Semantic Web Technologies Supporting the BBC Knowledge & Learning Beta Online Pages

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Abstract. The BBC has a rich collection of learning resources. The Knowledge and Learning website Beta aims to unlock the learning potential of this content for its users. To this purpose, the system employs semantic web technologies to organise the available learning resources. In this paper we describe the core data model that underlies the Knowledge and Learning website Beta[1]. The Curriculum Ontology formally describes the UK national curricula to allow users to easily discover content. We explain how the curriculum ontology supports the BBC Knowledge and Learning Beta website and discuss the challenges and benefits that such an architecture provides.

1 Introduction

Online learning resources have the potential to support a wide range of users. Each learner is an individual, with his or her own motivation for studying, accessing resources, and study habits and practices [5].

The BBC has understood the value of online learning from the early stages of the web, and has provided rich educational material to those wanting to learn. An example of this is the BBC Bitesize website[2], which started back in 1998 and is a popular formal education resource.

In the formal learning space the BBC has a number of sites: the already mentioned Bitesize, Skillswise[3] and Class Clips[4] amongst others. There are tens of thousands of content items across these sites, with each site having different mechanisms for publishing, discovering and describing the content it serves.

To provide a coherent learning experience to users, a model for describing content in the context of the UK national curricula was developed. This model provided the foundation for building the new Knowledge & Learning beta website, presenting learning resources in the context of the UK national curricula in a consistent way. In addition, it allows for consistent reflection of changes in the national curricula throughout the product.

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[1] `http://www.bbc.co.uk/education`

[2] `http://www.bbc.co.uk/bitesize/`

[3] `http://www.bbc.co.uk/skillswise`

[4] `http://www.bbc.co.uk/learningzone/clips/`

Designing the architecture of such a system is a challenging task. Each of the existing sites have similar yet different ways of describing and navigating through their content. In addition, the existing learning sites do not have a single content description model that could be reused in the beta site. Having a flexible structure in the backend that can reflect the national curriculum and that can be used for consistently describing and organising learning resources is a key feature of the architecture.

In this paper, we present the architecture behind the Knowledge & Learning Beta site and we focus on the curriculum ontology, which is central to the architecture. We show how it is used to describe and organise learning resources, how it supports navigation and how it is aligned with semantic markup vocabularies for Search Engine Optimisation (SEO). We will also present some of the challenges we faced and discuss future work.

2 The BBC Knowledge & Learning Online Content

The Knowledge & Learning Beta website aims to bring together the variety of BBC factual and learning content into a coherent model. At the time of writing, the education pages serve two types of learning content; (1) Video Clips and (2) Revision Guides.

Video Clips Figure 1 shows an example video clip from the education pages. Video clips are related to a learning topic and are accompanied by classroom notes, which are notes on how a clip can be used in the classroom. The users for these clips are mainly teachers. The material provided in these pages aims to educate as well as stimulate the mind around topics in genres like history, science, arts. A video clip can be suitable for many topics of study, however, the classroom notes add value by providing information on the context of a programme of study. For example, the video clip of Figure 1 is also featured in other topics of study like Energy and Atoms and radiation. However, the classroom notes can be different as the clip is presented in a different context.

Revision Guides Revision Guides are a rich interactive content format consisting of revision chapters, tests and activities. An example revision guide is shown in Figure 2.
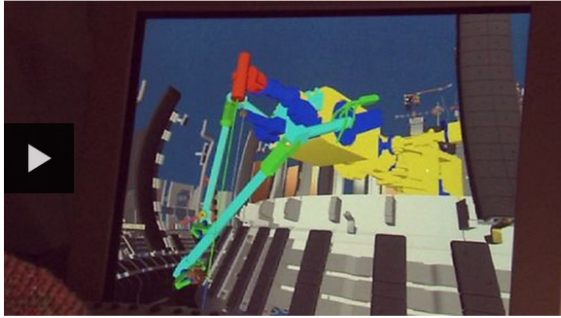
Revision Guides have a different learning purpose from video clips. They provide learning material in a stepwise way so that the learner moves from broader to more specific knowledge on a topic. Revision chapters provide an overview of educational material for a particular topic of study. Activities provide interactive material such as videos, games etc. The tests have multiple choice questions based on the revision chapters.

