

Connecting medical educational resources to the Linked Data cloud: the mEducator RDF Schema, store and API

Evangelia Mitsopoulou¹, Davide Taibi², Daniela Giordano³, Stefan Dietze⁴, Hong Qing Yu⁴, Panagiotis Bamidis⁵, Charalampos Bratsas⁵, Luke Woodham¹

¹ St George's University of London, Center for Medical and Healthcare Education, Cranmer Terrace, SW17 0RE London, United Kingdom
{emitsopo, lwoodham}@sgul.ac.uk

² Consiglio Nazionale delle Ricerche, Istituto per le Tecnologie Didattiche, Via Ugo La Malfa 153, 90146, Palermo, Italy
davide.taibi@itd.cnr.it

³ Università di Catania, Dipartimento di Ingegneria Elettrica, Elettronica e Informatica, Viale A.Doria 6, 95125, Catania, Italy
dgiordan@dieei.unict.it

⁴ The Open University, Knowledge Media Institute, MK7 6AA, Milton Keynes, UK
{s.dietze, h.q.yu}@open.ac.uk

⁵ Aristotle University of Thessaloniki, PO Box 323, 54124, Thessaloniki, Greece
{bamidis, mpampis}@med.auth.gr

Abstract. The existence of non-interoperable metadata schemas and limited use of shared vocabularies means that retrieving and processing educational resources across the Web represents a challenge. The emerging Linked Data paradigm has provided the tools and methods to share and expose metadata in a more unified and well interlinked manner, permitting both humans and machines to process Web data. The availability of vast amounts of RDF-based Linked Data is offering a worthwhile alternative to the isolated and heterogeneous data silos which previously dominated the Web. In the EC-funded project mEducator a standardised approach is proposed to describing and exposing medical educational resources. In this paper are described firstly the design considerations, and conceptual model upon which mEducator's metadata scheme approach was based. Afterwards, follows the description of the serialization of the scheme in RDF/XML, and in turn follows an example showing how medical educational resources are exposed on the Web using an RDF endpoint, and discuss the potential advantages of this approach.

Keywords: Metadata, Linked Data, RDF vocabularies, medical learning resources, mEducator, Conceptual Model, RDF Store

1 Introduction

Medical and Healthcare Education has been modernised lately by means of Information and Communication Technologies (ICT). Many European academic institutions use their own Learning Content Management Systems (LCMS) in order to deliver educational resources in their curriculum. These resources can have different formats, such as images, text, videos, podcasts, virtual patients, serious games about health, diagnostic tests such as electrocardiograms (ECGs) etc. Currently, it is difficult to exchange resources between different platforms due to lack of standardised content sharing mechanisms. An attempt to solve the above problem is being made by the mEducator Best Practise Network (BPN) [1], funded by the EC in the eContentplus programme, which aims to analyze the use of existing standards and reference models in the e-learning field to discover, retrieve, share and re-use medical educational resources. The goal of the current paper is to present this effort and to show how this effort could be further examined, evaluated and reused by a wider community.

The diffusion of learning experiences based on the Web has increased over the years, and the application of Semantic Web technologies to e-learning has been widely studied by researchers. In 2001 Tim Berners Lee presented the Semantic Web as a Web interpretable by machines [2]. Many research studies propose the application of Semantic Web technologies in different e-learning situations. In [3] and [4] ontologies are used to describe the contents of learning resources. The importance of the use of the Semantic Web approach to learning object metadata representation is discussed in [5], [6]. The use of Semantic Web services architecture for e-learning was proposed by [7] and [8]. The modeling of an e-learning environment by means of a multi agents system was studied by [9]. Virtual learning environments based on Semantic Web technologies were discussed in [10]. Recent developments in the social Semantic Web have focused on informal learning experiences [11], as well as the diffusion of Linked Data, which has opened up new opportunities for improving e-learning experiences.

Linked data can be useful to support interoperability, accessibility and reusability of learning resources. For this reason, in the mEducator project, a standardised metadata description scheme has been proposed, and an RDF triple-store repository compliant with Linked Data requirements has been created to store educational resources. By using a standardised format to describe resources a basis for interoperability and a framework for discovery will be provided [12].

The rest of this paper is structured as follows: Section 2 describes the development and structure of the conceptual model and the schema, along with its RDF serialization. The mEducator implementation and its application of Linked Data principles, including the RDF instance file, is discussed in Section 3. Details of the REST API and rdf repository are provided, as well as a description of the approach taken by the mEducator RDF schema and RDF endpoint to interlink educational resources with data sets as part of the Linked Data cloud.

