Curriculum data enrichment with ontologies

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ABSTRACT
Teachers are encouraged to handle a large amount of (digital) information (text, multimedia, composite documents). This information feeds data for teachers for their reflection, and can serve as raw material for training in a class. The semantic web can facilitate the process of learning by helping to cope with the multiplicity and complexity of data to be processed. It provides an extension to the current Web, so that access to relevant data is facilitated by automatic processes. In this paper, we propose a method to build an ontology from a corpus representing the French official curriculum for school. This ontology aims to describe and extend the data for educational purposes.

Categories and Subject Descriptors
I.7.2 [XML]: D.2.2 [OWL]:

General Terms
Algorithms, Design, Experimentation.

Keywords
Ontology, semantic web, Knowledge extraction, information retrieval, curriculum, DBpedia, RDF, OWL.

1. INTRODUCTION
In this paper, we present our work for the ILOT project, a collaborative project that aims to provide a warehouse of educational resources for the collaborative development of such resources, their annotation and operation in different consultation modes. The Multimedia Team of Telecom ParisTech contributes to the ILOT project by exploring the use of semantic technologies and web of data for the representation of educational resources.

This work focuses on the representation of the French curriculum in the form of an ontology in order to improve the indexing and ranking of resources produced or stored in ILOT, but also to facilitate their production and create opportunities for teachers and students. These objectives are not described in this paper. In this article, we limit ourselves of the description of the process of semiautomatic generation of an ontology of the French courses of study. Ontology building became necessary in our work. In fact, the work presented in [1] [2] and [3] show that the formalized representation of knowledge in ontology about a domain is an effective way to improve the handling of data in this area. Our hypothesis is that an ontology concerning the application domain of educational resources set is a favorable factor for the creation and exploitation of resources. In addition, this ontology helped to update knowledge about the French curriculum. Finally, the most recent work on web of data provide many resources to establish links between our ontologies and many web resources and, through it, the links between educational resources exploited within ILOT and external resources to the ILOT.

With the help of Bloom's taxonomy[1] we get a formal description of a large number of objectives fixed by the programs. A formal description of the school system allows us to capture the sequences followed by students on a subject during their schooling. The description of Art History program, used as a bridge between subjects, allows us to facilitate the implementation of this program and even helps to develop relationship between subjects through the Art history curriculum.

In this paper, we present a semi-automatic ontology building approach for the curriculum enrichment. In Section 2, we present the related work on the ontology building from a corpus. Section 3 describes our curriculum corpus. We present in Section 4 our approach to ontology building - in fact, created by putting together several basic ontologies. For this, we developed a tool called OntoPedagogy. Section 5 shows the result of our approach. Finally in Section 6, we present some perspectives for future works.

2. RELATED WORK
In the literature, several research works propose tools for transforming XML documents into an ontology represented in OWL or RDF. The outputs generated from these tools, are directly linked to the structure of the XML document. The Work in [4] proposes an approach to building an ontology from an XML schema and transforms the XML document into an RDF graph. The process of transforming the XML schema to OWL is based on predefined transformation rules. OWL classes emerge from complex types of XML schema, group definitions and model group definition attributes. Object properties in OWL are defined from the elements of complex types. The properties of the data types are defined from the elements and from simple type attributes. Class inheritance is defined by inheritance in the XML schema. The approach presented in [5] is similar to the creation of OWL ontology from the XML schemas approach. In this approach, OWL classes are defined using named XSD complex

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[1] The European Schoolnet Vocabulary Bank for Education : http://europeanschoolnet-vbe.lexaurus.net/vbe/browse#

types and XSD elements which contain other elements or have at least one attribute. When an element contains another element, an OWL object property is created between their corresponding OWL classes. The data type properties are defined using XML attributes and elements containing only one literal and no attributes.

According to [6], the approaches presented in [4] [5] introduce good basic rules for creating OWL ontology from an XML document. However, they only treat simple cases and do not refer to complex cases arising from the reuse of types and global elements. In addition, they do not mention how to specify the transformation between the XML source and the OWL ontology generated. (Ghawi & Cullot, 2009) propose a X2OWL tool for transforming XML documents into OWL ontology. The generated ontology contains concepts and properties between concepts (the TBox). This method is based on the schema of the XML document to generate the structure of the ontology. This method also includes a refinement step for the restructuring of the ontology.

