Use of Semantic Web Technologies in the Architecture of the BBC Education Online Pages

Eleni Mikroyannidi(✉), Dong Liu, and Robert Lee

British Broadcasting Corporation, Future Media Knowledge and Learning, Salford, UK
{eleni.mikroyannidi,dong.liu,robert.lee}@bbc.co.uk

Abstract. The BBC has a rich collection of learning resources. The Knowledge and Learning Bitesize website 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 (http://www.bbc.co.uk/education). The Curriculum Ontology formally describes the UK national curricula to allow users to easily discover content. We explain how the curriculum ontology supports the new version of BBC Knowledge and Learning 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[1], 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[2] and LearningZone 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 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. Thus, the extensibility of the model is also an important feature.

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

D. Mouromtsev and M. d'Aquin (Eds.): Open Data for Education, LNCS 9500, pp. 67–85, 2016.
DOI: 10.1007/978-3-319-30493-9_4

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 site. Having a flexible structure in the back-end 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.

We present the architecture behind the new Knowledge & Learning website 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.

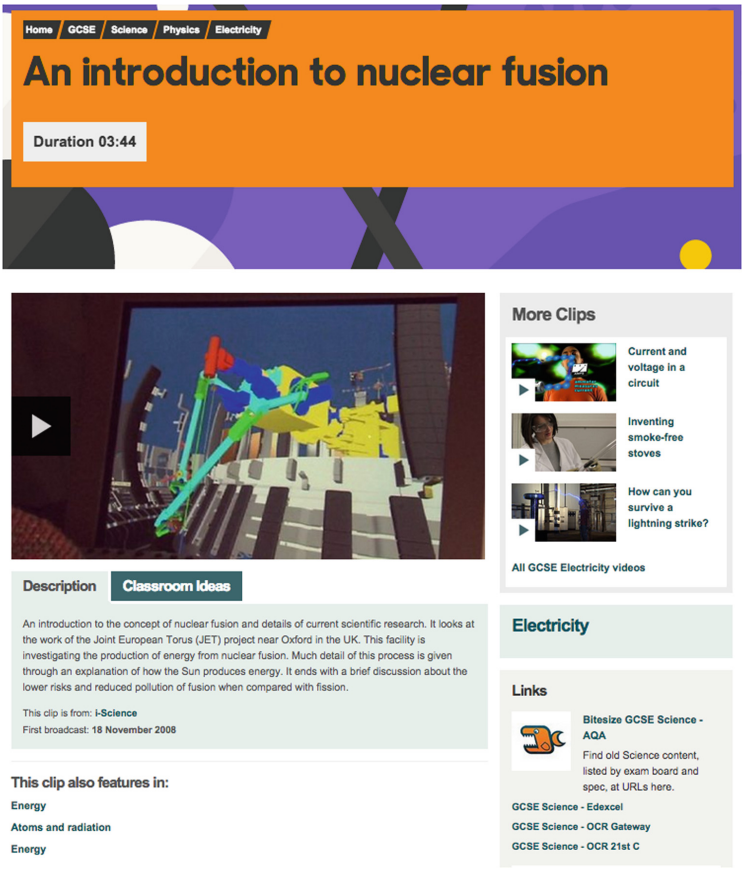

Fig. 1. An example video clip giving an introduction to nuclear fusion, for GCSE Physics. Taken from http://www.bbc.co.uk/education/clips/z4nwmp3.

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) Learner 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 Fig. 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.