2 A general schema for educational resources

2.1 In General

The first step when developing a metadata scheme is to specify what kind of metadata is needed in order to solve a problem in a specific domain of interest. In this case, the domain of interest is medical and healthcare education, and the problem is how to describe different types of medical resources in order to facilitate content sharing and re-use across institutions. In particular the description must allow resources to be efficiently repurposed, a process that involves all or part of a resource being modified and re-used to suit it to an audience or purpose different than was originally intended. Repurposing is a term first used in [13] to refer to the adaptation of existing online learning resources to different educational levels. Later in [14] the term repurposing was used in a wider sense to refer to the conversion of a Virtual Patient (VP) created for one purpose into a VP fit for another purpose i.e. a different subject, discipline or healthcare profession. Virtual Patient as defined in [13] is a specific type of medical educational resource that refers to an interactive computer simulation of real-life clinical scenarios for the purpose of medical training, education, or assessment.

In order to best determine the metadata requirements for the project a conceptual model for the description of medical educational resources was formulated. The needs of mEducator's target group were identified by conducting a survey of mEducator's partners. The results of the survey indicated the nature of current perceptions about the concept of educational content, educational content sharing and repurposing. Based on the survey's results and following an investigation of existing e-learning standards, an initial framework for the metadata concepts was set that allowed the above educational material to be annotated semantically and described in a machine readable format. A conceptual model of the schema was then developed based on this initial framework. Taking into consideration the fact that the intended users are not professional indexers and would tend to fill in the minimum required information, the generally agreed approach was to keep the schema as lean as possible and to maximise the re-use of existing e-learning standards.

2.2 Research on existing Standards

Existing standards for describing learning objects, in particular IEEE Learning Object Metadata (LOM) [15] and its extension Healthcare LOM [16] - designed by MedBiquitous to provide for the specific demands of medical and healthcare education - were considered as the starting point for the development of the schema. This starting point was also based on previous research done by [17] whose input to the current work was fundamental. To continue, the XML binding of IEEE LOM was initially reused by mEducator in order to implement the scheme in XML. However, as the need to ensure that the metadata was compliant with the principles of Linked Data became clear, RDF [18] was identified as the most appropriate framework to use. The notion of linking between resources and ontologies through RDF URIs offered a way of benefitting from the many advantages of Linked Data.

Work towards an implementation of IEEE LOM in RDF has been started by [19], but this work was discontinued around 2004. For this reason Dublin Core [20] was considered and Dublin Core's expression in RDF/XML [21], along with a further investigation of existing RDF Vocabularies, made up the final phase of the process of structuring mEducator's conceptual model. Examples of these RDF Vocabularies includes SKOS[22], which was used to provide a standard way of representing controlled vocabularies in RDF defined within mEducator, and FOAF [23], which was used to describe people in RDF.

Those properties of Dublin Core that met mEducator's conceptual model needs were reused in the scheme as super properties. They were not used in the same manner as they are defined in the Dublin Core element namespace [24], because this approach was considered to be too general. In contrast, the approach of the Dublin Core Terms Namespace [25], in which all properties are sub-properties of the ones defined in [24], was adopted i.e. mdc:creator, mdc:identifier, mdc:title, mdc:rights, mdc:subject, mdc:language are sub-properties of dc:creator, dc:identifier etc respectively, where mdc is the prefix for mEducator Namespace [26]. From the FOAF specification, some basic properties were reused i.e. those that are used to describe a person: foaf:name, foaf:Organisation, foaf:mbox_sha1sum.

Where existing standards did not meet mEducator requirements, additional properties were proposed. For example, a property was needed in the schema to describe to which organisation a person belongs to. The lack of such a property in FOAF necessitated the proposal of a new property within mEducator's namespace i.e. mdc:memberOf.

2.3 Conceptual Model

The conceptual model for the Learning Resource that was developed to be the basis of the mEducator schema is intended to:

- 1) Capture the semantics of the relationships (if any) among the metadata fields and the Learning Resource
- 2) Make evident the rationale of the design decisions in the schema
- 3) Identify potentially overlapping semantics in the metadata fields, and remove them in order to support the modular construction of metadata
- 4) Clearly locate the appropriate place for the development of mEducator-specific controlled vocabularies and taxonomies.