Both video clips and revision guides are structured based on the UK National Curricula. In the next section, we present the back-end architecture of this system.

Fig. 1: An example video clip giving an introduction to nuclear fusion, for GCSE Physics. Taken from `http://www.bbc.co.uk/education/clips/z4nwmp3`.

3   Architecture Overview

Figure 3 shows the architecture behind the Knowledge & Learning Online Pages. The main actors in this architecture are:

- **Curriculum Ontology:** The ontology is used for describing the curriculum vocabulary.
- **Curriculum API:** the API used to query the Linked Data Platform.
- **Linked Data Platform (LDP):** The BBC internal triple store and services for saving and managing the curriculum metadata.
- **Content Items like Learning Clip and Studyguides:** The learning resources that are shown in the education pages.
- **Content API:** The API for querying the Content Store.
- **Content Store:** The system where learning resources are authored and stored.

The Knowledge & Learning uses a Dynamic Semantic Publishing (DSP) model in its architecture [12]. In this architecture, semantic web models and

Fig. 2: An example Revision Guide. Taken from `http://www.bbc.co.uk/education/topics/z84k7ty`

linked data are key features. Similarly, in the Knowledge & Learning Online Pages, different components of the front end are served by different systems in the back-end. This is depicted in Figure 3. The curriculum ontology is the core component of the architecture, which supports the navigation and organises the learning resources based on the UK national curricula.

In a nutshell, the ontology and its instance data are served by the Linked Data Platform, which amongst other services it provides the BBC internal triple store. Learning content such as video clips and revision guides are saved as XML Documents in a different system named as Content Store. The Content Store serves all the educational resources that are shown in the online pages and it is also the main system used by the editorial team for authoring new content. The coupling between Learning resources and curriculum ontology is done through semantic annotation. In particular, the content items are tagged with curriculum instances so that the Application Layer can retrieve related content for curriculum ontology instances. The definition of new curriculum instances and the tagging procedure is part of the workflow for publishing content. Our editorial teams initially define the vocabulary (fields of study, topics of study etc) that is used for annotating educational content. Then video clips and revision guides are tagged with the corresponding topic of study. In this way the Application Layer can retrieve the corresponding topics of study and their associated content and render this information in the online pages.
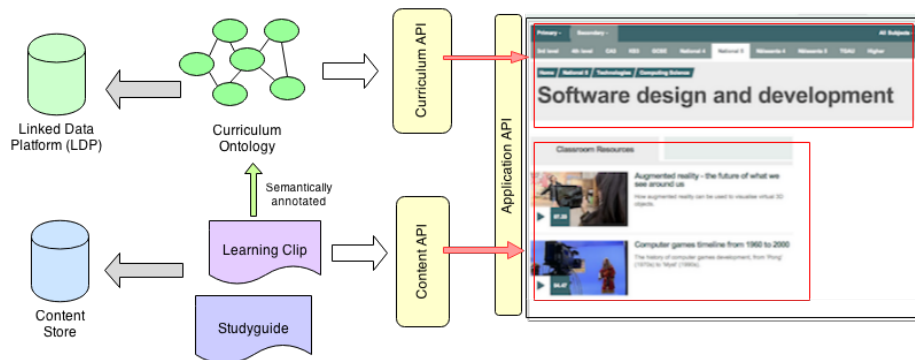
Fig. 3: The BBC Knowledge & Learning Architecture.

In the following sections, we will focus on the curriculum ontology and show the benefits of linked data for supporting online learning resources. One main benefit is that using linked data in the backend can offer flexibility on the aggregations of content. In addition we will present how the ontology is mapped with learning markup vocabularies and how linked data are used effectively with markup for improving search.

4 The Curriculum Ontology

The Curriculum Ontology is a core data model for formally describing the National Curricula across the UK. The full documentation as well as the latest version of the ontology are available online[5]. The instance data of the curriculum ontology are published on GitHub[6].

