

# Competence development of STE(A)M educators through online tools and communities

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## D2: STE(A)M educational objects meta-data profile

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*Abstract:* This deliverable provides a basis of the metadata profiles that will be used for STE(A)M educational objects as well as an ontology of STE(A)M education terms concepts and items that will be used to index STE(A)M education resources.

*Authors:* N. Spyropoulou, A. Iossifides (Iosifidis), I. Zaharakis and A. Kameas (CTI)



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## Abstract

The aim of this deliverable is twofold: to provide a consistent and solid basis of the metadata profiles that will be used for STE(A)M education objects and practices as well as an ontology of STE(A)M education terms concepts and items that will be used to index STE(A)M education resources. This deliverable is public and will be subjected to community consultation for improvement.

The document includes two parts, the initial metadata profiles design and the initial STE(A)M ontology. The introductory chapter provides the scope of the deliverable, its importance and contribution towards the objectives of the project. It describes the main outcomes and its coverage both in time and educational context of the project.

Chapter 2 deals with the metadata profile definitions for the educational objects (classes) that were created during the first six months of the project. In specific, Chapter 2 provides the methodology followed for the metadata design of the educational practices and policies as well as that of the general repository entries. The requirements, the background and the decisions that were made are first explained. Next, the detailed metadata profiles themselves are given, in tabular form, accompanied by all the necessary information to facilitate their understanding.

Chapter 3 provides the methodology that has been followed in order to develop a STE(A)M ontology. At first, an introduction regarding to what an ontology is, its structure and its importance are presented. Next, the adopted methodology (proposed by Noy and McGuinness [1]) is presented, describing all the necessary phases alongside with the detailed description of the STE(A)M ontology. Finally, in order to evaluate the ontology, the competency questions used to validate it with the use of DL Queries, are presented.

The main innovative contributions of this deliverable are two: first, a new, complete metadata scheme is proposed for educational practices and policies, based on the well defined DCMI (Dublin Core Metadata Initiative) approach; second, a novel ontology is established for STE(A)M education.

## 1 Introduction

This chapter provides the scope of the deliverable in the context of WP2 and STE(A)MonEdu project as a whole. It describes the necessity of a compact and interoperable metadata profile of the basic education objects as well as an expandable ontology of STE(A)M education terms and concepts.

The project has proposed to invest in the professional development of educators in order to facilitate and enhance the implementation of STE(A)M education. To this end, it has developed and continuously improves an online peer learning and crowdsourcing platform to support the community of educators in collecting good practices and STE(A)M education policies so as to deliver (a) the STE(A)M competence framework and the STE(A)M educator profile, (b) a STE(A)M education framework, including STE(A)M body of knowledge, template curricula and learning activities, (c) a training course for STE(A)M educators, including a MOOC, and (d) a STE(A)M readiness self-assessment online tool for educational organizations. The first steps to achieve these objectives include

- collection and assessment of practices based on local and regional initiatives that support STEM and STE(A)M education,
- collection, analysis and indexing using a proper metadata scheme of educational content uploaded to the platform,
- design of an initial STE(A)M ontology, which will be further enriched during the lifetime of the project.

The platform has to integrate archiving, training, collaboration, creative, research and social tools by offering an indexing and access mechanism based on a carefully designed metadata scheme. Further on, based on this, a core STE(A)M ontology will be developed, which will be used to create a draft Europeana-like repository of STE(A)M instructional methodologies, body of knowledge, open educational resources (OERs), learning activities, practices and policies.

Overall, the design and development of the metadata profiles of the different platform content types (that include learning objects and integrate properly the relevant with the project educational aspects and terms) is one of the most important tasks of the project. It must be noted that several educational resources of different kinds will be developed during the project lifetime for different purposes, such as scenarios, projects, activity templates, lesson plans, etc. These will mostly be based on the outcomes of WP2 “Establishment of European community of STE(A)M educators” and WP3 “Design of STE(A)M education framework”. Therefore, inclusion of all the content types and objects that will be created throughout the project is not possible in this deliverable. However, the basic decisions in the design of the metadata profiles of educational practices and policies as well as the metadata terms that have been used for them will be the basis of all the relevant content types that will be designed.

The starting points of the metadata design were the prior experience of CTI research team and the necessity to follow standardized metadata schemes; the latter was consider critical so that to satisfy the FAIR (findability, accessibility, interoperability, reusability) principle to

the best possible extent. In this context, DCMI/LRMI<sup>1</sup> metadata terms have been used for profiling the initial educational objects (classes), i.e., educational practices, policies and repository entries.

In Information Science, an ontology is a formal description of knowledge as a set of concepts within a domain and the relationships that hold between them. Some of the major characteristics of ontologies are that they ensure a common understanding of information and that they make explicit domain assumptions. As a result, the interconnectedness and interoperability of the model make it invaluable for addressing the challenges of accessing and querying data in large organizations. Also, by improving metadata and provenance, and thus allowing organizations to make better sense of their data, ontologies enhance data quality. In addition, by having the essential relationships between concepts built into them, they enable automated reasoning about data. Such reasoning is easy to implement in semantic graph databases that use ontologies as their semantic schemata [2].

As a result, the STE(A)M ontology, which is based on the metadata schemes that have been designed, will be used by the platform to provide semantically-enhanced access to a structured repository of all the important elements (policies, practices etc.) of the STEAMonEdu project. This version of the ontology reflects the knowledge regarding the needs of the STEAMonEdu project that we have on the specific time that this report is written. The ontology, however, will be updated throughout the lifetime of the project in order to serve as a first step towards a “Europeana of STE(A)M”.