As depicted below (Figure 1), the basic metadata of a medical learning resource consists of: its title, its identifier (i.e. url), the language in which it is created, the language of its metadata, the date of resource creation, the date of metadata creation the resource author, the author of the metadata, a brief description, a technical description, its IPR license, its citation and any further information that certifies its quality. In addition, further metadata has been proposed that provides pedagogical value such as: educational objectives, assessment methods, teaching instructions, educational level, educational prerequisites and educational outcomes. Further metadata will be used to provide keywords describing the resource, and to describe the discipline and discipline specialty to which a resource relates.

Another category of metadata fields included in the proposed scheme capture the repurposing history of the resource. The definition of the repurposing process is given in [14] and the metadata provided may include the title and identifier of the parent resource from which the current resource has been created, any further resource(s) that the current resource has been repurposed to, the type of repurposing that took place (i.e. change of language, change of target etc.) and a brief description about the repurposing process that took place.

There are different types of medical educational resources, and this information should be captured and described. Within mEducator two controlled vocabularies have been created to enable the categorisation of the resources based on two different criteria: the informational quality (including the nature of the information provided, how it is organized, presented or collected) and the media format of the resource (or the media formats included in the resource if this is complex and includes multiple media types). These use the resourceType metadata field and the mediaType metadata field.

Metadata fields for describing accompanied resources are also included. The rationale behind accompanied resources is that sometimes an educational resource is accompanied by other resources such as pdfs, videos, images etc in order it to be fully understood and better taught. In order to describe this information the isAccompaniedResource metadata field was proposed.

in the conceptual model become properties in the RDF Model. Each property should have a value i.e. the property title can have the value “cardiology”. Generally speaking, the type of value a property can take varies from a plain string, (datatype properties) to a more complex object composed of a group of properties and values (object properties). In order to describe more complicated values or to describe a value whose type is not described by an existing class (e.g. String) it is necessary to define classes. Thus the need to define a new class for a property is dependent on the type of the value that property can take.

Another component that was defined within the RDF Model is controlled vocabularies. A controlled vocabulary is a vocabulary consisting of a “prescribed list of terms or headings, each one having an assigned meaning, and provide a way to organize knowledge for subsequent retrieval” [29]. Controlled vocabularies are, in other words, another type of value that a property can take.

Below are the classes, properties and controlled vocabularies that were defined as part of the RDF Model for mEducator.

Classes
Resource, RepurposingResource, IPRTType, RepurposingContext, EducationalLevel, Discipline, DisciplineSpeciality, Subject, ExternalTerm

Properties
creator, identifier, repurposingIdentifier, description, language, rights, created, metadataCreated, memberOf, profileURI, assessmentMethods, educationalOutcomes, educationalObjectives, teachingLearningInstructions, citation, discipline, disciplineSpeciality, externalTerm, externalSource, conceptID, educationalPrerequisites, educationalContext, educationalLevel, title, repurposingTitle, isAccompaniedBy, toRepurposingContext, fromRepurposingContext, isRepurposedTo, isRepurposedFrom, resourceType, mediaType, technicalDescription, metadataCreator, metadataLanguage, quality, repurposingDescription

Controlled Vocabularies
ResourceType, MediaType, EducationalOutcome, IPRTType, EducationalLevel, RepurposingContext

3 Deployment: an RDF store and API compliant with the mEducator schema

The Linked Data cloud is based on publishing structured data on the Web using RDF, SPARQL and interconnected URIs to reference data entities. That has led to a large

amount of well-connected and interlinked data sets and has emerged as an extremely useful approach for exposing data.

In the mEducator project, a sharing mechanism which exposes educational resource descriptions as rich and well-interlinked Linked Data has been proposed. This approach requires the implementation and application of the mEducator metadata scheme and the provision of an API that enables access to a repository containing this data. This is part of a more general semantic solution based on Linked Services [37] that allows distributed searches and queries across the Web. The detailed description of this solution is outside the scope of the present paper (a more complete description can be found in [30]). While external resource metadata is discovered and processed on the fly, an RDF store complying with the schema proposed in this paper is used to expose retrieved metadata as LOD and enrich it with links to structured LOD data sets. The store's API could be directly accessed by a 3rd party application allowing users to insert new resources or search resources using their metadata, likewise software agents can collect resource metadata using web service endpoint of compliant LCMS, and use the API to store them in the repository.

