Quemada, J., & Simon, B. (2003). A Use-Case Based Model for Learning Resources in Educational Mediators. *Educational Technology & Society (ISSN 1436-4522)*, 6(4), 149-163.

Simon, B., Duval, E., & Van Asche, F. (2004). *Simple Query Interface (SQI) for Learning Repositories, Version 0.6.*
<http://nm.wu-wien.ac.at/e-learning/interoperability/sqi/sqi.pdf>.

Simon, B., Retalis, S., & Brantner, S. (2003). Building Interoperability among Learning Content Management Systems. In *Proceedings of the 12th World Wide Web Conference*. Budapest.

Sun. (2003). *Project JXTA*: <http://www.jxta.org/>.

ULI. (2001). *Universitärer Lehrverbund Informatik*:
<http://www.uli-campus.de/english/project.html>.