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<sup>1</sup> <https://www.dublincore.org/>

## 2 Metadata profiles design

This chapter provides the approach that has been followed to define the necessary metadata profiles for the educational practice, the educational policy and the repository entry. Next, the full metadata sets are described in tabular form providing with each information element the corresponding DCMI/LRMI metadata terms and the set of values decided to be used by the project. Specific details are given in the case of educational alignments to support information elements that cannot be mapped to predefined DCMI/LRMI terms.

### 2.1 Metadata requirements and design methodology

#### 2.1.1 Rationale and requirements

The basic requirements for the design of metadata originate from

- their use in the context of the project,
- general principles that facilitate FAIR data, and
- technical and practical issues related to the platform itself and its potential users.

Data management is critical in any project. STE(A)MonEdu focuses on several and diverse aspects of education, from the designer, organizer, educator and policy maker points of view. Therefore, providing metadata for the educational content of the project is very important, as has already been stated in Chapter 1. On the other hand, it is substantial that the project data, especially those relevant to the educational aspects, follow the FAIR principle, i.e., they are findable (with well-defined naming conventions, unique identification, versions, keywords etc.), openly accessible, interoperable (following standard formats), and reusable (with proper license definition, data quality assurance, etc). While open accessibility may be satisfied by the platform, design and development decisions, findability, interoperability and reusability are facilitated by proper metadata design [3].

In this context, special care has to be given to assure compatibility with standardized or commonly used metadata designs in the same (educational) context. Following specific standards or recommendations helps to: (a) benefit from the experience of other researchers, (b) improve exchange and interoperability, (c) define a starting bundle of metadata terms which are commonly used in similar designs, and (d) subsequently add the significant (for the project objectives) information elements by defining, when necessary, new structures and terms. The final set of metadata terms to be used has been formed through two steps:

- Enumeration of the necessary information (properties) accompanying each data (educational, in this case) object (class).
- Decision on the information that will be included in the metadata set.

A significant aspect of the decision on the metadata set for each object has to do with practical issues, as abovementioned, i.e., the platform design and the type of users that will populate the forms generating the metadata. While a very detailed educational metadata set would be useful in the context of the project, our experience in educational platform development<sup>2</sup>

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<sup>2</sup> <https://umi-sci-ed.cti.gr/umiscied/?q=content/welcome-umi-sci-ed-platform>

shows that including a large number of input fields in user unfriendly forms results in a small number of data entries or forms that are half filled. In specific, requiring a huge number of input elements may inhibit participation of non-dedicated users and prevent crowdsourcing. Therefore, there has to be a compromise between the plurality of information to gather and the necessity to collect a significant number of data entries. On the other hand, especially in the beginning of the project, the users uploading information may be teachers, educators, managers, etc. originating from different educational frameworks which would like to share their educational practices and projects. Thus, a second important factor is the competence of the users to understand the rationale behind each information element. So, the information element definitions have to be clear, concise and manageable in number by the average user while giving the opportunity to more involved users (including researchers and project partners) to provide fine details. A simple approach is to split the information in two parts, namely, the mandatory and the optional information. This has mainly to do with the project objectives and the specific focus areas of interest; however, it is in general a difficult task.

Last, but not least, it is critical to note that the selection of information elements to be included in an educational object is irreversible as soon as the users upload their data. The average user won't return to provide further information or provide the information in a different way. Even if the user does, this will compromise the validity and reliability of the platform and the project as a whole. So, the metadata terms have to be carefully designed and tested as much as possible before released to the end users.

The above considerations, together with the fact that some educational resources will be developed as outcomes of the crowdsourcing process, research and analysis, have driven the consortium to decide that the metadata profiles of the remaining objects, which will be used as the project evolves, will be defined at a later time. This will allow us to make mature choices regarding the metadata sets, towards enhancing interoperability and reusability of the objects.

The first educational object types that have to be uploaded on the platform are the *educational practices* and the *educational policies*.

- Educational practices are expected to be uploaded and commented by average users and assessed by project partners. The design of the educational practice metadata profile is very important. Firstly, because it is the main object of crowdsourcing, therefore it is necessary to follow the above-mentioned requirements. Secondly, because it has to facilitate the assessment of the practices in the framework of the project as well as in wider frameworks, by concisely profiling important information. Finally, because it will be the basis for the design of the metadata profiles of future educational objects, such as activity templates, lesson plans, etc.
- Educational policies are expected to be uploaded by project partners and to a smaller extent, by education executives and managers. Therefore, it will overall be easier to gather the necessary, for each policy, information. Still, the accompanying metadata are very important since they will allow us to organize the qualitative information included in the policies in an efficient way.

Finally, a third category of general input (e.g. educational resources, research or other material) is expected to be uploaded on the platform, to facilitate discussion, opinion exchange and fermentation. This will be placed in a general repository where metadata to be used should be minimum but representative.

### 2.1.2 Background

Several recommendations and specifications have been created during the last twenty years for metadata of educational resources. Among them, Institute of Electrical and Electronics Engineers (IEEE) learning object metadata (LOM) [4] is among the most popular and used ones. IEEE LOM focuses on learning objects and includes 76 elements in nine categories. It has been used as the basis for several metadata specifications (e.g. IMS Global Learning Consortium Learning Resource Meta-data) as well as several online repositories. IEEE LOM has been used extensively over the last decade and a lot of efforts have been done to enrich the sets of values given by the original specification in specific domains (e.g. see [5]).

