An Assessment Framework for eLearning in the Semantic Web

Lilia Cheniti-Belcadhi[1], **Nicola Henze**[2], **Rafik Braham**[1]
[1] PRINCE, University of Center
Sousse, Tunisia
lcheniti@yahoo.fr
[2] ISI-KBS, University of Hannover, Germany
henze@kbs.uni-hannover.de

Abstract

In this paper we present a flexible assessment framework for eLearning based on semantic web technologies. The assessment techniques are formalized as reasoning rules. These rules are able to reason over resources annotated with semantic web metadata formats and according to the standards LOM and IMS QTI. The framework is tested using TRIPLE, a rule-based language for the semantic web.

1 Motivation

With the rapid development of distance learning, assessment functionality becomes one of the key factors of online learning. Based on assessment, the learning with electronic materials can be enriched by a quality and timely feedback, by just-in-time problem solving aid, by guided and personalized learning, thus turning the learning process into a highly interactive learning experience with Web-based courses and learning materials. In this paper we present a flexible framework for assessment technology which is based on recent eLearning standards. The realization of the framework uses semantic web technologies such as description and reasoning about semantically enriched Internet resources.

Many of currently existing eLearning and assessment systems focus on simple assessment strategies, e.g. only on single or multiple-choice questions (MCQ) with several answers, and radio-buttons to select the correct answer. Furthermore most of these systems are unable to support different needs of individual users as they focus mainly on assessment of the "average user". The assessment framework which we present in this paper allows the flexible use of assessment techniques, and provides in addition an adaptive selection, embedding and presentation of learning materials according to the learners' performances.

The assessment framework combines research from two major research disciplines: *adaptive educational hypermedia* and *semantic web technologies*.

Research in *adaptive educational hypermedia* has ascertained several techniques for adaptation [Brusilovsky, 2001]. These techniques can be divided into two categories: navigational level adaptation in which the leaner is provided with a set of recommended links, and content level adaptation, which selects the text fragments that have to be assembled together for a specific user need. Through combining both techniques, the learner will be provided with a flexible learning process. We use technologies from adaptive educational hypermedia to provide adaptive, personalized access to learning materials in order to guide the learner in the learning process.

During the last few years, research in the area of *semantic web* brought new ideas in setting up a new form of Web content that is meaningful to computers [Berners-Lee *et al.*, 2001]. Several technologies have been developed for constructing and developing the semantic web. RDF/S [RDF, 2001] [RDFS, 2001] and its extension such as OWL [OWL, 2003] have been developed to define metadata schemas, domain ontologies and resource descriptions. Regarding the semantic web tower, we find on top of the RDF and ontology-layer, the layer of rules and logic framework [BernersLee, 2002]. Rules languages are defined to query and transform resources annotated in RDF, making possible the exchange of data. In our framework resources are exchanged based on reasoning rules specified in TRIPLE [Sintek and Decker, 2002], a rule language for querying and transforming RDF models.

In the eLearning domain there are emerging standards for describing learning resources, among them LOM (Learning Objects Metadata [LOM, 2002]) or Dublin Core [DC, 2001]. LOM is gradually becoming the reference standard for educational systems managing learning objects of many kinds. Assessment resources can also be specified through standards among them we find IMS QTI (Question and Test Interoperability)[QTI, 2004]. IMS QTI enables developing and sharing banks of questions and activities that could be shared for compiling a variety of assessment vehicles such as tests, exams, and worksheets. Therefore the assessment information in this standard format can be interoperable and reusable among different systems.

This paper is structured as follows. In section 2 we describe our assessment framework, and the metadata annotations according to the semantic web technologies and eLearning standards and give an overview over its formalization based on First Order Logic (FOL). In section 3 we describe how our approach is being tested. This section is divided into two parts. In the first part we give an overview over the used rule language TRIPLE. In the second part we describe how the annotated resources are queried based on TRIPLE. In section 4 we relate our approach to other work. Finally, we draw some conclusions and proposals for further work in section 5.