The Curriculum Ontology aims to:

– provide a model of the national curricula across the UK
– organise learning resources, e.g. video clips and revision guides
– allow users to discover content via the national curricula

The Curriculum Ontology has been designed to organise content in a way that allows students and teachers to navigate and discover learning resources. It achieves this by providing broad units of learning (e.g. a Topic) and more finely grained units (e.g. a Topic of Study). Figure 4 depicts the classes and properties in the curriculum ontology.

4.1 Core concepts of the ontology

The core concepts in the ontology are (1) Level, (2) Field of study, (3) Programme of Study, (4) Topic of Study and (5) Topic. In the ontology, these con-

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[5] http://www.bbc.co.uk/ontologies/curriculum
[6] https://github.com/BBC-Knowlearn/curriculum-data

Fig. 4: The Curriculum Ontology Diagram.

cepts are represented as OWL Classes [9]. The rationale for these concepts in the domain model is outlined below.

Level and its sub-concepts Level refers to different stages of education. Typically, there are four different ways to specify the levels: Age Range, Year, Key Stage and Phase. Thus, in the ontology these concepts are modeled as subclasses of Level.

Key Stage is a way to specify the stage of the state education system in England, Wales, Northern Ireland. Some example Key Stages are KS3, GCSE etc. Year is a way to specify the stages of education.

The Phase sub-concept is borrowed from the controlled terms for describing phase of education, which are published by the data.gov.uk[7]. The phases of education include Primary, Secondary and 16-Plus.

Fields of Study It refers to the discipline of a curriculum. Some example fields of study are Science, Maths, English Literature etc.

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[7] http://education.data.gov.uk/

Programmes of Study A programme of study is the combination of a nation, an educational level and the subject (Field of Study) being studied. Thus, in the ontology, the Field of Study class is connected to the Field of Study with the taughtInField predicate and to the Level with the taughtAtLevel predicate. Some example programmes of study are 'GCSE Maths', 'Higher Biology' etc.

Topics of Study A Topic of study is a topic within the context of a programme of study. It aims to provide a formal learning context to an asset or a collection of assets. An example topic of study is 'Circuits', which is taught in the 'KS2 Science' programme of study.

Ordering Topics of Study The ordering of Topics of Study is a key requirement in the Curriculum Ontology, because some Topics of Study can be prerequisites of others. For instance, students have to learn the English alphabet before English grammar. The TopicOfStudyList class uses the external Ordered List Ontology [2] to curate the sequences of Topics of Study. This is achieved by assigning an indexed slot to each Topic of Study. For allowing multiple indexing per Topic of Study, instead of directly assigning the index in the Topic of Study, the TopicOfStudyList class is used, which is subclass of the OrderedList class from the external Ordered List Ontology. This pattern allows a Topic of Study to appear in many lists and have different order in each list. The Ordered List Ontology is also described in the Ontology Design Pattern (ODP) catalogue[8] [8].

Topics A Topic can highlight the content of the learning resources in a more specific way than the Field of Study. For example, energy is a topic of physics.

Topics of Study viewed as Topics In the curriculum ontology, the difference between a Topic of study and a topic is that mapping content to a Topic of Study makes it easy to find specific content whilst mapping to a generic Topic allows users to discover a wider range of content.

A Topic of Study is defined as a Topic in the context of Programme of Study. It addresses the following issues:

- **A Topic across Levels.** The meaning of a Topic, e.g. 'Geometry (Shape & Space)', can vary for different Levels. Geometry for KS1, usually called 'Shape & Space', needs a different description to Geometry in KS3 as KS1 is typically for primary-age students whereas KS3 is for secondary-age students.
- **A Topic across Fields of Study.** For example, 'Energy Resources' is a Topic of both Physics and Geography, but the learning content for 'energy resources for physics' and 'energy resources for geography' can be different.
- **Topic synonyms.** The topic of 'algebra' is usually described as 'relationships' in the Scottish national curricula and as 'Algebra' in the English curricula.