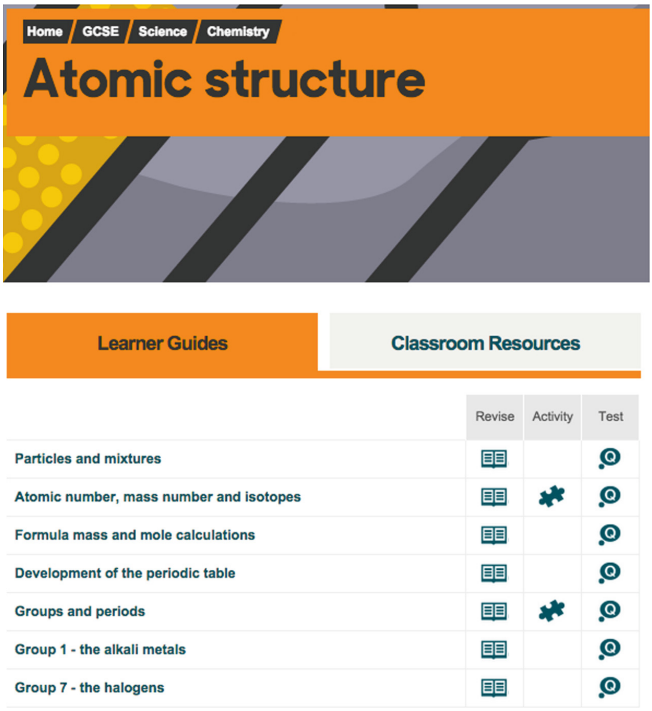

Fig. 2. Example learner guides. Taken from http://www.bbc.co.uk/education/topics/z84k7ty.

Learner Guides. Learner Guides are a rich interactive content format consisting of revision chapters, tests and activities. An example list of learner guides is shown in Fig. 2.

Learner 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 learner guides are structured based on the UK National Curricula. In the next section, we present the back-end architecture of this system.

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 Learner Guides:** 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 [13]. In this architecture, semantic web models

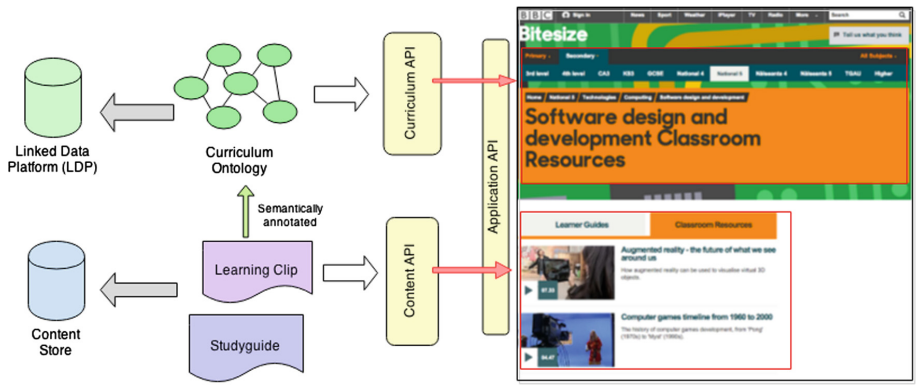

Fig. 3. The BBC knowledge & learning architecture.

and 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 Fig. 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 learner 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 learner 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.

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[3]. The instance data of the curriculum ontology are published on GitHub[4].

The Curriculum Ontology aims to:

- provide a model of the national curricula across the UK
- organise learning resources, e.g. video clips and learner 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.

[3] http://www.bbc.co.uk/ontologies/curriculum.
[4] https://github.com/BBC/curriculum-data.

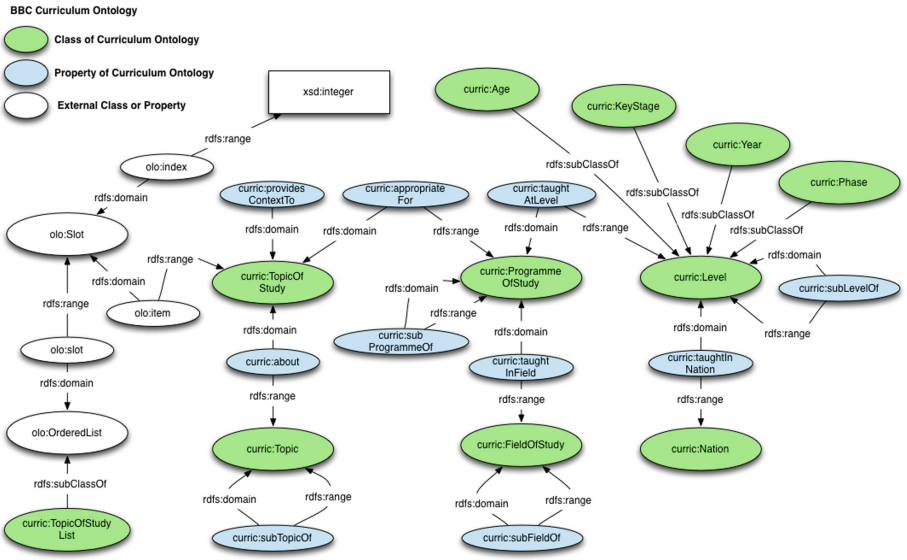

Fig. 4. The curriculum ontology diagram.