2 Assessment framework description

Based on semantic web technology and eLearning standards we propose a dynamic approach for learner assessment that enables an adaptive presentation of content according to the progress of the learner. Our assessment framework provides the learner with two kinds of content: learning content, containing the courses and their different sections, and assessment content, containing the tests for evaluation of the learner knowledge. During the learning process, a dynamic selection and presentation of both contents will be accomplished.

In the following subsections we will first present the metadata annotations required in our assessment framework based on eLearning standards. We will then describe the process of learner assessment. Finally we propose a formalism of this process based on First Order Logic (FOL).

2.1 Metadata in the assessment framework

Semantic Web Technologies like RDF (Resource Description Framework) and RDFS (Resource Description Framework Schema) provide us with interesting possibilities to annotate resources through combining structure and semantic of resources. In our assessment framework, we propose to combine Semantic web technologies and learning standards so that we can enhance interoperability of resources. In the following we will present the metadata used to describe both kinds of content and discuss briefly the learner specific data.

Describing Learning Resources

For structuring and describing learning resources we used the Dublin Core standard and the Learning Object Metadata standard (LOM). The first LOM version was approved in June 2002. LOM contains an abstract data model of descriptors, or elements divided into nine categories, and used to describe learning objects (**LO**). The LOM elements can be managed in many different formats, including SQL tables, HTML meta tags, and so on. A technical realization of the abstract model in a specific format is called a ”binding”. A binding in RDF was proposed in [Nilsson *et al.*, 2003]

As an example, we present part of an RDF based metadata annotation for a learning resource in a freely available online version of a java Programming course [Campione and Walrath, 2000]:

```
1 <rdf:Description
    rdf:about="http://java.sun.com/docs/
               .../javaOO/index.html">
2 <lom-gen:aggregationLevel
     rdf:resource=
        "lom-gen;AggregationLevel2"/>
3 <rdf:type
   rdf:resource="http://ltsc.ieee
           .../lom-educational#Lecture"/>
4 <dc:title>Classes & Inheritance</dc:title>
5 <dcterms:isPartOf
    rdf:resource="http://java.sun...
                /tutorial/index.html"/>
6 <dcterms:hasPart>
7    <rdf:Seq>
8       <rdf:li
         rdf:resource="http://java.sun...
             /javaOO/classes.html"/>
10   </rdf:Seq>
11 </dcterms:hasPart>
12 <lom-cls:prerequisite
      rdf:resource="http://java.sun...
                 /data/objectcreation.html"/>
13 <lom-cls:prerequisite
       rdf:resource="http://java.sun
             .../data/usingobject.html"/>
14 <lom-cls:educationalObjective
     rdf:resource="http://hoersaal.kbs.uni-
            hannover.de/rdf/
            java_ontology.rdf#nested_class"/>
15 <lom-cls:educationalobjective
     rdf:resource="http://hoersaal.kbs.uni-
            hannover.de/rdf/
            java_ontology.rdf#inner_class"/>
16 </rdf:description>
```

Learning resources are structured according to their functional granularity (AggregationLevel), as e.g. in line 2. This element from the category General in LOM data model is scaled from 1 to 4. Regarding our assessment framework, we have used only three levels of granularity. The smallest level (Aggregation level=1) corresponds e.g. to raw media data or fragments, the second level (2) corresponds to a lesson, and the last level (3) represents a course. Based on this attribute and according to the element structure from the category General in LOM data model, we can differentiate between the learning objects. We have restricted our use to two kinds of structure: atomic learning object (**atomic-LO**) and linear learning object (**linear-LO**), respectively designing an indivisible object(Aggregation level=1) and a set of ordered objects (Aggregation level=2 or 3). These two kinds can good reflect the structure of academic courses. The relationship between the course sections (atomic-LOs) according to a predefined order is good established in a linear-LO. Course parts can be exchanged thanks to the granularity of the atomic-LOs. Furthermore LOs may have a one of the following types: Diagram, Graph, Table, Lecture (e.g. line 3)

The course hierarchy is described through the properties hasPart and isPartOf from Dublin Core as in line 5 and 6. Prerequisites of a linear-LO are specified through the property lom-cls:prerequisite (line 12, 13), from the category classification, defining the resources that have to be learned prior to the current resource. Objectives of a linear-LO are introduced with the property lom-cls:educationalobjective, also from the category classification, e.g. as in line 14, through setting up the relationship to a predefined concept in the java programming ontology [Dolog *et al.*, 2003].