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[8] http://ontologydesignpatterns.org/wiki/Ontology:Ordered_List_Ontology

Fields of Study viewed as Topics A Field of Study could also be viewed as just a Topic covering a broader area of learning. The reasons for defining them as two separate concepts are:

- **Fields of Study are published by Government bodies.** For instance, the Fields of Study taught at primary schools in England are published by the government here. In general the national curricula define the breadth of a field of study but do not provide a prescriptive list of individual topics, although in some levels (e.g. GCSE) exam boards do specify a list of Topics of Study for each Field of Study.
- **Usage of topics across different Fields of Study.** As mentioned previously, some Topics can be used across Fields of Study.

5 Describing Learning Content with the Curriculum Ontology

Effective description and organisation of learning content is achieved by semantically annotating learning content with instance data from the Curriculum Ontology. Figure 5 shows an example instantiation of the core concepts from the curriculum ontology.

Figure 5 depicts the interlinking of two topics of study ('GCSE Physics Electricity' and 'KS2 Science Circuits') that belong to different programmes of study, but they are around the same topic, which is 'Electricity'. The 'GCSE Physics' programme of study has a relationship with the corresponding Field ('Physics') and Level ('GCSE')[9]. The information about a topic of study holds also information about the level, programme of study and related topic. Having such a structure in the backend has multiple benefits, such as achieving more dynamic aggregations of content and providing a meaningful organisation of the content that reflects the UK National Curricula.

5.1 Dynamic Semantic Publishing

The Curriculum Ontology is the glue that holds the content together and the basis of the website navigation. Following a Dynamic Semantic Publishing approach we moved away from a relational publishing model to one that separates semantics from content and allows dynamic aggregations.

Figure 6 shows an example of the use of the curriculum ontology instance data for organising content and for the provision of the main navigation in the website. In particular, it shows how the topic of study GCSE Physics Electricity and related data of Figure 5 are shown in the front end. Related information about the Level, Superfield (Science) and sibling fields (Biology, Chemistry, Physics) are presented in a hierarchical way in the navigation panel. This information is retrieved by querying the triple store through the Curriculum API. The curriculum API

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[9] More precisely, 'GCSE' is the Phase but it is inferred to be a Level too.
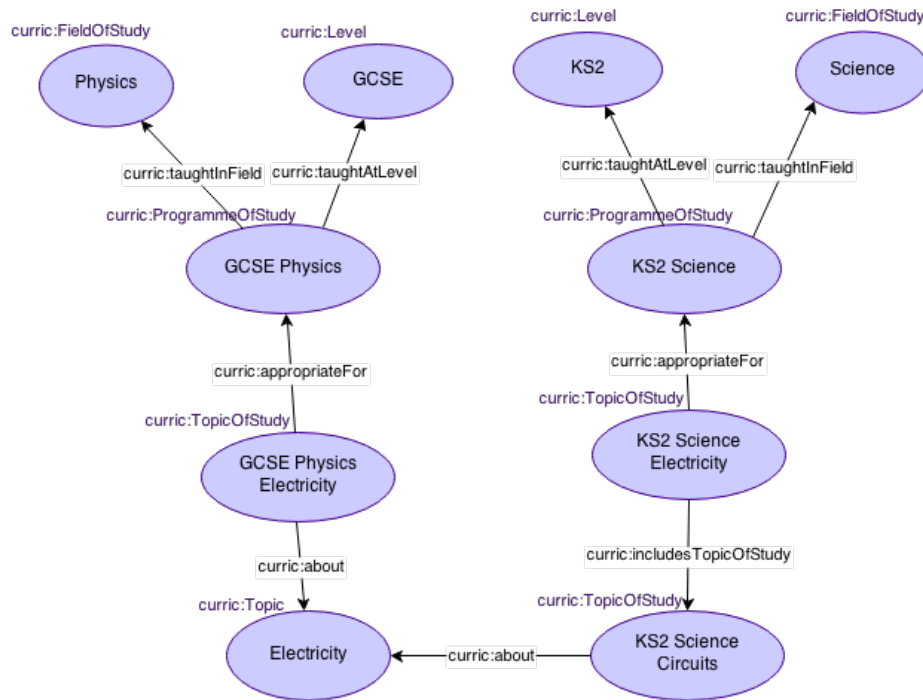
Fig. 5: Example instantiation of the the core concepts from the curriculum ontology.

provides the result of the SPARQL queries in the Application API (Figure 3). In addition, the list of topics of study shown in Figure 6 is implemented with the Ordering List Ontology Design Pattern (ODP), described in Section 4.1.