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 concepts 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[5]. 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.

[5] 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[6] [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.

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

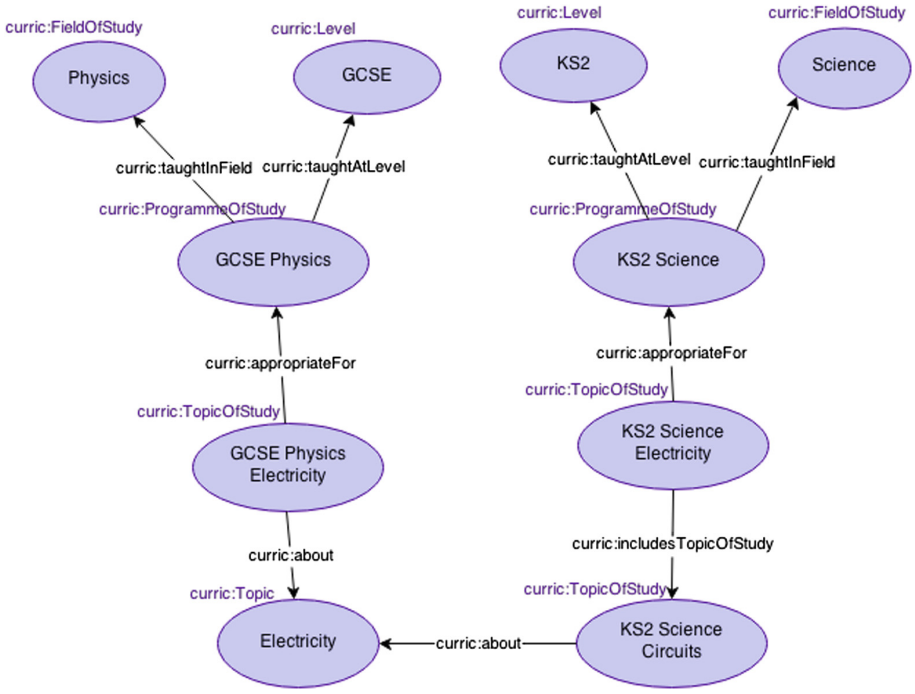

Fig. 5. Example instantiation of the the core concepts from the curriculum ontology.

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')[7]. 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.

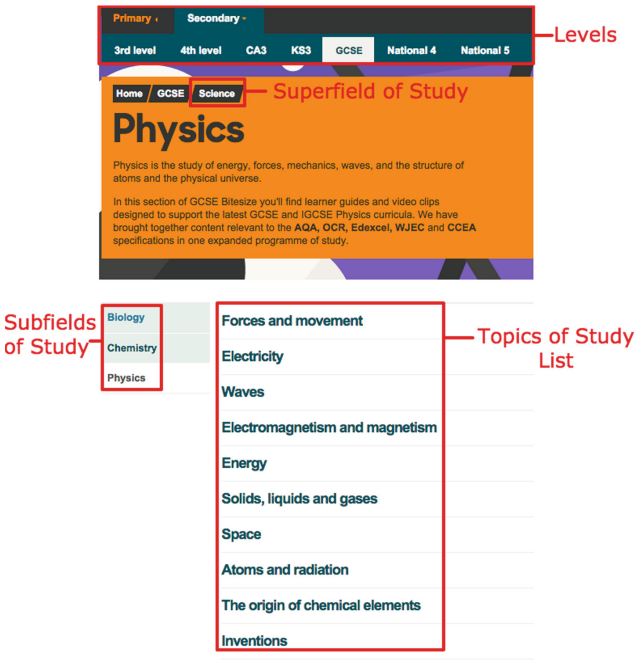

Fig. 6. Example showing the curriculum ontology supporting the BBC knowledge & learning online navigation.

[7] More precisely, 'GCSE' is the qualification (Phase) but it is inferred to be a Level too.

In particular, it shows how the topic of study GCSE Physics Electricity and related data of Fig. 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 provides the result of the SPARQL queries in the Application API (Fig. 3). In addition, the list of topics of study shown in Fig. 6 is implemented with the Ordering List Ontology Design Pattern (ODP), described in Sect. 4.1.