A second, commonly used specification is the Dublin Core Metadata Initiative (DCMI) element set<sup>3</sup> which, starting from 1995 has been continuously evolved. Internet Engineering Task Force (IETF) formalized it in 1998 (RFC 5791) while International Standards Organization provided the first relative standard in 2003 (i.e., ISO 15836-2003). The most recent update is ISO 15836-1:2017 [6], while the corresponding definitions of properties and classes have been standardized in ISO 15836-2:2019 [7], which was released in January, 2020. DCMI includes 15 core metadata terms (which will be supported evermore) plus a set of 55 more terms. DCMI is a more general specification than IEEE LOM and its scope involves any digital (not only educational) resource.

The Learning Resource Metadata Initiative (LRMI)<sup>4</sup> is a newer specification (initiated in 2011) that was based on several metadata initiatives (e.g., IEEE LOM DCMI, IMS, ARIADNE, SCORM, etc.). LRMI was spurred by Schema.org<sup>5</sup>, an initiative launched by Google, Microsoft, Yahoo and Yandex to create, maintain, and promote schemas for structured data on the Internet. LRMI was adopted by schema.org in 2013 and builds on the vocabulary provided by schema.org by defining properties that describe educational characteristics of learning resources.

One of the most important features of LRMI [8] is the use of alignment objects and specific properties (educationalAlignment) to relate a learning resource to a standard in an existing educational framework. Based on this feature, the Horizon 2020 project UMI-Sci-Ed<sup>6</sup> defined a concise set of metadata for educational resources [9], focusing on educational scenarios and projects which, in the broad sense, are educational practices. This prior experience together with the fact that LRMI specification was transferred to DCMI since 2014, led to the adoption of DCMI/LRMI for the metadata profiles of the educational objects that will be defined throughout the life time of STEAMonEdu project.

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<sup>3</sup> <https://www.dublincore.org/>

<sup>4</sup> [https://www.lrmi.net/specifications/lrmi/lrmi\\_1/](https://www.lrmi.net/specifications/lrmi/lrmi_1/)

<sup>5</sup> <https://schema.org/>

<sup>6</sup> <http://umi-sci-ed.eu>

### 2.1.3 Methodology

The development of metadata profiles began from the very beginning of the project. The procedure to conclude to the metadata profiles of practices and policies followed five major steps:

- Up to 15/2/2020: Submission of a first set of initial information elements necessary to concisely describe the practices and policies by project partners CTI and EOS, respectively, as defined during the January kickoff meeting.
- Up to 15/3/2020: Commenting and ideas sharing among all project partners regarding the number, the type of the information elements (mandatory or optional), their scope and set of values. Differentiation, removal as well as addition of new information elements has taken place during this step. Following the previous experience of CTI, the metadata terms to be used were selected from [schema.org/LRMI](http://schema.org/LRMI).
- Up to 30/4/2020: Testing of the information elements and metadata usability by all project partners using the online forms of the platform. Several minor corrections have been applied, especially in the auxiliary text accompanying every information element, so as to facilitate user understanding of the form fields (information elements). Furthermore, the set of values to be used with each.
- Up to 30/5/2020: Uploading of practices by platform (other than the partners) users. Identification of misuses, flaws and corrections that may be necessary to be applied in next steps for other educational objects metadata.
- Up to 15/6/2020: Final definition of metadata terms for practices, policies and repository entries, following the above mentioned (section 2.1.2) decision on adopting the DCMI/LRMI standards.

In order to ensure compatibility with DCMI/LRMI, a three step procedure was applied: first, the set of the 15 core DCMI metadata terms were used to map specific information elements of educational practices and policies; next, a set of as many as possible information elements was mapped to the general list of DCMI/LRMI terms, and finally, for the information elements that could not be properly mapped to predefined DCMI/LRMI terms, the LRMI procedure of defining proper educational alignments was used. In addition, it must be noted, that the metadata terms used may be easily redefined to follow the [schema.org](http://schema.org) hierarchy and metadata terms as an alternative (not included herein). In specific, LRMI terms are predefined in [schema.org](http://schema.org) while almost all DCMI terms have equivalent classes and properties in [schema.org](http://schema.org). These facts, in combination with prior use of [schema.org](http://schema.org) by CTI make redefinition an easy task, if this is found to be necessary in the future, within or out of the context of the project.

It must be emphasized that similar procedures and methods as the ones described herein will be used for the rest of educational objects that will be defined during the project. The experience that was gained from the design and use of the metadata profile of the educational practice will be of significant importance during the next steps. Towards this end, a full analysis of the platform user uploads will take place to identify points of confusion, inaccuracies, flaws, etc. These may lead to a redesign of the already defined educational

practice metadata for future use, better metadata term descriptions, as well as better metadata designs of other educational objects.

## 2.2 Metadata profiles

### 2.2.1 Educational practice

Being one of the most important classes in the beginning of the project, educational practice aims to be the core of crowdsourcing for activities, projects, lessons, curricula and any kind of implementations in the context of STE(A)M education. Following the considerations and decisions of Section 2.1, the educational practice was split in five parts, to facilitate information input:

- **General Info**, which includes the basic data of the practice, namely, title, language, abstract, STE(A)M area/topic of use in the practice, key terms, license information and any related source (e.g., a link or a document where this practice was originally described or used).
- **Author**, where the leading author's name, capacity and affiliation is given, together with names of any co-authors.
- **Audience and Educational Framework**, where the characteristics of the targeting audience are provided (capacity, age range, competence) as well as the educational framework where this practice was designed and/or used for.
- **Educational Details**, where the specific data of the practice are provided, i.e. the teaching topic where the practice was applied, its duration, difficulty, learning outcomes and specific use, the orientation/focus, the delivery mode, the pedagogical theory/mode/strategy followed, the necessary resources to be applied, and a full textual description that can be accompanied by any resources (documents or URLs). Resources uploaded (or mentioned) as part of the practice have their own metadata.
- **Implementation**, that is used to record data regarding the application of the practice, such as the country and organization, the type of education and audience size as well as details about the evaluation (if any) and the lessons learned by the application.