[7] [8] proposes an approach for integrating heterogeneous XML sources. The integration of the ontology contains two steps: schema transformation and ontology merging. In the first step, RDFS is used to model each XML source as a local RDF ontology to achieve a uniform representation basis for the ontology merging step. Transforming XML to RDF is as follows: the elements of a complex type are converted to *rdfs:Class*, attributes and simple type elements are transformed to *rdfs:Property*, and the relationship between element and sub-element is coded as a class-to-class relationship using a new RDFS predicate *rdfx:contain*.

[9] propose an approach using an entity-relationship model. They propose an approach to processing XML-to-Relational (XTR) to map an XML document into an entity-relationship model and a Relational-to-Ontology (RTO) approach to map an entity-relationship model to an OWL ontology. However, the OWL ontology generated can not be considered as an ontology domain.

In [10] [11] propose a JXML2OWL tool to map XML schema to existing OWL ontology and to transform XML documents (instance of the mapped schema) into instances of the mapped ontology.

The Piazza system proposed in [12] [13] does not transform XML data into RDF or OWL, but mediates between pairs of XML sources through a mediating schema. Piazza system can create a huge semantically interlinked database.

[14] present a flexible method to enrich and populate an existing OWL ontology from XML data. Basic mapping rules are defined in order to specify the conversion rules on properties. Advanced mapping rules are defined on XML schemas and OWL XML schema elements in order to define rules for the population process. In addition, this flexible method allows users to reuse rules for other conversions and populations.

The work presented in [15] proposes an automatic mapping from XML to RDF called WEESA[2]. The definition of the mapping is created manually between the XML schema and the existing OWL ontology. This system can be used to generate web pages with RDF annotations with regard to the constructs defined in the ontology. In [16], the authors propose an approach to extend the incomplete mapping of WEESA system to produce complete mapping. WEESA mainly suffers from loops in the mapping that lead to incomplete mapping.

[2] WEb Engineering for Semantic web Applications

All of these approaches can be divided into two categories. Approaches that create ontology from XML documents, and approaches that enrich an existing ontology with the data of the XML documents. Our approach is inspired by the second approach. In the second approach, the source and the target documents must be known to produce a mapping but initially the source document has to be known to propose an ontology and an appropriate mapping.

The authors in [17] define a mapping between the DBPedia ontology and the Wikipedia articles. The DBPedia community project creates mappings from Wikipedia information representation structures to DBPedia ontology. This framework extracts this structured information from Wikipedia and turns it into a rich knowledge base.

The DBPedia extraction framework uses the infobox representing the Wikipedia content as a list of attributes. The infobox in [17] for describing automobiles is shown below:

Table 1. Wikipedia infobox

```
{{Infobox automobile
| name = Ford GT40
| manufacturer = [[Ford Advanced Vehicles]]
| production = 1964-1969
| engine = 4181cc
(…)
}}
```

This infobox describes the Wikipedia page[3] of Ford GT automobile. The first line specifies the infobox type and the subsequent lines specify various attributes of the described entity.

Table 2. The mapping Template

```
{{TemplateMapping
| mapToClass = Automobile
| mappings =
  {{ PropertyMapping
| templateProperty = name
| ontologyProperty = foaf:name }}
 (…)
  }}
}}
```

As we will see later, our method is a combination of the latter with methods using the XML structure.

3. Corpus description

For our experimentation, the textual corpus of the French official curriculum was constituted. This corpus is available on the *éduscol* (The national portal of educational professionals)[4],

[3] http://fr.wikipedia.org/wiki/Ford_GT40

[4] http://eduscol.education.fr/pid23391/programmes-ecole-college.html

established by the French Ministry of National Education. These official programs are designed for teachers as the guideline for building their courses in secondary education.