The workflow for publishing new content in the website is shown in Fig. 7. Editorial teams create new content based on a DSP approach. The content that is commissioned is always in the context of the UK National Curricula. That allows the editorial team to initially define the curriculum vocabulary for the new content. These are the instance data of the curriculum ontology. An example is the creation of a new programme of study e.g. 'KS1 Computing' and topics of study for this programme. On the second step editorial team authors new content like study guides and learning clips. The DSP approach allows to associate the curriculum ontology instance data with the content. For example, a video for KS1 Computing is tagged with a corresponding topic of study from the curriculum ontology, which is named as 'Computer science'. Figure 8 shows how

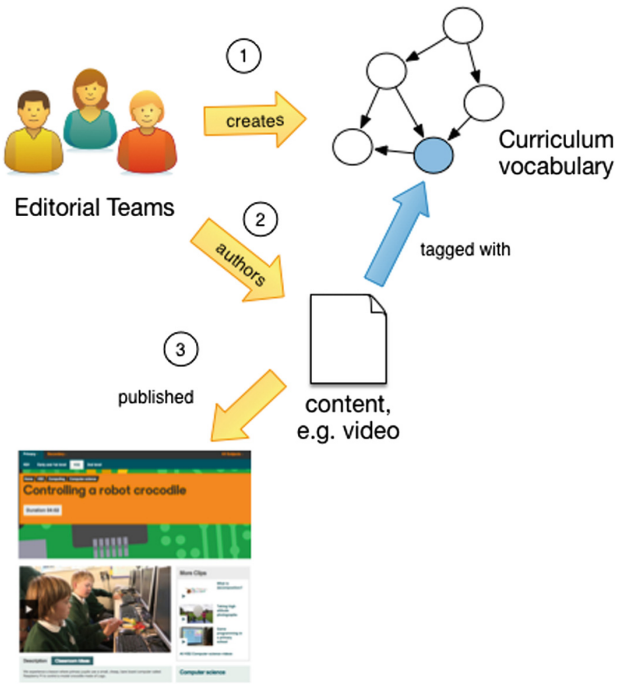

Fig. 7. Dynamic semantic publishing workflow for bitesize content.

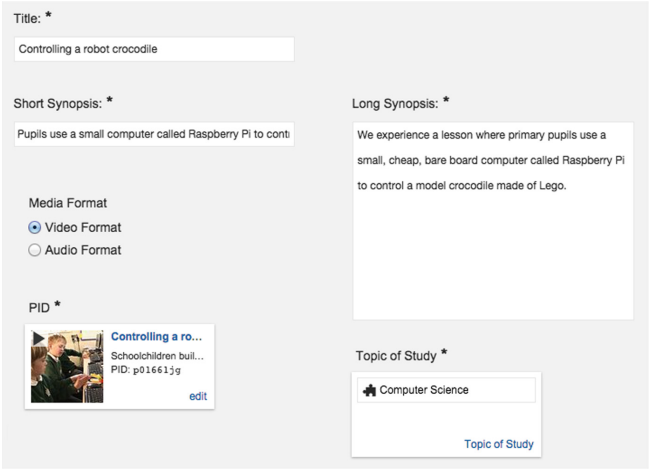

Fig. 8. A semantically annotated video for bitesize in the content store.

tagging happens in the content store. A member from the editorial team, applies the curriculum topic of study 'Computer Science' to a learning clip about controlling a robot crocodile.

As mentioned in Sect. 3, the description of new content is saved in the form of XML in the content store. The web interface for creating new content contains a tag picker where the content is associated with a particular topic of study from the curriculum ontology data. To achieve this, the content store is connected with the LDP for picking topics of study. A consistent tagging approach is adopted, where content in the context of the Curriculum is always tagged with a topic of study. Thus in the web form of Fig. 8, the editorial team can select only a topic of study to associate it with the clip. There are two reasons for this. First, the content is coupled in the navigation with topics of study and second, topics of study are interlinked with other concepts from the curriculum ontology such as programme of study, field of study etc. so this information can be retrieved through property paths.

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. Figure 9 shows how a video can be used in different education context. For example, the figure shows that a learning clip about 'The social effects of automation' used for the topic of study, 'Computers in society' also features in other topics of study, such as 'the history of ICT' and 'Industrial and commercial applications'. Thus, a clip can be used in the context of multiple topics of study with different classroom ideas. In this way the user can browse other related topics to a particular clip.