The total number of mandatory information to upload a practice has been selected to be as small as possible, so that not to discourage potential users while still gathering the critical information to profile a practice at the minimum level. Thus, 14 out of the total 32<sup>7</sup> fields to be filled by the user are mandatory; these are: **Title, Language, Abstract, STE(A)M discipline and area/topic, Key terms, License, Audience, Age Range, Audience competence, Educational/training framework, Educational subject, Description, Duration and Difficulty.**

In addition, a set of eight automatically generated data fields are created when the user uploads the practice; these are: a unique **Identifier**, the **Uploader** (registered user), the **Date** of upload and modification and a relation (**Has part**) with any resources that are parts of the practice. Finally, a predefined set of values are used for the **Type, Format and Publisher** terms,

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<sup>7</sup> The total number of fields (mandatory and optional) is greater when resources are added as parts of the practice.



namely, “Educational Practice”, “html”, “STE(A)MonEdu project”, respectively, to complete the identity of the practice.

Finally, it was decided that educational resources (file or URL) that are “connected” with a practice should have their own metadata so that to be independently identifiable and reusable. Therefore, educational resources, being part of the Educational Details above mentioned have two mandatory fields, i.e., Description and License, and they are accompanied by a set of optional qualitative as well as automatically generated metadata terms. Optional fields include the **Educational Resource Type**, the **Interactivity Type**, **Additional Comments** about the resource, the **Language**, etc., while auto-generated data include an **Identifier**, **Date** of upload and modification, **File Format**, etc.

Table 1 provides the full set of metadata terms for the educational practice while Table 2 provides the metadata profile of each educational material or resource that accompanies the practice in URL or file form. The DCMI properties in boldface font correspond to the core Dublin Core metadata terms. It must be noted that in certain cases, for these terms, a one-to-two or two-to-one mapping has been used so that to profile the information closely to DCMI metadata definitions.

DCMI/LRMI has already integrated a lot of definitions and metadata terms that can be directly mapped and used by the educational practice. However, three new properties and six new educational alignments have been defined, using the LRMI educational alignment feature in order to include all the important information elements in the metadata profile. In specific, the properties *competence*, *audienceType* and *size* have been defined for the **audience** class of DCMI, all three similar to schema.org existent properties.

New educational alignments have been defined for the **Educational Subject**, **Difficulty**, **Learning Outcomes**, **Orientation/Focus** and **Hardware/Software/Other Resources** information elements. For each educational alignment, the *educationalFramework*, *alignmentType* and *targetName* or *TargetDescription* properties have been defined to complete the metadata term definitions. Their definitions and value spaces are given in detail in Table 1. Three of them originate from IEEE LOM and they are commonly used in LRMI alignments, namely, *difficulty*, *teaches* and *requires*. Two of them, i.e., *learningOutcomes* and *orientationFocus*, have been previously used in UMI-Sci-Ed project [9]. The term *learningOutcomes* or a similar one is surprisingly not included in either DCMI or LRMI definitions. We believe that this is very common information included in all aspects of educational activities, so its use is very important. Finally, the *educationType* term was introduced to include "formal learning", "non-formal learning", "informal learning", and "Other" values. This was considered to be important in the context of the project and the comparison of practices among them.

The “Other” value has been used in other fields as well to give the users the opportunity to enrich the vocabulary provided by the project partners with additional individuals that will enhance the ontology. Especially for the **STE(A)M discipline** and **area/topic** double field, the complete set of values is given in Figure 3 (Section 3.2).

### 2.2.2 Educational policy

Educational policies are expected to be uploaded mainly by the project partners. However other educational professionals who are involved in policy-making may also upload policies. In either case, these users are much more familiar with the terms of education and are expected to fill in carefully the corresponding platform forms, allocating the necessary time and communicating with the project partners in case of problems or unclear definitions. There are 20 fields in total, 16 out of which are mandatory; they are organized in three parts, as follows:

- **General Info**, which includes all the primary fields of interest that provide the identity of the practice, namely, the title, language, purpose, the key terms, the country and authority that issued the policy and a source (text or URL) that points to the original policy.
- **Applicability and audience**, which includes specific information of the target audience, the coverage (applicability area) and the educational framework that the policy was created for.
- **Details**, which allows a brief or extensive description of the policy (reason, implementation procedures, implementation structures, definitions) as well as monitoring and evaluation that is applied, related policies and the helpdesk (cognizant office) that can provide further details, if necessary.

These are accompanied by seven automatically generated fields i.e., a unique **Identifier**, the **Uploader** (registered user), the **Date** of upload and modification and a relation (**Has part**) with any resources that are parts of the policy. Finally a predefined set of values are used for the **Type** and **Format** terms, namely, “Educational Policy”, and “html”, respectively, to complete the identity of the practice.

Table 3 provides the full set of metadata terms for the educational policy while Table 4 provides the metadata profile of each material or resource that accompanies the policy in URL of file form. The DCMI properties in boldface font correspond to the core Dublin Core metadata terms. All the information elements have been mapped to pure DCMI terms. In some cases several policy fields are combined and mapped to a single DCMI term, e.g., *description*. It is left for future consideration to create new metadata terms, if necessary, so to increase the granularity of the descriptive elements of a policy. This can only be decided later (during the project lifetime) when an adequate number of policies will have been uploaded, so that to assess the quality and suitability of the initially defined metadata terms.

Finally, the value “Other” has been used for the **Audience** and **Educational Framework** policy fields to allow the users complement the predefined values with others that may be useful in the corresponding context.