Describing Assessment Resources

Assessment resources contain tests, that have to be presented to the learner in order to evaluate his/her level of knowledge. The assessment framework provides a dynamic generation of tests. Questions will be selected based on the progress of the learner. This flexible approach is supported by the IMS QTI standard.

This standard is composed of two data models: IMS QTI Assessment-Section-Item (ASI) model [QTI/ASI, 2004] and IMS QTI Results Reporting (RR) model[QTI/RR, 2004]. The ASI component is used to describe the actual evaluation resources to be presented to the learners; The RR component is used to contain the results to be reported once an evaluation is undertaken by a learner. Due to space limitations we will focus in this paper only on the IMS ASI datamodel. Based on this model, tests are specified as **assessment**. Every assessment can be composed of one or many **sections** and each section consists of several **items**. An Item is the smallest object needed for the assessment which represents generally a question, defined as a combination of interrogatory, rendering, and feedback information. Furthermore one of the tasks that have to be fulfilled by any assessment system is to record the performances achieved by the learner, so that learning content will be presented according to his/her current state of knowledge. The

IMS QTI RR datamodel enables us to store the students answers. The current IMS QTI specification provides a binding in XML. A binding of the main elements in RDF is defined in [Dolog, 2004]. We have used this binding and extended it to our needs.

As an example we describe part of an RDF based metadata annotation for an assessment resource (item) on the java Programming course:

```
1 <rdf:Description
   rdf:about="http://java.sun.../item1.html">
2 <rdf:type
   rdf:resource="http://wwwlearninglab.de
   /~dolog/learnerrdfbindings/qti.rdfs#Item"/>
3 <qti:title>MCOOP1</qti:title>
4 <qti:itemmetadata>
5 <rdf:Description>
6    <qti:qmd_itemtype
       rdf:value="MultipleChoice" />
7   </rdf:Description>
      ..........
8 </qti:itemmetadata>
9 <dcterms:isPartOf  rdf:resource=
  "http://java.../section1.html"/>
10 <qti:Objective
    rdf:resource="http://hoersaal.kbs.uni-
    hannover.de/rdf/
    java_ontology.rdf#OO_Methods"/>
11 </rdf:Description>
```

The most important information commonly used in our assessment framework are type, itemtype, structure and objective. Each assessment resource possess a type according to the ASI model, as stated e.g. in line 2. In case the assessment resource is an item, the type of the question is specified with the property qti:qmd_itemtype. Items may have one of the following three types: Multiple Choice, Fill-In-Blanks and Problemsolving. The two first types are already specified in QTI standard. We have defined the question type Problemsolving, according to the Bloom taxonomy for assessment [Bloom and Krathwohl, 1956] to represent questions, where the student will be asked to write programming instructions, as our assessment framework will be applied to Programming courses.

The section to which belongs the item is described through the property dcterms:isPartOf (line 9) from Dublin Core standard. Similarly to the learning resources each item has an objective, specified through the property qti:Objective, e.g. as in line 10, in reference to one of a predefined concept in the java programming ontology.

Describing Learners

The assessment framework has to keep track on the progress of the student. Therefore it is interesting to describe learners data and profile through standards in order to customize a learning' experience. In recent years there have been some efforts to standardize the information about a user, which should be maintained by a system. The standard IEEE PAPI (Public and Private Information for Learners [PAPI, 2002]) is one example of a standard for maintaining data on users, which are ordered according to the following categories: personal, relations, security, preference, performance, and portfolio information. The personal category contains information about names, contacts and addresses of a user. Relations category serves as a category for specifying relationships between users (e.g. classmate, teachers, ..). Security specifies mainly the access rights. Preference indicates the types of devices and objects, which the user is able to recognize. Performance is for storing information about measured performance of a user through learning material (i.e. what does a user know). Portfolio is for accessing previous experience of a user. Based on these elements we can store data on the learning experience of the user. The category performance is used to score the learners Responses based in the results reported by the IMS RR datamodel.