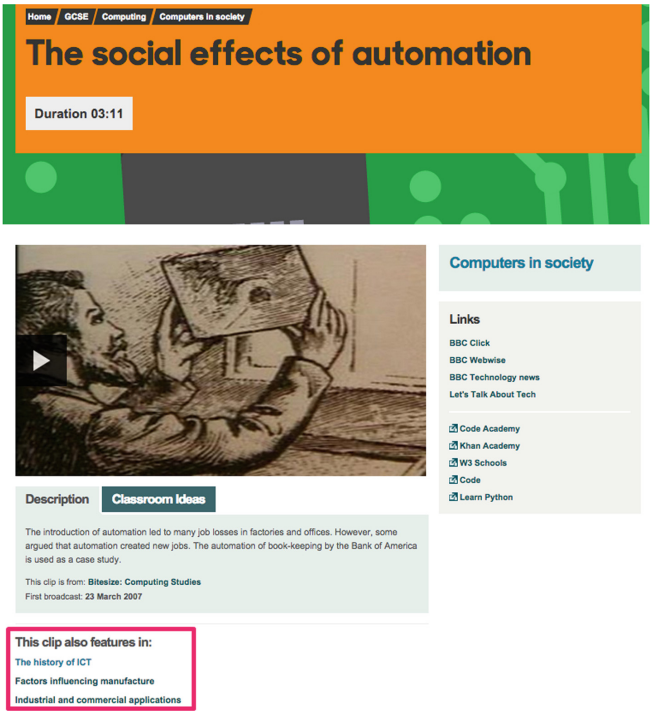

Fig. 9. The use of a learning clip in multiple topics of study.

5.2 SPARQL Support

The main views and navigation of the website are driven by the curriculum LDP data. In particular, for every view a SPARQL CONSTRUCT query is run for creating this view by querying the right part of the curriculum graph.

For example, the SPARQL CONSTRUCT query shown in Fig. 10 aims to retrieve the programmes of study associated with a specific educational level i.e. GCSE. The navigation components on the corresponding Web page[8] of the GCSE level are shown according the results of this query. The presented SPARQL query returns the label, description and the depiction image of the relevant programmes of study and fields of study, as well as detailed information about the required educational level itself. In addition, the results of this query also tells for which nation the educational level is appropriate.

As shown below, the SPARQL query was written using concepts and predicates defined in the aforementioned BBC Curriculum Ontology and the BBC Core Concepts Ontology[9]. In more detail, Line 13 to 18 of the SPARQL query gathers information about the given educational level, while Line 19 to 22 trying

[8] http://www.bbc.co.uk/education/levels/z98jmp3.
[9] http://www.bbc.co.uk/ontologies/coreconcepts.

```
CONSTRUCT {
  ?klPos a curric:ProgrammeOfStudy ;
    rdfs:label ?posLabel ; dc:description ?description ;
    curric:taughtAtLevel ?klLevel ; curric:taughtInField ?klField ;
    klal:depictionPID ?posDepictionPID ; curric:subProgrammeOf ?klSuperPos .
  ?klLevel a ?levelType ; curric:taughtInNation ?nation ;
    rdfs:label ?levelLabel ; dc:description ?levelDescription .
  ?klField a curric:FieldOfStudy ; rdfs:label ?fieldLabel ;
    klal:depictionPID ?fieldDepictionPID ; dc:description ?fieldDescription ;
    curric:subFieldOf ?klSuperField .
  ?nation a curric:Nation ; rdfs:label ?nationLabel .
} WHERE {
  ?level a ?levelType ;
    core:sameAs <http://www.bbc.co.uk/education/levels/z98jmp3#level> ;
    core:sameAs ?klLevel ; core:preferredLabel ?levelLabel .
  OPTIONAL {
    ?level curric:preferredDescription ?levelDescription .
  }
  OPTIONAL {
    ?level curric:taughtInNation ?nation .
    ?nation a curric:Nation ; core:preferredLabel ?nationLabel .
  }
  OPTIONAL {
    ?pos a curric:ProgrammeOfStudy ; core:sameAs ?klPos ;
      core:preferredLabel ?posLabel ; klal:depictionPID ?posDepictionPID ;
      curric:taughtAtLevel ?level ; curric:taughtInField ?field .
    ?level core:sameAs <http://www.bbc.co.uk/education/levels/z98jmp3#level> .
    OPTIONAL {
      ?pos curric:preferredDescription ?description .
      OPTIONAL {
        ?pos dc:description ?descriptionlang
          BIND(?descriptionlang as ?description)
          FILTER ( lang(?descriptionlang) = "en-gb") .
      }
    }
    OPTIONAL {
      ?pos curric:subProgrammeOf ?superPos .
    }
    ?field a curric:FieldOfStudy ; core:sameAs ?klField ;
      klal:depictionPID ?fieldDepictionPID ; rdfs:label ?fieldLabel
      FILTER ( lang(?fieldLabel) = lang(?levelLabel) ) .
    OPTIONAL {
      ?field curric:preferredDescription ?fieldDescription .
    }
    OPTIONAL {
      ?field curric:subFieldOf ?superField .
      ?superField core:sameAs ?klSuperField .
    }
  }
} ORDER BY ?fieldLabel
```