The solution proposed respects the four principles of Linked Data [31]:

1. The first principle requires the use of URI as a namespace to identify resources
2. The second principle proposes the use of HTTP URI in order to look for information about the resources.
3. The third principle recommends to provide useful information, using RDF when someone looks up a URI.
4. The fourth principle consists in creating links to other resources on the Linked Data cloud

3.1 RDF Schema Level

As shown in the previous section, mEducator's metadata description scheme uses an RDF model to represent its data. Generally speaking, the usage of URIs and RDF in the schema demonstrates the implementation of the basic principles of Linked Data. PURLs [32] along with targeted locations were used in order to develop mEducator's namespaces, and the domain <http://www.purl.org/meducator> has been registered for mEducator. In turn, further subdomains have been registered to define namespaces for both the schema and the controlled vocabularies defined within mEducator. The namespace of the schema is <http://purl.org/meducator/ns/> and the namespaces for the controlled vocabularies are named similarly.

RDF entities – classes and instances - are described using URIs, and most specifically, via HTTP URIs, conforming to the first two design principles of Linked Data. By referencing classes using HTTP URIs and also providing further information regarding their definition, their meaning can be understood even in the event that they become dereferenced.

The definition of properties is done in a similar fashion, with HTTP URIs and additional information regarding their meaning also being provided. In addition to this, property definitions include links to other properties or to classes of other standards. This is one of the strengths of RDF and Linked Data. By connecting

existing standards, and linking to other widely used standards such as Dublin Core the interoperability of the mEducator scheme is maintained.

The use of controlled vocabularies also complies with Linked Data principles, and is implemented in RDF/XML. Some vocabularies were implemented using SKOS i.e. `mediaType`, `ResourceType` and `educationalOutcomes`, while others were implemented using just RDF i.e. `IPR Type` and `Repurposing Context`. In both cases, HTTP URIs have been used to refer to each concept of a controlled vocabulary, e.g. <http://purl.org/meducator/licenses#Attribution> for an IPR license and <http://purl.org/meducator/mediaType#image> for a media type. All of them include the `<rdfs:label>` element that provides useful information in the event that they become dereferenced.

3.2 RDF Instance Level

The incorporation of Linked Data principles at the RDF instance level is similar to that at the schema level. Firstly, each RDF instance is described by an HTTP URI. Secondly, all the properties whose value will be taken from a controlled vocabulary use HTTP URIs. For example, the `ResourceType` property may have the value <http://purl.org/meducator/resourceType#virtualPatient>.

A critical advantage of Linked Data is the interlinking of resources by considering available datasets (bioportal ontologies, mEducator controlled vocabularies) and reusing schemas (FOAF, Dublin Core). In mEducator's case, this is done via the `owl:sameAs` [33] property that is used along with `Subject`, `Discipline`, `DisciplineSpeciality`. For example, the `Subject` property is used to provide keywords that describe the medical resource. These keywords are identified by the user but are defined in an external source. Using the `owl:sameAs` property links to other URIs are established where the definition of the same keyword exists in other taxonomies, enabling other resources to be discovered. In this way mEducator's RDF Schema applies the fourth design principle of Linked Data, linking to other, related URIs to improve the chances of discovering other related information on the Web.

3.3 The mEducator API

The mEducator instances described above are stored in an RDF repository that provides a Representational State Transfer (REST) API, enabling access to the repository by third parties with no knowledge of the underlying schema used to store the data. During the inserting phase the mEducator REST API validates the RDF instances to be inserted against the mEducator RDF schema, and creates a universal unique identifier (UUID) for the mEducator resources inserted in the store according to the mEducator HTTP URI¹.

The mEducator educational resource store provides simplified search mechanisms in order to retrieve information related to the resources in RDF format. The API aims to simplify the search for resources by using properties and features defined in the