2.2 Assessment based learning process

The aim of the Assessment Framework is to conduct adaptive assessment and adaptive learning content presentation. The framework provides the learner with an appropriate learning content based on an accurate evaluation of his/her level of knowledge. In the following, we will describe the learning and the assessment process offered by the framework:

After login and identification, the learner can select a lesson (linear-LO). The system checks then the data regarding the profile of the learner, according to the standard PAPI, such as the already learned resources, the previous performances and historical progress of the learner. Based on this information the system can detect the set of learning resources (atomic-LO) that are needed to be known prior to the selected learning resource. The framework selects then for each atomic-LO a question (item) and forms to the learner a Pre-test (assessment) containing questions (items) on all the prerequisites course parts. Once the learner answers the questions in the test, his/her answers are checked. The results of the assessment are reported based on the IMS RR standard. Two situations are possible: the first one is that all the learner answers are correct. Therefore he/she will be allowed to read the selected lesson. Otherwise, the system forms a lesson (linear-LO) containing the atomic-LOs that are not known. In both cases the students performances saved by the framework are updated according to the reported results; a test (assessment) will be then generated to the learner. Regarding the first situation, it will be a post test, containing questions on the predefined objectives of the selected linear-LO. For the second situation it will be another pretest containing questions only on the atomic-LOs that are not learned.

2.3 Logic based characterization of the Assessment Framework

A logic based definition of the adaptive educational hypermedia system has been proposed in [Henze and Nejdl, 2003]. According to this definition an AEHS has four components a document space containing information about the documents exchanged in the system as well as their relations, a user model for storing information on the different users, an observation component to analyze interactions of the user with the resources offered in the system and finally an adaptation component to define the adaptive processing provided to a particular user. This logic based definition is used to define the assessment framework based on the selected standards. The adaptive functionality of the assessment framework is generated based on the characteristics of the learner and his/her recoded performances.

We have defined four annotations for a given linear-LO, regarding the kind of assessment that is recommended for it: *PreAssessmentRecommended*, *PostAssessmentRecommended*, *PreAssessmentNotRecommended*, *PostAssessmentNotRecommended*. Regarding the assessment objects (items) we have defined the following two status : *PreTest and PostTest*. Various rules could be established in order to set up the linear-LO annotation. As an example we present the following rule:

A linear-LO is recommended for PreAssessment if at least one of its prerequisite atomic LOs has not been learned by the user.

$\forall$L $\forall$U
$\exists$A Prerequisite_Atomic(A,L) $\wedge$
$\neg$ p_obs(A,U,Learned) $\Longrightarrow$
Linear_annotation(L,U,PreAssessmentRecommended).

Candidate items, which represent possible questions that can be assigned to a linear-LO once its assessment status (e.g. PreAssessment) is detected, are derived via the following rule:

$\forall$A $\forall$L $\forall$U
Prerequisite_Atomic(A,L) $\wedge$
$\neg$ p_obs(A,U,Learned) $\wedge$
$\exists$I Question_of_Atomic(I,A) $\wedge$
$\neg$ obs(I,U,Solved)
$\Longrightarrow$ Candidate_Item(L,I,U,PreTest).

A linear-LO is not recommended for post assessment if all its objective atomic-LOs have been learned by the user.

$\forall$L $\forall$U
$\forall$A (Objective_Atomic(A,L) $\Longrightarrow$
p_obs(A,U,Learned)) $\Longrightarrow$
Linear_annotation(L,U, PostAssessmentNotRecommended).