The idea of collecting and formalizing such data is justified by the study of user experience in the Learning Resource Exchange (LRE) portal[5], European *Schoolnet*[6]. The survey has shown that: "*85% of teachers define the quality of resource as the correspondence between contents and educational programs on which they are handling. And the indexation by concepts extracted from the programs improves the results of searching*" [18]. Moreover, in the same perspective, one aspect of the European project *Intergeo* [19], aimed at the maximal reuse of geometry resources through Europe, was based on the conception of the *GeoSkills* [20] Ontology by information extraction from the geometry program.

The information of our corpus covers all official programs of the *Collège* in the secondary education (the first four years including the sixth grade until the third grade). It contains 12 curriculums: Fine arts, Musical education, Physical education and sports, French language, Modern languages, Ancient languages and cultures, Biology and geology, Art History, History-geography-civics, Technology, Mathematics, Physics-chemistry. 45 digital documents in PDF and HTML format were collected. The documents are not all have the same structure, but some common educational elements as theme, competency, knowledge, topic and so on can be extracted for constructing the basic ontologies. The latter is designed to be semi-automatically enriched by the user.

4. APPROACH

[21] provided us with bass for building ontology and their enrichment.

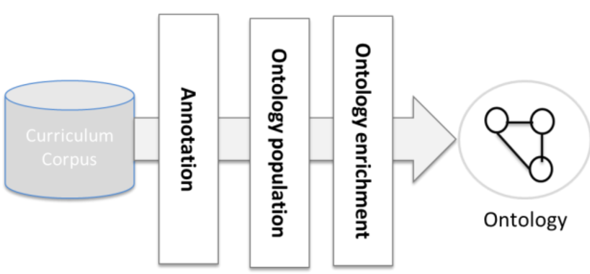

Figure 1. The building and enrichment phase.

Our enrichment architecture consists of three main steps (see Figure 1). Annotation step concern data processing. PDF and HTML documents of the curriculum corpus are transformed into XML. The data in the XML documents are annotated. A lemmatization step is necessary for automatic word recognition. The data is extracted to constitute an ontology population. The initial basic ontology with concepts like theme and topics is then instantiated.. In the enrichment step and Following [21] the extraction and the retrieval processes can both be used to integrate external dictionaries, existing ontologies or a more general resources of structured knowledge, such as WordNet [22], DBPedia [23].

4.1 XML annotation

In our first experiment, the documents have different formats, mainly PDF, difficult to handle by our data processing. We decided to work primarily with representations based on XML. A first representation is obtained by a conversion of PDF to HTML. This translation has the advantage of providing a representation that can be visually enhanced and is taken into consideration by many semantic web tools.

A second representation is based on a conversion to text content of the PDF document adds some structural elements. The XML elements used closely follow the model of documents that we handle. We seek thereafter to have a more generic representation that lends itself to the representation of many documents. We will study the possibility of using DocBook[7] or EPUB[8].

In order to properly decouple preparing the documents and populating the ontology. The ontology is populated directly from HTML or XML documents where information structures are present (in our case: title, introduction, themes that can be included in other themes, ability section, knowledge section, procedures section, etc…).

The first step uses a Bloom ontology related to educational field by classifying educational activities in the infinitive form of the verb. We have created this ontology by hand. Each verb class is represented in both English and French label. Our usage of Bloom is similar to [24].

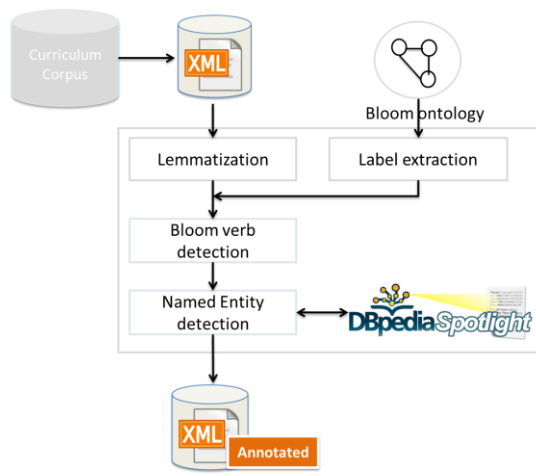

Figure 2. XML annotation architecture.