Fig. 10. The SPARQL query for retrieving information about the educational level GCSE.

to get the nations in which the education level is taught. Line 23 to 38 generates a set of the programmes of study which are linked to the given level via *curric:taughtAtLevel*. Furthermore, for the purpose of rendering the Web page, we use Line 39 to 48 of the query to retrieve the fields of study associated with those programmes of study.

Figure 11 shows the RDF triples aggregated by executing the SPARQL query against the data repository. Those RDF statements describe the programmes of study related to the educational level of GCSE. It is worth noting that the resulting RDF triples forms a graph since we use CONSTRUCT to query the RDF repository. The reason for using CONSTRUCT instead of SELECT is that it facilitate parsing the results, because all the data are in the format of RDF.

```
<http://www.bbc.co.uk/education/levels/z98jmp3#level> a curric:KeyStage, curric:Level;
   rdfs:label "GCSE"@en-gb ;
   dc:description "GCSE is the qualification taken by 15 and 16 year olds to mark their graduation from the Key Stage 4 phase
of secondary education in England, Northern Ireland and Wales."@en-gb ;
   curric:taughtInNation <http://www.bbc.co.uk/things/00eb010f-568a-4b89-bbfe-799d5b812bed#id>,
      <http://www.bbc.co.uk/things/06dbdeed-0f5e-41f7-b2ef-0f3e3039a72f#id>,
      <http://www.bbc.co.uk/things/9ba4d1e5-7cc7-48c0-9793-ad198403c54c#id> .

<http://www.bbc.co.uk/things/00eb010f-568a-4b89-bbfe-799d5b812bed#id> a curric:Nation ;
   rdfs:label "Wales"@en-gb .

<http://www.bbc.co.uk/things/06dbdeed-0f5e-41f7-b2ef-0f3e3039a72f#id> a curric:Nation ;
   rdfs:label "Northern Ireland"@en-gb .

<http://www.bbc.co.uk/things/9ba4d1e5-7cc7-48c0-9793-ad198403c54c#id> a curric:Nation ;
   rdfs:label "England"@en-gb .

<http://www.bbc.co.uk/education/subjects/zpsvr82#programme-of-study> a curric:ProgrammeOfStudy ;
   rdfs:label "GCSE Business"@en-gb ;
   dc:description "GCSE Business Studies is designed for students finishing secondary school to learn skills for running a
business, such as managing money, advertising and employing staff."@en-gb ;
   klal:depictionPID "p017b7l9" ;
   curric:taughtAtLevel <http://www.bbc.co.uk/education/levels/z98jmp3#level> ;
   curric:taughtInField <http://www.bbc.co.uk/education/subjects/zjnygk7#field-of-study> .

<http://www.bbc.co.uk/education/subjects/zrkw2hv#programme-of-study> a curric:ProgrammeOfStudy ;
   rdfs:label "GCSE Science"@en-gb ;
   dc:description "Science is the systematic study of the physical and natural world through observation and
experimentation."@en-gb ;
   klal:depictionPID "p017dpn3" ;
   curric:taughtAtLevel <http://www.bbc.co.uk/education/levels/z98jmp3#level> ;
   curric:taughtInField <http://www.bbc.co.uk/education/subjects/z7nygk7#field-of-study> .

<http://www.bbc.co.uk/education/subjects/z2f3cdm#field-of-study> a curric:FieldOfStudy ;
   rdfs:label "Geography"@en-gb ;
   dc:description "Geography is the study of the shape and features of the Earth's surface, including countries, vegetation,
climates and how humans use the world's resources."@en-gb ;
   klal:depictionPID "p017dmsh" .

<http://www.bbc.co.uk/education/subjects/zjnygk7#field-of-study> a curric:FieldOfStudy ;
   rdfs:label "Business"@en-gb ;
   dc:description "Business studies covers the different skills for running a business, such as managing money, advertising and
employing staff."@en-gb ;
   klal:depictionPID "p017b7l9" .

<http://www.bbc.co.uk/education/subjects/z7nygk7#field-of-study> a curric:FieldOfStudy ;
   rdfs:label "Science"@en-gb ;
   dc:description " "@en-gb ;
   klal:depictionPID "p017dpn3" .
```