¹ <http://purl.org/meducator/resources/UUID>

mEducator RDF schema. The general purpose SPARQL interface provided by the Sesame triple store is replaced with a simpler endpoint appropriately designed to handle mEducator resources. In order to create links with other resources on the Linked Data cloud the mEducator resources have been connected to the BioPortal² vocabularies with regard to disciplines and subjects. A detailed description of these search methods will be discussed in Section 3.4.

```

<rdf:Description rdf:about="http://purl.org/meducator/resources/45b5ab54-4a09-4100-88bb-93057f256da2">
  <rdf:type rdf:resource="http://www.purl.org/meducator/ns/Resource" />
  <rdfs:seeAlso rdf:resource="http://metamorphosis.med.duth.gr/uid#8332" />
  <mdc:identifier>http://www.med.helsinki.fi/tuke/meducator/Kansio_1004/Patient%201004.pdf</mdc:identifier>
  <mdc:title><![CDATA[ ECG Patient case 1004 limb and chest leads & thrombolysis ]]></mdc:title>
  <mdc:rights rdf:resource="http://purl.org/meducator/licenses/Attribution-Non-Commercial-Share-Alike" />
  <mdc:creator>
    <foaf:Person>
      <foaf:name>Timo Kuusi</foaf:name>
    </foaf:Person>
  </mdc:creator>
  <mdc:metadataCreator>
    <foaf:Person>
      <foaf:name>Jarkko Mylläri</foaf:name>
      <mdc:profileURI>http://metamorphosis.med.duth.gr/pg/profile/Jarkko?view=foaf </mdc:profileURI>
    </foaf:Person>
  </mdc:metadataCreator>
  <mdc:created>2010-04-19</mdc:created>
  <mdc:metadataCreated>2010-04-19</mdc:metadataCreated>
  <mdc:subject>
    <mdc:Subject rdf:about="http://meducator.open.ac.uk/ontology/SNOMEDCT/51308006">
      <rdfs:seeAlso>http://purl.bioontology.org/ontology/SNOMEDCT/51308001</rdfs:seeAlso>
      <rdfs:label>Thrombolysis</rdfs:label>
      <mdc:externalSource>SNOMED Clinical Terms</mdc:externalSource>
    </mdc:Subject>
  </mdc:subject>
  <mdc:resourceType rdf:resource="http://purl.org/meducator/resourceType/IMAGE"/>
  <mdc:discipline>
    <mdc:Discipline rdf:about="http://meducator.open.ac.uk/ontology/SNOMEDCT/51308001">
      <rdfs:seeAlso>http://purl.bioontology.org/ontology/SNOMEDCT/51308001</rdfs:seeAlso>
      <rdfs:label>Cardiology</rdfs:label>
      <mdc:externalSource>SNOMED Clinical Terms</mdc:externalSource>
    </mdc:Discipline>
  </mdc:discipline>
  <mdc:educationalContext>Teaching of ECG</mdc:educationalContext>
  <mdc:educationalObjectives>Reading and interpreting ECG</mdc:educationalObjectives>
</rdf:Description>

```

Fig. 2. Example of a mEducator resource description

Figure 2 shows an example of a mEducator resource, in which:

- the mEducator namespace (<http://www.purl.org/meducator/ns/>) is used to identify the type of the resource;
- subject and discipline are connected to the Bioportal ontology;
- educational context and objective are properties of the resource as defined in the mEducator schema;
- digital rights of the resource is connected to the Creative Commons;
- the FOAF ontology is used to reference creator and metadata creator.

² <http://bioportal.bioontology.org/>

3.4 The mEducator repository architecture

The mEducator repository stores medical learning resources in RDF format using a SESAME RDF triple store. In the project, a REST API has been created with the aim of making resources compliant with the four Linked Data principles and simplifying the repository interoperability with external environments (data stores, software applications, web agents, and so on). At present a social collaborative educational network [34], *Metamorphosis* based on the social environment Elgg, uses this API to provide a web user interface to the mEducator resources. However, as mentioned above, the API is available to any 3rd party applications to, for instance, query and retrieve resource metadata. Basically the API is an interface that external software agents (clients, web services, and so on) could use to handle mEducator resources. Moreover, future developments envisage the access to the API functionalities considering different types of authentication levels.

It is important to note that a SESAME triple store already offers a complete set of REST methods to work with the resources and the entities belonging to the store. However, these methods are designed to work with general RDF resources; for this reason it was necessary to develop functionalities specifically designed to handle and process mEducator RDF schema compliant data.

Taking into consideration the characteristics of mEducator resources, the API implements methods to insert the resources into the store, to retrieve the resources using different search criteria, and to update the description of a resource and to delete resources. The REST protocol uses the HTTP methods POST, GET, PUT and DELETE to implement the typical database CRUD (create, retrieve, update, delete) operations. The mEducator resources REST API is written in Java, specifically the project uses Jersey, the reference implementation of the JSR-311 [35], to create a RESTful endpoint for the mEducator repository.