### 2.2.3 Repository entry

Efficient use of repository requires quick, simple input that, on the other hand, includes all the necessary information to identify and access unambiguously the resource provided. Therefore, it was decided to use the minimum information elements that are commonly used

by similar repositories such as Zenodo<sup>8</sup>. These include **Title**, **Author(s)**, **Keywords**, **Type**, **Language** and **License**, information elements that are set as mandatory and are easily mapped to DCMI terms as shown in Table 5. While repository entries are expected to be of various types, the project is mainly interested in educational resources and research material that are related with the project activities and content. Therefore these two categories have been distinctively used in the **Type** field of the repository entry, leaving all other cases to be characterised as “Other”.

Three more optional fields complete the user input, namely, **Description**, **Resource Type**, and **URL/DOI**. Resource Type field focuses mainly on characterizing educational resources through the *learningResourceType* that has been used in the educational practice class as well. This facilitates searching and aggregation of similar resource types that belong to both classes, i.e., educational practice and repository entry.

Finally, a set of automatically generated metadata is created to uniquely identify the entry and the accompanying file characteristics while bonding them together.

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<sup>8</sup> <https://zenodo.org/>

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
General Info					
Title	M	U	Text	title	http://purl.org/dc/elements/1.1/title
Language	M	U	IETF BCP47	language	http://purl.org/dc/elements/1.1/language
Abstract	M	U	Text	abstract	http://purl.org/dc/terms/abstract
STEAM discipline and area/topic	M	U	"Science", "Technology", "Engineering, "Arts", "Mathematics" *	subject	http://purl.org/dc/elements/1.1/subject
Key Terms	M	U	Text		
License	M	U	Text or URL	rights	http://purl.org/dc/elements/1.1/rights
Related Source	O	U	Text or URL	source	http://purl.org/dc/elements/1.1/source
				relation	http://purl.org/dc/elements/1.1/relation
Author (if different from uploader)					
Author of the practice	O	U	Text	creator	http://purl.org/dc/elements/1.1/creator
Author's occupation	O	U	Text		
Author's organization	O	U	Text		
Additional Author(s)	O	U	Text	contributor	http://purl.org/dc/elements/1.1/contributor
Audience & Educational Framework					
Audience	M	U	"Educator", "Learner", "Author", "Manager/policy maker", "Parents, librarian", "Other"	audience	http://purl.org/dc/terms/audience
Age range	M	U	Text	typicalAgeRange	http://purl.org/dcx/lrmi-terms/typicalAgeRange
Audience competence	M	U	"Starter", "Beginner", "Capable", "Proficient", "Expert"	competence	new property of educationalAudience class
Audience type	O	U	Text	audienceType	new property of educationalAudience class, compatible with schema.org
Educational/Training framework	M	U	"Kindergarden", "Elementary/Primary school", "Middle/Junior high school", "Upper high school/Lyceum", "Further education", "Higher education (College - University)", "Initial VET", "Continuous VET", "Adult education/Life Long Learning", "Non-Formal", "Other"	educationLevel	http://purl.org/dc/terms/educationLevel

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
Educational/EQF Level	O	U	Text		
<b>Educational Details</b>					
Educational Subject	M	U	Text	educationalAlinment properties: educationalFramework = "STE(A)M Education", alignmentType = "teaches", targetName **	<a href="http://purl.org/dcxl/rmi-terms/targetName">http://purl.org/dcxl/rmi-terms/targetName</a>
Description of the practice	M	U	Enriched text	<b>description</b>	<a href="http://purl.org/dc/elements/1.1/description">http://purl.org/dc/elements/1.1/description</a>
Duration	M	U	IEEE LOM	timeRequired	<a href="http://purl.org/dcxl/rmi-terms/timeRequired">http://purl.org/dcxl/rmi-terms/timeRequired</a>
Difficulty	M	U	"very easy", "easy", "medium", "difficult", "very difficult"	educationalAlinment properties: educationalFramework = "IEEE LOM", alignmentType = "difficulty", targetName **	<a href="http://purl.org/dcxl/rmi-terms/targetName">http://purl.org/dcxl/rmi-terms/targetName</a>
Educational Use	O	U	Text	educationalUse	<a href="http://purl.org/dcxl/rmi-terms/educationalUse">http://purl.org/dcxl/rmi-terms/educationalUse</a>
Learning Outcomes	O	U	Text	educationalAlinment properties: educationalFramework = "Revised Bloom Taxonomy", alignmentType = "learningOutcomes", targetName **	<a href="http://purl.org/dcxl/rmi-terms/targetName">http://purl.org/dcxl/rmi-terms/targetName</a>
Orientation/Focus	O	U	"acquire new knowledge", "develop new skills", "attain attitudes"	educationalAlinment properties: educationalFramework = "STE(A)MonEdu project", alignmentType = "orientationFocus", targetName **	<a href="http://purl.org/dcxl/rmi-terms/targetName">http://purl.org/dcxl/rmi-terms/targetName</a>
Delivery mode	O	U	"face to face learning", "blended learning", "online learning"	instructionalMethod	<a href="http://purl.org/dc/terms/instructionalMethod">http://purl.org/dc/terms/instructionalMethod</a>
Pedagogical Theory/Model/Strategy	O	U	"active learning", "reflective learning", "collaborative learning", "Other"		
Hardware/Software/Other Resources	O	U	Text	educationalAlinment properties:	<a href="http://purl.org/dcxl/rmi-terms/targetDescription">http://purl.org/dcxl/rmi-terms/targetDescription</a>