Fig. 11. RDF triples generated by executing the SPARQL query.

5.3 Mapping to LRMI Vocabulary

The Learning Resource Metadata Initiative (LRMI) [1,15] 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 Fig. 12.

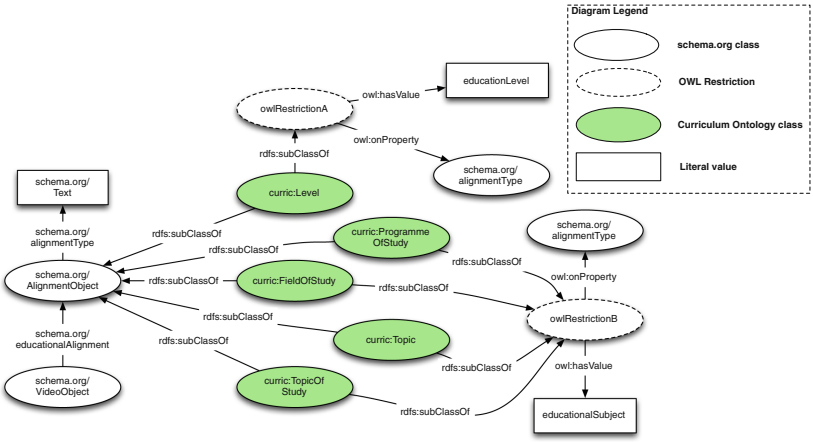

Fig. 12. A model representing the mappings of the curriculum ontology to Schema.org LRMI vocabulary.

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 Fig. 12, 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 owl:Class ;
    rdfs:subClassOf _:owlRestrctionA ;
    rdfs:subClassOf schemorg:AlignmentObject .

_: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".