The use of Linked Data in the architecture of the system can help towards a dynamic aggregation of content. Additional views can be implemented by querying a different part of the graph like for example, creating an aggregation view of content grouped by topic.

5.2 Mapping to LRMI Vocabulary

The Learning Resource Metadata Initiative (LRMI) [1,14] has been adopted by http://schema.org and aims to establish an open standard for adding semantic mark-up to online learning resources. Using the LRMI vocabulary enables easier discovery of content by search engines and other organisations. Thus, mapping concepts from the BBC curriculum ontology to the LRMI vocabulary contributes towards a model of consistent organisation and discovery of content. The conceptual mappings between the Curriculum Ontology and LRMI are shown in the Figure 7.
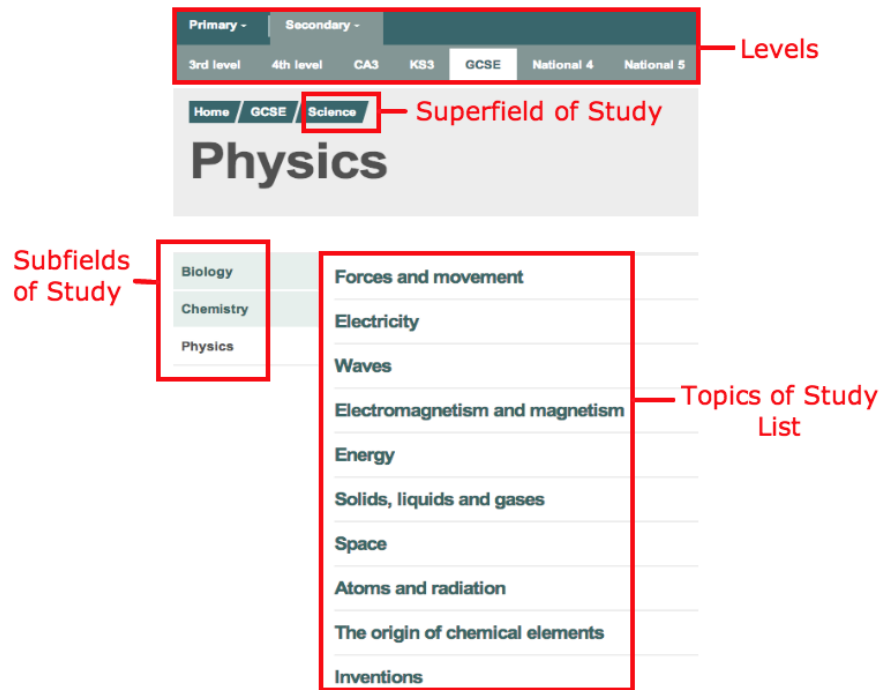
Fig. 6: Example showing the curriculum ontology supporting the BBC Knowledge & Learning Online navigation.

Instead of modeling school curricula, LRMI provides a generic framework for describing learning resources, which is independent from certain educational frameworks. To this end, LRMI introduces the concept AlignementObject and the educationalAlignment property [3]. The AlignementObject is an abstract concept mapped to educational levels, subjects and topics. The educationalAlignment links a learning resource with an educational concept. The Curriculum Ontology classes share the same intent as the Schema.org AlignmentObject, thus they are defined as sub-concepts of the AlignmentObject concept.