Considering the software architecture the main part of the API consists of:

- Rest Interface: this module implements the endpoint for the services defined in the mEducator project. It manages the HTTP requests, defining the map between http URL and the Java method that implements the required behaviour.
- Controller: this module addresses the requests coming from the Rest Interface to the right handler. In particular, during the inserting phase, it uses the Schema Validator to check the validity of a new resource with respect to the mEducator schema, and for the searching functionalities it delegates the Query Manager module to address a query to the Sesame store.
- Schema Validator: this module uses the Jena Validity Report to perform validation of the RDF file representing a resource against the mEducator RDF schema. If the model is not valid, the resource is not inserted into the store and the conflicts that have caused the invalid condition is reported.
- Repository Manager: this module manages the connection with the Sesame store.
- Query Manager: this part of the architecture is responsible for managing the search requests and obtaining the results from the Sesame store.

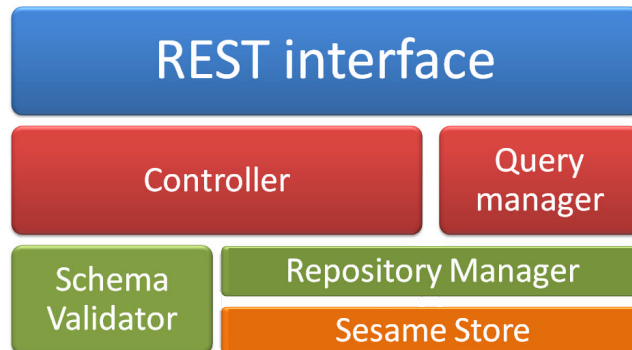


Fig. 3. Main architectural components of the mEducator resources REST API.

The following query types have been developed in this version of the API:

1. the `searchByPropertyValue`, this kind of search uses the couple property-value to perform a search on the resources stored in the Sesame store.
2. the `searchByKeyword` this query creates an RDF graph of the resources with a specified keyword in one of its values.
3. the `searchByID` this query uses the DESCRIBE statement to return an RDF graph related to the resource with a specified UUID
4. the `searchBySeeAlso` this query is used to search the repository for the resources with a specified `seeAlso` property.

In retrieving the resources from the SESAME store, particular attention was given to managing the enclosures and blank nodes of the resources. In SPARQL, the DESCRIBE queries return all the RDF triples of a resource but not the RDF triples of the blank nodes related to it. A similar problem arises from deleting resources using the DELETE statement, even though in this case only the main resource is deleted and not all the related blank nodes.

4 Conclusions

The work presented in this paper has been designed to facilitate the connection of the mEducator repository to the Linked Data cloud. [36] reports the basic steps needed to publish data as Linked Data on the Web; it is necessary to assign a URI to the objects described by the data and to create links to other data on the Web, as well as providing metadata about the published data.

All the work that has been done so far is in line with the approaches being taken by big initiatives such as the Dublin Core Metadata Initiative. Taking this approach ensures alignment with current versions of controlled vocabularies, allowing for a rich choice of terminology (from external sources) to be made available as suggestions both during the search and the metadata filling process. The investigation of existing e-learning standards and their adoption, along with the reuse of existing RDF vocabularies within the schema, ensured that the work of mEducator is as interoperable as possible. This interoperability allows for connections to be made with other communities using strict Healthcare LOM or other schemas.

The scheme will initially be used by mEducator partners to describe their medical educational resources in two sharing mechanisms developed as part of the mEducator Best Practice Network and recommendations, and best practices will be produced. At present, the mEducator RDF store REST API assigns a valid URI to the new resources inserted into the repository, and metadata about resources are also provided using search methods. Interlinking of mEducator resources to the Linked Data cloud is currently being supported by enriching data sets with references to biomedical data available via the BioPortal vocabularies. That way, for instance, free text descriptions of subjects, keywords or disciplines are (semi-)automatically extended with references to related terms in established vocabularies.

While recent work has established the infrastructure to expose medical educational resources in mEducator, ongoing and future work is dealing with populating the data store, enhancing the enrichment process and integrating the data/store via its API into third-party educational applications. The intention is also to permit third parties to use the schema for their own resource description, while the submission of the schema to standardisation groups would also be of importance.

You can find further information about the schema, best practice guidelines, related tools and the created API at the mEducator project website <http://www.meducator.net>.

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