3 Assessment framework implementation

The logically described assessment framework, proposed in section 2 is implemented in TRIPLE. This transformation and query language for the semantic web has been introduced to reason over distributed annotations of resources. TRIPLE is able to query web resources in a declarative way based on a background knowledge like ontological knowledge. The formal description of adaptive systems in FOL allows us to reuse the adaptation rules in different contexts. We have used these rules to access learning resources from the Sun Java Tutorial described with RDF and annotated according to the E learning standards LOM and IMS QTI as explained in the previous section. Our framework has been tested in the Personal-reader environment (www.personal-reader.de), a framework for designing and maintaining personalization services on the semantic web.

3.1 TRIPLE Overview

TRIPLE is a rule language, designed for querying and transforming RDF models. Through the use of clause-like constructs, TRIPLE supports the namespaces and resources identifiers in the form of nsabbbrev:= namespace e.g., rdf:='http://www.w3.org/1999/02/22-rdf-syntax-ns#'.

TRIPLE supports also statements in the form of subject[predicate$-$ >object], e.g.

```
Learner[hasScore ->10].
```

RDF models, i.e. set of statements, written as "@model" are also expressed in TRIPLE, e.g.

```
Learner[hasScore\->10]@assessmentresult.
```

TRIPLE supports also the definition of clauses which are a set of facts or rules. To assert that a set of clauses is true in a specific model, a block is defined as follows: @Model{clauses}. Logical formula in TRIPLE are expressed through a set of connectives and quantifiers: $\forall$, $\exists$, $\neg$, $\vee$, $\wedge$, etc. In case that the TRIPLE program is in ASCII syntax, the symbols AND, OR, NOT, FORALL, EXISTS, $\leftarrow$, $\rightarrow$, etc. are used. All variables must be introduced via quantifiers, therefore marking them is not necessary.

3.2 Reasoning Rules for assessment

As stated above our assessment framework has been tested in the personal-reader environment. This AEHS offers an open architecture on the semantic web and provides mainly three services: a visualization service, which has the role of user interface, by displaying the learning resources selected by the user, a connector service, which plays the role of mediator between the other two services, through conversion of the input/output data in the corresponding format of each service and finally a reasoner service for annotation of resources according to predefined rules. The functionalities of the latest service are formulated in TRIPLE. We have integrated our rules, in the reasoner service of the Personal-reader environment. In the following we will describe the main rules that enable adaptive learning process based on assessment.

The structure of the resources is queried through the following rules, which checks whether the resource is an atomic-LO or a linear-LO according to the LOM standard. Similarly for assessment resources, where we check whether the current resource is an item, a section or an assessment according to QTI specification. The two following rules e.g. derive the fact that a resource is an atomic-LO or an item.

```
FORALL A Atomic(A) <-
 A[lom-general:aggregationLevel
    ->'lom-gen;AggregationLevel1'].
FORALL I Item(I)<-
   I[rdf:type -> qti: 'Item'].
```

Items may have one of the following three types: Multiple Choice, Fill-In-Blanks and Problemsolving. As an example we propose the following rule that derives all multiple choice items through using the QTI binding.

```
FORALL I Multiple_Choice(I) <-
  Item(I) AND
EXISTS Y (I[qti:itemmetadata -> Y] AND
EXISTS Z (Y[qti:qmd_itemtype -> Z] AND
      Z[rdf:value ->'MultipleChoice'])).
```

Atomic-LOs and linear-LOs are related through the Dublin Core property dc:isPartOf. The following rule lists all atomic-LOs of a given Linear-LO:

```
FORALL L, A
Atomic_of_Linear(L,A) <-
Atomic(A) AND Linear(L)AND A[dc:isPartOf->L].
```

The structure of a linear-LO may be very complex. A linear-LO may have also for example another linear-LO part of it. This recursive structure is derived through many rules, as an example we present the following rule:

```
FORALL L1, L2
 Linear_Partof_Linear(L1, L2) <-
  Linear(L1) AND Linear(L2)
  AND L1 [dc:isPartOf -> L2].
```