We have created several ontologies for educational activities and pedagogy, eg Bloom taxonomy of educational objectives, Chacón typology of learning strategies, the typology of pedagogical scenarios and the French school system. The latter is for storing information about the entire school system (level, subject ....). The "educational activities" ontology and the Bloom ontology will be imported into each curriculum ontology to characterize each activity.

In Figure 2, the lemmatization of XML documents is used to represent words in their generic form. For example, verbs in their conjugated form will be replaced by their infinitive form, words in the plural by their singular form. The next step detects Bloom verbs described in the Bloom ontology to determine the

[5] http://lreforschools.eun.org/web/guest

[6] http://www.eun.org/web/guest/home

[7] http://www.docbook.org/

[8] Electronic PUBlication. http://idpf.org/epub/30

educational curriculum capacities. After the detection of all the Bloom verbs, a recognition step of named entities is launched. This step uses DBPedia SpotLight web service freely available for public use; it is known to return very good results [25] [26]. It and has been used in several projects like Virtuoso, Faveeo, Melina+ (to enrich medical educational content for the *mEducator*[9] project) and other projects. Each named entity detected in the xml document is marked by an XML tag. The XML tag contains two attributes, the DBPedia URI of the named entity and the named entity type (actor, movie, place…).

4.2 Ontology population

There are many works for ontology building from the XML documents as described in Section 2. Most of them build an ontology based on the XML schema and populate or not this Ontology schema with the instance of the XML document. For instance, the work presented in [10] [11] is very interesting and close to our work for populating an existing ontology but has a limit in recognizing the object property (property between classes in the ontology) and the API tool is very limited.

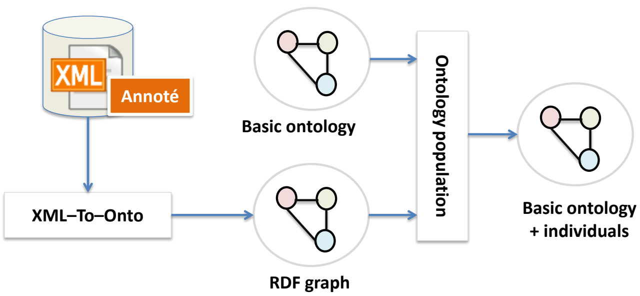

Figure 3. The ontology population architecture.

In our approach described in Figure 3, the annotated XML documents are transformed to RDF. So that contents can be represented in triples. This transformation is accomplished via XSLT[10] [27]. After that, a mapping step between the RDF documents and the basic OWL ontology of the curriculum field is applied to populate the OWL ontology. Each RDF document is mapped to the appropriate ontology because several basic ontologies have been defined, one for each subject (maths, physics, history, etc…). A more general approach will be defined soon with only one basic ontology of the different ontology subject.

The alignment between Wikipedia infobox and the ontology defined in [17] are aligned via community provided mappings that help to normalize name variations in properties and classes. In the template mapping defined in Table 2, attributes are mapped to properties in the DBPedia ontology. The line *mapToClass* specifies the name of the DBPedia ontology class.

This mapping defines a single ontology class but not the Object Properties. In our approach, we use the mapping described in [17] to map the RDF document with the basic ontology. Each class instance value is defined by the predicate "rdf:value" attached to the property name defined in the line *templateProperty* of the mapping template. The SPARQL query in Table 3 give the class instance defined in the property "titre".

[9] http://www.meducator.net/

[10] eXtensible Stylesheet Language Transformations

Table 3. SPARQL query for classes

```
PREFIX mp: <http://.../mathXML2mathRDF.rdf#>
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT ?vti WHERE {
    ?th <mp:titre> ?ti .
    ?ti rdf :value ?vti .
}
```

The result of the SPARQL query on the RDF graph is used to populate each class of our ontology. To solve the problem of Object Property in our ontology, we propose a method based on the generation of a SPARQL query in order to link the individuals. For each object property of the ontology, we had a domain class and a range class. For each instance of the domain class, we generate a SPARQL query to get the instances of the range class which are related to the value of the domain class instance defined in the query. In our ontology the "Theme" class is linked with the "Knowledge" class by the object property "HasKnowledge". To link the individuals of the different classes we generate the SPARQL query described in the Table 4. This query gives a list of all individuals that are linked with the individual value '1.3. Traitement des données' of the "Theme" class.