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
				educationalFramework = "IEEE LOM", alignmentType = "requires", targetDescription **	
<b>Implementation</b>					
Country that was implemented	O	U	ISO 3166	<b>coverage</b>	<a href="http://purl.org/dc/elements/1.1/coverage">http://purl.org/dc/elements/1.1/coverage</a>
Organization that was applied to	O	U	Text		
Type of education	O	U	"formal learning", "non-formal learning", "informal learning", "Other"	educationalAlinment properties: educationalFramework = "STE(A)MonEdu project", alignmentType = "educationType", targetName **	<a href="http://purl.org/dcx/lrmi-terms/targetName">http://purl.org/dcx/lrmi-terms/targetName</a>
Audience size	O	U	Number	size	<i>new property of educationalAudience class</i>
Evaluation and lessons learned	O	U	Text	<b>description</b>	<a href="http://purl.org/dc/elements/1.1/description">http://purl.org/dc/elements/1.1/description</a>
<b>Auto-generated data</b>					
Identifier	M	A	URI	<b>identifier</b>	<a href="http://purl.org/dc/elements/1.1/identifier">http://purl.org/dc/elements/1.1/identifier</a>
Type	M	A	"Educational Practice"	<b>type</b>	<a href="http://purl.org/dc/elements/1.1/type">http://purl.org/dc/elements/1.1/type</a>
Format	M	A	"html"	<b>format</b>	<a href="http://purl.org/dc/elements/1.1/format">http://purl.org/dc/elements/1.1/format</a>
Uploader	M	A	Any registered user	<b>creator</b>	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>
Date of upload	M	A	ISO 8601	<b>date</b>	<a href="http://purl.org/dc/elements/1.1/date">http://purl.org/dc/elements/1.1/date</a>
Modification Date	M	A	ISO 8601	modified	<a href="http://purl.org/dc/terms/modified">http://purl.org/dc/terms/modified</a>
Publisher	M	A	"STE(A)MonEdu project"	<b>publisher</b>	<a href="http://purl.org/dc/elements/1.1/publisher">http://purl.org/dc/elements/1.1/publisher</a>
Has part	M	A	Educational material/resoure	hasPart	<a href="http://purl.org/dc/terms/hasPart">http://purl.org/dc/terms/hasPart</a>

\* Further details on the set of values are given in the text.

\*\* These terms are defined via LRMI educational alignments. Details are given in the text.

Field "Type": M = Mandatory, O = Optional. Field "Input": U = User input, A = Automatically generated

**Table 1. Educational practice metadata profile**

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
Description	M*	U	Text	title	<a href="http://purl.org/dc/elements/1.1/title">http://purl.org/dc/elements/1.1/title</a>
License	M*	U	Text or URL	rights	<a href="http://purl.org/dc/elements/1.1/rights">http://purl.org/dc/elements/1.1/rights</a>
Educational Resource Type	O	U	"presentation", "handout", "exercise", "simulation", "questionnaire", "diagram", "figure", "graph", "exam", "experiment", "lecture"	learningResourceType	<a href="http://purl.org/dc/elements/1.1/learningResourceType">http://purl.org/dc/elements/1.1/learningResourceType</a>
Interactivity Type	O	U	"active", "expositive" or "mixed"	interactivityType	<a href="http://purl.org/dc/elements/1.1/interactivityType">http://purl.org/dc/elements/1.1/interactivityType</a>
Language	O	U	Text, as defined in IETF BCP47	language	<a href="http://purl.org/dc/elements/1.1/language">http://purl.org/dc/elements/1.1/language</a>
Additional comments about this resource	O	U	Text	description	<a href="http://purl.org/dc/elements/1.1/description">http://purl.org/dc/elements/1.1/description</a>
URL	O	U	url	source	<a href="http://purl.org/dc/elements/1.1/source">http://purl.org/dc/elements/1.1/source</a>
Identifier	M*	A	URI	identifier	<a href="http://purl.org/dc/elements/1.1/identifier">http://purl.org/dc/elements/1.1/identifier</a>
Date/Time of upload	M*	A	ISO 8601	date	<a href="http://purl.org/dc/elements/1.1/date">http://purl.org/dc/elements/1.1/date</a>
Modification Date	M*	A	ISO 8601	modified	<a href="http://purl.org/dc/terms/modified">http://purl.org/dc/terms/modified</a>
Name	M**	A	Text	alternative	<a href="http://purl.org/dc/terms/alternative">http://purl.org/dc/terms/alternative</a>
File Format	M**	A	txt, pdf, docx, doc	format	<a href="http://purl.org/dc/elements/1.1/format">http://purl.org/dc/elements/1.1/format</a>
Size or duration	M**	A	ISO 8601 or size in MB	extent	<a href="http://purl.org/dc/terms/extent">http://purl.org/dc/terms/extent</a>
Is Part of	M*	A	Practice	isPartOf	<a href="http://purl.org/dc/terms/isPartOf">http://purl.org/dc/terms/isPartOf</a>

\* These terms are optionally mandatory, in the sense that they are mandatory if the user selects to declare a resource (via a URL) or upload a resource (file).

\*\* These terms are mandatory only for files that uploaded on the platform.