As stated in the previous section, To define a prerequisite of a linear-LO we use the lom-classification:prerequisite property. The following rule derives all prerequisites atomic-LOs of a given linear-LO.

```
FORALL L, A
Prerequisite_Atomic(L,A) <-
 Linear(L) AND Atomic(A) AND
 L[lom-classification:prerequisite -> A].
```

The concepts are the main information entities from domain knowledge communicated by a linear-LO or an atomic-LO. Following rule derive all concepts from metadata based on types taken from the ontology

```
FORALL C Concept(C) <-
  C[rdf:type -> Concept].
```

Concepts and atomic-LOs are related through dc:subject property (from Dublin Core standard). The following rules finds out the concepts of a given atomic-LO.

```
FORALL A,C Concepts_of_Atomic(A, C) <-
 Concept(C) AND Atomic(A)AND
 A[dc:subject -> C].
```

Concepts and linear-LOs are related through lom-classification: educationalObjective property. The following rule derives all objectives of a given linear-LO:

```
FORALL L, C Concepts_of_Linear(L, C) <-
 Concept(C)AND Linear(L)AND
 L[lom-classification:educationalObjective
                                -> C].
```

Based on the previous rules, we can find out all objective atomic-LOs for a linear-LO, which means all concepts that have to be mastered by the learner by the end of a lesson.

```
FORALL L, A
  Objective_Atomic(L,A) <-
   Linear(L) AND Atomic(A) AND
   Atomic_of_Linear(L,A) AND
   EXISTS C (Concepts_of_Atomic(A, C)
         AND  Concepts_of_Linear(L,C)).
```

We need also to set up the relationship between a question (item) and a part of lesson (atomic-LO). Therefore we have to proceed according to the following steps: we have assigned to each item an objective, by using the property qti:Objective. The objective of each item is derived according to the following rule.

```
FORALL I, O Obj(I, O) <-
  Item(I) AND Concept(O) AND
  I[qti:Objective -> O].
```

The second step is to find out the corresponding atomic-LO to a given Item based on the common objective. This task is expressed through the following rule:

```
FORALL I, A
  Question_of_Atomic(I, A) <-
    Item(I) AND Atomic(A) AND EXISTS O
   (Obj(I,O) AND Concepts_of_Atomic(A, O)).
```

All previously mentioned rules are used to set up the assessment rules. We have six rules for assessment annotations, according to the six assessment states defined in Section 2. The following rule determines the linear-LOs, for which a Pre-assessment is recommended. The recommendation rule is performed according to a FOL sentence from section 2 that states that a pre-assessment is recommended for a linear-LO if at least one prerequisite atomic-LO has not be learned by the user.

```
FORALL L, U
Assessment_state
   (L,U,PreAssessmentRecommended) <-
 Linear(L) AND user(U) AND EXISTS A
 (Atomic(A) AND Prerequisite_Atomic(L, A)
 AND p_obs(A, U, Highlighted)).
```

Based on this rules a list of questions (items) will be derived according to the following rule, in order to generate an appropriate pretest for the given linear-LO, containing questions on its prerequisite atomic-LOs.

```
FORALL L, I, U
 Candidate_Item(L, I, U,PreTest) <-
 Linear(L) AND user(U) AND Item(I)AND
 Assessment_state
  (L,U,PreAssessmentRecommended)
  AND (EXISTS A
   (Question_of_Atomic(I, A) AND
    ((Prerequisite_Atomic(L, A) AND
     p_obs(A, U, Highlighted))
    OR (EXISTS L1
    (Linear_Partof_Linear(L1,L)
    AND Prerequisite_Atomic(L1, A)
    AND p_obs(A, U, Highlighted)))
    OR (EXISTS L2
    (Linear_SubPartof_Linear(L2,L)
    AND Prerequisite_Atomic(L2, A)
    AND  p_obs(A, U, Highlighted)))))).
```