The AlignmentObject class provides an alignmentType property that describes the type of alignment being specified. In Figure 7, there are two types of alignment, the 'educationLevel' and the 'educationalSubject'. These types allow alignment to the corresponding Curriculum Ontology classes. OWL restrictions are used to enforce that correct alignmentType properties are used. Thus, if we want to say that all instances of curric:Level are of schemorg:AlignmentType "EducationalLevel" this can be implemented in OWL as:

```
curric:Level a rdfs:Class ;
    rdfs:subClassOf _:owlRestrctionA ;
    rdfs:subClassOf schemorg:AlignmentObject .
```
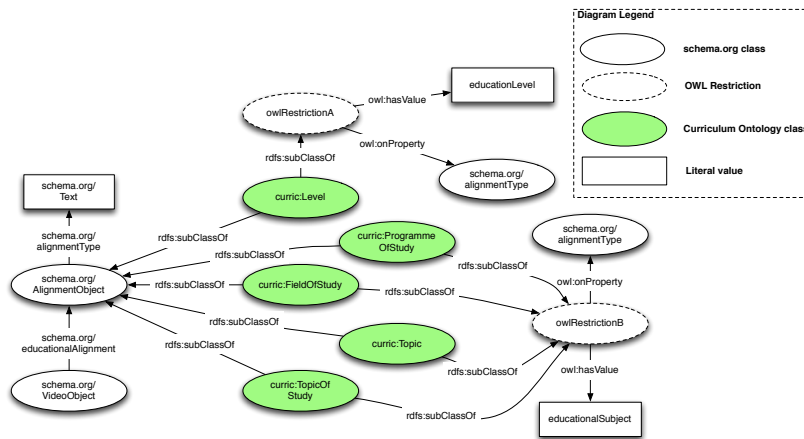
Fig. 7: A model representing the mappings of the Curriculum Ontology to Schema.org LRMI vocabulary.

```
_:owlRestrctionA a owl:Restriction ;
    owl:onProperty schemorg:alignmentType ;
    owl:allValueFrom "EdcuationalLevel" .
```

Similarly every instance of a curric:ProgrammeOfStudy, a curric:Topic, curric:FieldOfStudy, curric:TopicOfStudy can be implied to be an schemorg:AlignmentType "edcationalSubject".

5.3 Markup on BBC Education Website

In order to feed search engines with metadata about learning resources and the UK curricula, semantic markup is added to the HTML pages of a content item, i.e. a video clip. Figure 8 demonstrates an example markup using typicalAgeRange and educationalAlignment. GCSE is associated to an instance of VideoObject. The content of the alignmentType property indicates that GCSE is an educational level. Similarly, a field of study and topic of study can be defined as educational subjects by defining the value of alignmentType to educationalSubject.

Google Custom Search engines[10] can be easily built with the help of semantic markup. A custom search engine built with refinement for GCSE and KS3 (more:p:AlignmentObject-name:KS3, more:p:AlignmentObject-name:GCSE)[11] is shown in Figure 9. The screenshot shows the results for GCSE and KS3 levels when searching for 'Hamlet'.

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[10] https://www.google.com/cse
[11] https://www.google.com/cse/publicurl?cx=005635636900202455771:
   bttbeggy8g0

```
<div itemscope="itemscope" itemtype="http://schema.org/
    VideoObject">
    ...
    <meta itemprop="typicalAgeRange" content="14-16" />
    <meta itemprop="educationalAlignment" itemscope=""
        itemtype="http://schema.org/AlignmentObject">
        <meta itemprop="targetName" content="GCSE" />
        <meta itemprop="targetUrl" content="http://www.bbc.co
            .uk/education/levels/z98jmp3" />
        <meta itemprop="targetDescription" content="GCSE is
            ..." />
        <meta itemprop="alignmentType" content="
            educationLevel" />
    </meta>
    ...
</div>
```

Fig. 8: Example of semantic markup.