Field "Type": M = Mandatory, O = Optional. Field "Input": U = User input, A = Automatically generated

**Table 2. Metadata profile of educational material/resource of an educational practice**

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
General Info					
Title	M	U	Text	title	http://purl.org/dc/elements/1.1/title
Language	M	U	IETF BCP47	language	http://purl.org/dc/elements/1.1/language
Purpose	M	U	Text	abstract	http://purl.org/dc/terms/abstract
Issuing date	M	U	ISO 8601	issued	http://purl.org/dc/terms/issued
Key Terms	M	U	Text	subject	http://purl.org/dc/elements/1.1/subject
Originating country/region	M	U	ISO 3166	publisher	http://purl.org/dc/elements/1.1/publisher
Policy approval authority	M	U	Text		
	M	U	Text	creator	http://purl.org/dc/elements/1.1/creator
Initiator / author	O	U	Text	contributor	http://purl.org/dc/elements/1.1/contributor
Related Source	M	U	Text or URL	source	http://purl.org/dc/elements/1.1/source
				relation	http://purl.org/dc/elements/1.1/relation
Applicability and Audience					
Audience	M	U	"School managers", "School directors", "Educators", "Trainers", "Formal education managers or directors", "Adult education managers or directors" "Policy makers", "Other"	audience	http://purl.org/dc/terms/audience
Aplicability area	M	U	"European", "National", "Regional", "Local", "School level", "Institutional level"	coverage	http://purl.org/dc/elements/1.1/coverage
Educational Framework	M	U	"Kindergarden", "Elementary/primary school", "Middle/junior high school", "Upper high school/lyceum", "Further education", "Higher education (college - university)", "Initial VET", "Continuous VET", "Adult education/life long learning", "Other"	educationLevel	http://purl.org/dc/terms/educationLevel
Details					
Reason for policy	M	U	Text	description	http://purl.org/dc/elements/1.1/description
Description of the policy	M	U	Text		
Implementation procedures and plan	M	U	Text		



Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
Structures for implementation	M	U	Text		
Monitoring and evaluation	O	U	Text		
Definitions	O	U	Text		
Cognizant office / helpdesk	O	U	Text		
Related policies / references	O	U	Text	references	<a href="http://purl.org/dc/terms/references">http://purl.org/dc/terms/references</a>
<b>Auto-generated data</b>					
Identifier	M	A	URI	<b>identifier</b>	<a href="http://purl.org/dc/elements/1.1/identifier">http://purl.org/dc/elements/1.1/identifier</a>
Type	M	A	"Educational Policy"	<b>type</b>	<a href="http://purl.org/dc/elements/1.1/type">http://purl.org/dc/elements/1.1/type</a>
Format	M	A	"html"	<b>format</b>	<a href="http://purl.org/dc/elements/1.1/format">http://purl.org/dc/elements/1.1/format</a>
Uploader	M	A	Any registered user	<b>creator</b>	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>
Date of upload	M	A	ISO 8601	<b>date</b>	<a href="http://purl.org/dc/elements/1.1/date">http://purl.org/dc/elements/1.1/date</a>
Modification Date	M	A	ISO 8601	modified	<a href="http://purl.org/dc/terms/modified">http://purl.org/dc/terms/modified</a>
Has part	M	A	Material/resoure	hasPart	<a href="http://purl.org/dc/terms/hasPart">http://purl.org/dc/terms/hasPart</a>

Field "Type": M = Mandatory, O = Optional. Field "Input": U = User input, A = Automatically generated

**Table 3. Educational policy metadata profile**

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
Title	M*	U	Text	title	<a href="http://purl.org/dc/elements/1.1/title">http://purl.org/dc/elements/1.1/title</a>
Language	M*	U	Text, as defined in IETF BCP47	language	<a href="http://purl.org/dc/elements/1.1/language">http://purl.org/dc/elements/1.1/language</a>
URL	O	U	url	source	<a href="http://purl.org/dc/elements/1.1/source">http://purl.org/dc/elements/1.1/source</a>
Size or duration	M**	A	ISO 8601 or size in MB	extent	<a href="http://purl.org/dc/terms/extent">http://purl.org/dc/terms/extent</a>
Identifier	M*	A	URI	identifier	<a href="http://purl.org/dc/elements/1.1/identifier">http://purl.org/dc/elements/1.1/identifier</a>
Date/Time of upload	M*	A	ISO 8601	date	<a href="http://purl.org/dc/elements/1.1/date">http://purl.org/dc/elements/1.1/date</a>
Modification Date	M*	A	ISO 8601	modified	<a href="http://purl.org/dc/terms/modified">http://purl.org/dc/terms/modified</a>
Name	M**	A	Text	alternative	<a href="http://purl.org/dc/terms/alternative">http://purl.org/dc/terms/alternative</a>
File Format	M**	A	txt, pdf, docx, doc	format	<a href="http://purl.org/dc/elements/1.1/format">http://purl.org/dc/elements/1.1/format</a>
Is Part of	M*	A	Policy	isPartOf	<a href="http://purl.org/dc/terms/isPartOf">http://purl.org/dc/terms/isPartOf</a>

\* These terms are optionally mandatory, in the sense that they are mandatory if the user selects to declare a resource (via a URL) or upload a resource (file).

\*\* These terms are mandatory only for files that uploaded on the platform.

Field "Type": M = Mandatory, O = Optional. Field "Input": U = User input, A = Automatically generated