Table 4. SPARQL query for object property

```
PREFIX mp:<http://.../mathXML2mathRDF.rdf#>
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT  ?know WHERE {
    ?tt <mp:theme> ?th .
    ?th <mp:titre> ?ti .
    ?ti rdf :value '1.3. Traitement des données' .
    ?th <mp:connaissances> ?cc .
    ?cc  rdf:value  ?know .
}
```

4.3 Ontology enrichment

To enrich the initial official curriculum ontologies, we use different collections of open data. Actually, the identification of such data can be classified in two groups: general data and specific data. The first covers different types of information extracted from DBpedia. For example, a concept "Architecture", defined as an example of Art of Space domain in the Art History official curriculum, will be extracted as a class in the initial ontology. This concept is also available in DBpedia as category (Category:Architecture)[11]. Our system is expected to collect this categorized data set, including *one-to-many navigational path* [28] for user validation and personalization, according to the need, for enriching the initial Art History ontology.

The second kind of data which could be exploited for enriching or mapping with the initial official curriculum ontologies, is the specific data related to the content of official curriculum, established by public authorities. For example, *Histoire des arts* portal[12] metadata set[13], a list of 156 pedagogical folders of the

[11] http://dbpedia.org/page/Category:Architecture

[12] http://www.histoiredesarts.culture.fr/

Centre national d'art et de culture Georges Pompidou[14] or the data collection of the French National Library on *data.bnf.fr*[15] provided by the Ministry of Culture and Communication. This data could be used for enriching the initial official curriculum ontologies particularly for Art History, French, and History.

The mapping between such data sets and the initial official curriculum ontologies will be extremely helpful not only for teachers for finding appropriate educational resources according to the official curriculum, but also for cultural data producers as a way for their resources to be reused and valorization in education. Their connection is in progress.

5. RESULTS

In our experimentation, we use our Bloom ontology to detect the capacities in our curriculum corpus. This ontology contains 83 concepts labeled in the French and English language.

We calculate the number of capacities and the named entities detected by our approach of "History and Geography" curriculum subject in Table 5.

Table 5. Corpus Information

	Words	Capacities	Named Entities
History & geography	23227	276	909

To evaluate our approach, we calculate the precision *P* and the recall *R* of the detected capacities (see Table 6). For this calculation, we need to count the number of capacities correctly (True Positives; TP) and incorrectly (False Positives; FP) detected. We need also the number of capacities undetected (False Negative; FN).

Table 6. The precision and the recall result.

	Capacity	
	P	**R**
History & geography	0,787	0,816

We are at the beginning of this innovation and the results are very promising. We do not calculate the precision and the recall of the named entity detection because the performance of the DBpedia Spotlight API is described in [25] [26].

6. CONCLUSION

In this paper, we present an approach for ontology building from a curriculum corpus in order to enrich data. We defined an ontology base for each subject of the curriculum (maths, physics, art history, etc…) in order to serve as a basis for our ontology creation. These ontologies facilitate the creation and enrichment (ontology population) with terms extracted from the corpus of the different curriculum.

Our approach to curriculum enrichment consists of three main steps (see Figure 1). First the data is annotated with capacities and named entities using the DBpedia Spotlight [25] [26]. The annotated documents are converted into an RDF structure. The RDF representation is used in next step to instantiated the initial ontologies for each domain. . The mapping described in [17] has been adapted to enables us to map our RDF documents and the different basic ontologies. The final step enriches the ontologies with information extracted from DBpedia, WordNet and others.

We are currently working on enriching our ontologies with external ontologies as DBPedia and the specific data related to the content of official curriculum as mentioned in Section 3.3. We are enriching the Bloom ontology by including a set of synonyms for each verb. This extension allows us to detect more capacities in the curriculum corpus and increases the precision.

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