5.4 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 13 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.

```
<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. 13. Example of semantic markup.

Google Custom Search engines[10] can be easily built with the help of semantic markup. A custom search engine built with refinement for levels GCSE, KS3 (more:p:AlignmentObject-name:KS3, more:p:AlignmentObject-name:GCSE)[11]

[10] https://www.google.com/cse.

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

and other levels is shown in Fig. 14. The screenshot shows the results when searching for 'Hamlet'. The results can be categorised by level, e.g. show video clips that are appropriate for level KS3.

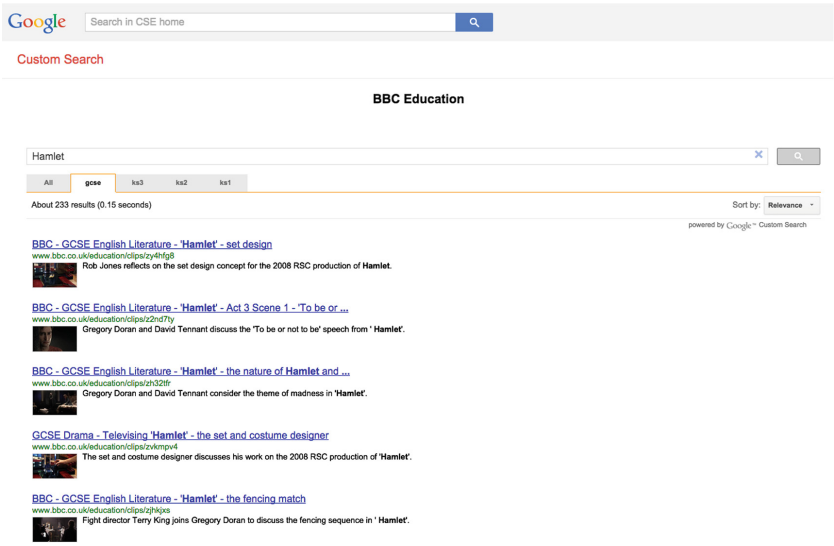

Fig. 14. Google custom search engine for BBC education.

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 [11], MONTO, A Machine-Readable Ontology for Teaching Word Problems in Mathematics is described. The MONTO ontology is based on a Mathematical thinking framework for the representation of the users cognitive model and learning strategy and it is aligned with the generation of domain specific topics (e.g. learning the topic of Circumference in Mathematics).

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

In addition, the work from [12,14] was also reviewed when designing the curriculum ontology. It is one of 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].

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.

The adoption of an ontology model in the architecture of the system also allows the seamless extension of the data to reflect changes in the National Curricula. For example there are plans for the inclusion of the '16 Plus' Phase and its corresponding Programmes of Study in the Bitesize pages.

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.

[13] http://linkeduniversities.org/lu/.
[14] http://linkedup-project.eu/.

Acknowledgments. The authors would like to thank Ali Craigmile, Jemma Summerfield, Paul Rissen, Amaal Mohamed and Zoe Rose for their help on the design of the BBC Curriculum Ontology.

References

1. The Learning Resource Metadata Initiative (LRMI) Specification. http://www.lrmi.net/the-specification. Accessed 03 July 2014
2. Abdallah, S.A., Ferris, B.: The Ordered List Ontology Specification (2010). http://smiy.sourceforge.net/olo/spec/orderedlistontology.html. Accessed 03 July 2014
3. Barker, P.: Explaining the LRMI Alignment Object [blog post] (2014). http://blogs.cetis.ac.uk/philb/2014/03/06/explaining-the-lrmi-alignment-object/
4. Berthold, M., Dahn, I., Kiefel, A., Lachmann, P., Nussbaumer, A., Albert, D.: ROLE learning ontology: an approach to structure recommendations for self-regulated learning in personalized learning environments. In: The Future of Learning Innovations and Learning Quality, p. 104 (2012)
5. Collison, G., Elbaum, B., Haavind, S., Tinker, R.: Facilitating online learning: Effective strategies for moderators. In: ERIC (2000)
6. d'Aquin, M.: Linked Data for Open and Distance Learning (2012)
7. Demartini, G., Enchev, I., Gapany, J., Cudré-Mauroux, P.: The bowlogna ontology: fostering open curricula and agile knowledge bases for europe's higher education landscape. Semant. Web **4**(1), 53–63 (2013)
8. Gangemi, A., Presutti, V.: Ontology Design Patterns. In: Staab, S., Studer, R. (eds.) Handbook on Ontologies. International Handbooks on Information Systems, pp. 221–243. Springer, Heidelberg (2009)
9. Horrocks, I., Patel-Schneider, P.F., Van Harmelen, F.: From SHIQ and RDF to OWL: the making of a web ontology language. Web Semant. Sci., Serv. Agents World Wide Web **1**(1), 7–26 (2003)
10. Kobilarov, G., Scott, T., Raimond, Y., Oliver, S., Sizemore, C., Smethurst, M., Bizer, C., Lee, R.: Web-How, media meets semantic the BBC uses DBpedia, linked data to make connections. In: Aroyo, L., et al. (eds.) The Semant. Web: Res. Appl. LNCS, vol. 5554, pp. 723–737. Springer, Heidelberg (2009)
11. Lalingkar, A., Ramanathan, C., Ramani, S.: MONTO: A machine-readable ontology for teaching word problems in mathematics. J. Edu. Technol. Soc. **18**, 197–213 (2015)
12. Morris, R.D.: Web 3.0: Implications for online learning. TechTrends **55**(1), 42–46 (2011)
13. Rayfield, J.: Dynamic semantic publishing. In: Maass, W., Kowatsch, T. (eds.) Semantic Technologies in Content Management Systems, pp. 49–64. Springer, Heidelberg (2012)
14. Rissen, P.: A Curriculum Ontology [blog post] (2011). http://www.r4isstatic.com/179. Accessed 03 July 2014
15. Waters, J.K.: Sifting the data. T.H.E. J. **40**, 15–18 (2013)