4 Discussion and Related Work

The approach that we are suggesting is a learner dynamic assessment and adaptive course presentation. The Framework observes the learner and adapts to his/her progress the generated course. If the student's performance does not meet the expectations, the course is dynamically re-organized and assessment content is presented to the learner. Each student is able to get a highly personalized course appropriate to his/her level of knowledge. This approach is well suited for individual students taking a self-study distance eLearning course. These students can be employees in an organization who arrive with different experience and background knowledge, or students in an online course. The separation of content from presentation inherent in LOM and QTI means that learning objects questions and tests can be created, stored and exchanged. QTI specification incorporates a schema for the exchange of results, another element of key interest to our framework. The automatic capture of student input during formative assessment means that tutors can identify problem and support the learner by providing him with the appropriate learning material.

Many eLearning tools and services have been developed to manage content delivery and testing activities. Regarding the assessment activities, which is the main objective of our framework only few of them are compliant to IMS QTI (QuestionMark [Van Rentergem, 2001]). Another important issue in this area is that the majority of assessment tools focus only on one type of assessment, which is Multiple Choice question. One of the major contributions of our work is that we have defined taxonomy of tests according to the IMS QTI and we propose to handle the programming exercises by integrating the question type ”ProblemSolving” that makes possible to run students answers with test data and to validate them by invoking of appropriate compiler.

Our approach contributes also to the domain of open hypermedia. It overcomes the main disadvantage of the classic adaptive educational hypermedia systems, which work on a closed set of documents. Related approaches in this area can be found in [Henze and Nejdl, 2001]. Our assessment framework takes benefits from the new technologies in the area of semantic web.

The semantic web could be considered as a very suitable platform for implementing and delivering of eLearning courses, because it permits the querying and the navigation through learning materials, through an ontology-based annotation. This facilitates the selection of the relevant learning parts of a course according to the user level of knowledge. An approach for implementing an eLearning scenario using Semantic Web technologies can be found in [Stojanovic *et al.*, 2001]. Related approaches for personalization based on semantic web reasoning can be found in [Dolog *et al.*, 2003] . Regarding the implementation of our approach, we have used TRIPLE, since it permits to query over resources annotated in RDF. A rule language for querying XML resources can be found in e.g. [Bry and Schaffert, 2002].

5 Conclusion and Further Work

In this paper, we have described a flexible assessment framework based on the eLearning standards LOM and IMS QTI, reasoning over semantic web and using techniques from adaptive hypermedia. The framework permits a dynamic learning and assessment process. The logical characterization of the assessment rules permit a formalization of the learning process using First Order Logic. The rule-based language TRIPLE allowed us to implement this functionality and reason over resources annotated based on standards and semantic web technology.

The current IMS QTI standard version does not provide a possibility to assess the programming exercises. We proposed therefore an extension of this standard through offering the problem solving type. We would like to continue with experiments with the all offered assessment types by IMS QTI and to investigate also more complex types basically for programming exercises. This enables us to provide the learner with a wide range of assessment possibilities, to permit a dynamic learning process based on an accurate evaluation of his/her level of knowledge.

Acknowledgements

This work was partially supported by the Network of Excellence REWERSE (www.rewerse.net).

References

[BernersLee, 2002] Tim Berners-Lee. The semantic web- mit/lcs seminar. Available at: *http://www.w3c.org/2002/Talks/09-lcs-swebtbl/*.

[BernersLee *et al.*, 2001] Tim Berners-Lee, James Hendler, and Ora Lassila. The semantic web. *Scientific American*, May 2001.

[Bloom and Krathwohl, 1956] Benjamin S. Bloom and David R. Krathwohl. Taxonomy of Educational Objectives: The Classification of Educational Goals, by a committee of college and university examiners. *Handbook I: Cognitive Domain*. New York, Longmans, Green, 1956.

[Brusilovsky, 2001] Peter Brusilovsky. Adaptive Hypermedia. *User Modeling and User-Adapted Interaction*, 11:87–110, 2001.

[Bry and Schaffert, 2002] Francois Bry and Sebastien Schaffert. A rule-based query and transformation language for xml. In *Proceedings of the International Workshop on Rule Markup Languages for Buisiness Rules on the Semantic Web*, Sardinia, Italy, June 2002.