6   Related work

For this work a number of online education resources and vocabularies were researched. The UK government[12] provides a very useful structure in their online educational resources, which were considered in the curriculum ontology as well. In particular, the notion of Educational Phase is also used in the BBC curriculum ontology. Other ontologies like the Bolowgna ontology [7] and the ROLE Learning ontology [4] have been developed as part of educational projects before the curriculum ontology. The purpose of the Bolownga ontology was to model an academic setting and to support the publication and exchange of information among universities. The ROLE Learning ontology was developed to support self-regulating learning and it represents a Psycho-Pedagogical Integration Model of connecting learning strategies, techniques and activities.

In addition, the work from [13,11] was also reviewed when designing the curriculum ontology. It is one the most structured resources related to education that preexisted the curriculum ontology and its analysis was a precursor to the development of this ontology.

The support of education data with Semantic Web Technologies [6] has been a key element in efforts like the Linked Universities initiative[13] and the LinkedUp[14] project. In this work semantically annotate learning content using the curriculum ontology. The details of semantic annotation of media are presented in [10].

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[12] http://education.data.gov.uk/
[13] http://linkeduniversities.org/lu/
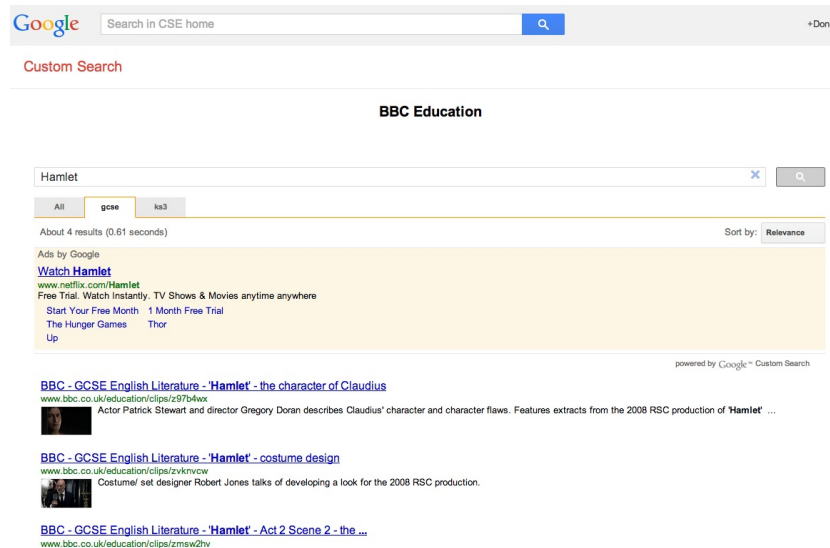[14] http://linkedup-project.eu/

Fig. 9: Google Custom Search Engine for BBC Education.

7 Discussion and Future Work

The BBC offers tens of thousands of learning resources across its sites, with each site having different mechanisms for publishing, discovering and describing the content it serves.

To improve consistency, we incorporated ontology models and linked data in the architecture of the BBC Knowledge & Learning Beta Online Pages. In particular, the development and use of the curriculum ontology in the architecture of the system allowed for interlinking curriculum concepts allowing every content item to be semantically annotated with relevant curriculum topics. In addition, content can be discovered consistently and shown in context with other similar content. This is achieved by semantically annotating learning content with Curriculum Ontology instance data. Mapping the Curriculum Ontology concepts with learning markup vocabularies, such as the Learning Resource Metadata Initiative (LRMI), allowed for better precision in search using the metadata of the learning content.

Hiding the model's complexity and providing a consistent navigation is a challenge of the architecture, which is achieved with the implementation of services and APIs on the top of the linked data. A benefit of the ontology supporting the BBC online education pages is that it can offer dynamic aggregations of content achieved by querying the linked curriculum data. It can also help to easily discover content. For example, the recommendations on other relevant topics to a clip is done via the ontology data. Building additional recommendation services using the curriculum ontology and other ontologies is a good future work direction.

One key requirement of the new Knowledge & Learning is to provide a consistent model reflecting the UK National curricula where users can learn more about science, nature, history, religion, arts and more, in a continuous learning journey. Semantic Web Technologies and Linked Data can give a leverage in accomplishing this task as they allow an effective interlinking and querying of web data.

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