[Campione and Walrath, 2000] Mary Campione and Kathy Walrath. The java tutorial. Available at *http://java.sun.com/docs/books/tutorial/*.

[DC, 2001] The Dublin Core Metadata Initiative. Available at: *http://dublincore.org/*.

[Dolog *et al.*, 2003] Peter Dolog, Nicola Henze, Wolfgang Nejdl, and Michael Sintek. Towards the Adaptive Semantic Web. In *Proceedings of the 1st Workshop on Principles and Practice of Semantic Web Reasoning (PPSWR'03)*, Mumbai, India, December 2003.

[Dolog, 2004] Peter Dolog. IMS QTI RDF binding. Available at: *http://www.learninglab.de/ dolog/ learnerrdf-bindings/qti.rdfs*.

[Henze and Nejdl, 2001] Nicola Henze and Wolfgang Nejdl. Adaptation in open corpus hypermedia. *IJAIED Special Issue on Adaptive and Intelligent Web-Based Systems*, 12, 2001.

[Henze and Nejdl, 2003] Nicola Henze and Wolfgang Nejdl. Logically Characterizing Adaptive Educational Hypermedia Systems. In *Proceedings of Adaptive Hypermedia 2003 Workshop, Adaptive Hypermedia Conference*, Budapest, Hungary, August 2003.

[LOM, 2002] LTSC Learning Technology Standards Committee. Learning Object metadata standard,2002. Available at: *http://ltsc.ieee.org*.

[Nilsson *et al.*, 2003] Mikael Nilsson, Matthias Palm and Jan Brase. Towards the Adaptive Semantic Web. In *Proceedings of 3rd Annual Ariadne Conference*, Leuven, Belgium, November 2003.

[OWL, 2003] Web Ontology language (OWL), 2003. Available at: *http://www.w3.org/2001/sw/WebOnt/*.

[PAPI, 2002] IEEE PAPI. IEEE P1484.2.5/D8, 2002. Draft standard for learning technology. public and private information (papi) for learners (papi learner). Available at: *http://jtc1sc36.org/doc/36N0179.pdf*.

[QTI/ASI, 2004] IMS Global Learning Consortium Inc. IMS Question and Test Interoperability ASI Information Model, V1.2. Available at: *http://www.imsglobal.org/question/qtiv1p2/* .

[QTI/RR, 2004] IMS Global Learning Consortium Inc. IMS Question and Test Interoperability Results Reporting,V1.2. Available at: *http://www.imsglobal.org/question/qtiv1p2/* .

[QTI, 2004] IMS Global Learning Consortium Inc. IMS Question and Test Interoperability Specification,V1.2. Available at: *http://www.imsglobal.org/question/index.cfm*.

[RDF, 2001] W3C. Semantic Web Activity: Resource Description Framework (RDF), 2001. Available at: *http://www.w3.org/RDF/*.

[RDFS, 2001] W3C. Resource Description Framework (RDF) Schema Specification 1.0, 2001. Available at: *http://www.w3.org/TR/2000/CR-rdf-schema-20000327/*.

[Sintek and Decker, 2002] Michael Sintek and Stefan Decker. TRIPLE-An rdf query, inference, and transformation language for the semantic web. In *Proceedings of 1st International Semantic Web Conference (ISWC2002)*, LNCS 2342, pages 364-378, Sardinia, Italy, June 2002.

[Stojanovic *et al.*, 2001] Ljiljana Stojanovic, Steffen Staab and Rudi Studer. eLearning in the Semantic Web. In *Proceedings of the World Conference on the WWW and the Internet (WebNet 2001)*, Orlando, Florida, USA, October 23-27, 2003.

[Van Rentergem, 2001] Luc Van Rentergem. A Campus Wide Set up of Question Mark Perception V2.5 at the Katholieke Universiteit Leuven - Facing a Large Scale Implementation. In *Proceedings of the 6th International CAA Conference*, Loughborough University, 2001.