**Table 4. Metadata profile of material/resource of an educational policy**

Information element (field)	Type	Input	Value space	DCMI property	DCMI URI
Title	M	U	Text	title	<a href="http://purl.org/dc/elements/1.1/title">http://purl.org/dc/elements/1.1/title</a>
Author	M	U	Text	creator	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>
Keywords	M	U	Text	subject	<a href="http://purl.org/dc/elements/1.1/subject">http://purl.org/dc/elements/1.1/subject</a>
Type	M	U	"Educational resource", "Research material", "Other"	type	<a href="http://purl.org/dc/elements/1.1/type">http://purl.org/dc/elements/1.1/type</a>
Language	M	U	Text, as defined in IETF BCP47	language	<a href="http://purl.org/dc/elements/1.1/language">http://purl.org/dc/elements/1.1/language</a>
License	M	U	Text or URL	rights	<a href="http://purl.org/dc/elements/1.1/rights">http://purl.org/dc/elements/1.1/rights</a>
Description	O	U	Text	description	<a href="http://purl.org/dc/elements/1.1/description">http://purl.org/dc/elements/1.1/description</a>
Resource Type	O	U	"Artefact", "Article", "Activity", "Audio/Video", "Case study", "Dataset", "Exam", "Example", "Exercise", "Experiment", "Figure", "Graph", "Guidelines", "Handout", "Image", "Lesson", "Presentation", "Project", "Publication", "Questionnaire", "Software", "Other"	learningResourceType	<a href="http://purl.org/dcxl/rmi-terms/learningResourceType">http://purl.org/dcxl/rmi-terms/learningResourceType</a>
URL/DOI	O	U	url/doi	source	<a href="http://purl.org/dc/elements/1.1/source">http://purl.org/dc/elements/1.1/source</a>
Date/Time of creation	M	A	ISO 8601	date	<a href="http://purl.org/dc/elements/1.1/date">http://purl.org/dc/elements/1.1/date</a>
Creator	M	A		mediator	<a href="http://purl.org/dc/terms/mediator">http://purl.org/dc/terms/mediator</a>
hasPart	M	A	File	hasPart	<a href="http://purl.org/dc/terms/hasPart">http://purl.org/dc/terms/hasPart</a>
<b>Accompanying file metadata</b>					
Identifier	M	A		extent	<a href="http://purl.org/dc/terms/extent">http://purl.org/dc/terms/extent</a>
Size/duration of content	M	A	ISO 8601	date	<a href="http://purl.org/dc/elements/1.1/date">http://purl.org/dc/elements/1.1/date</a>
Date/Time of upload	M	A	ISO 8602	modified	<a href="http://purl.org/dc/terms/modified">http://purl.org/dc/terms/modified</a>
Modification Date	M	A	Text	alternative	<a href="http://purl.org/dc/terms/alternative">http://purl.org/dc/terms/alternative</a>
Name	M	A		format	<a href="http://purl.org/dc/elements/1.1/format">http://purl.org/dc/elements/1.1/format</a>
File Format	M	A	URI	identifier	<a href="http://purl.org/dc/elements/1.1/identifier">http://purl.org/dc/elements/1.1/identifier</a>
Part of	M	A	Repository entry	isPartOf	<a href="http://purl.org/dc/terms/isPartOf">http://purl.org/dc/terms/isPartOf</a>

Field "Type": M = Mandatory, O = Optional. Field "Input": U = User input, A = Automatically generated

**Table 5. Metadata profile of a repository entry**

### 3 The STE(A)MonEdu Ontology

This chapter provides the approach that has been followed with the aim to develop a semantically description of the important terms, concepts and relations. At first, an introduction regarding ontologies and their structures is presented. Next, the adopted methodology is provided, while specific details are given for each step, alongside with the full description of the developed ontology. Finally, in order to evaluate the ontology, competency questions were used to validate it with the use of Description Logics (DL) Queries.

#### 3.1 Introduction to ontologies

##### 3.1.1 What is an ontology and why it is important

In recent years the development of ontologies—explicit formal specifications of the terms in a domain and relations among them—has been moving from the realm of Artificial-Intelligence laboratories to the desktops of domain experts. Ontologies have become common on the World-Wide Web. The ontologies on the Web range from large taxonomies categorizing Web sites (such as on Yahoo!) to categorizations of products for sale and their features (such as on Amazon.com). Many disciplines now develop standardized ontologies that domain experts can use to share and annotate information in their fields. Medicine, for example, has produced large, standardized, structured vocabularies such as SNOMED and the semantic network of the Unified Medical Language System [1].

More specifically, in Information Science, an ontology is a formal description of knowledge as a set of concepts within a domain and the relationships that hold between them. Here is another popular definition: “An ontology is a formal, explicit specification of a shared conceptualization that is characterized by high semantic expressiveness required for increased complexity” ([10], [11]). Note that all nouns used in this sentence are equally important!

Or, to put it more simply, an ontology is “everything someone cares to know about something”: an ontology provides a description of “something” (a point of interest, such as a thing, a person, an organization, a service, a topic etc.) that includes “everything” (so, it tries to be as complete as possible) that is of interest to “someone” (therefore, ontologies are by definition biased, because they represent the needs and perspective of their builder).

To enable such a description, there is a need to formally specify components such as individuals (instances of objects), classes, attributes and relations as well as restrictions, rules and axioms. As a result, ontologies do not only introduce a sharable and reusable knowledge representation but can also add new knowledge about the domain<sup>9</sup>.

The ontology data model can be applied to a set of individual facts to create a knowledge graph – a collection of entities, where the types and the relationships between them are expressed by nodes and edges between these nodes. By describing the structure of the

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<sup>9</sup> More information about ontologies and their structure can be found in [https://en.wikipedia.org/wiki/Ontology\\_components](https://en.wikipedia.org/wiki/Ontology_components)  
[https://en.wikipedia.org/wiki/Ontology\\_\(information\\_science\)#cite\\_note-19](https://en.wikipedia.org/wiki/Ontology_(information_science)#cite_note-19).

knowledge in a domain, the ontology sets the stage for the knowledge graph to capture the data in it.

But why would someone want to develop an ontology? Some of the reasons are described by Noy and McGuinness [1]:

- To share common understanding of the structure of information among people or software agents
- To enable reuse of domain knowledge
- To make domain assumptions explicit
- To separate domain knowledge from the operational knowledge
- To analyze domain knowledge

### 3.1.2 The structure of an ontology

An ontology is a formal explicit description of concepts in a domain of discourse (classes), properties of each concept describing various features and attributes of the concept slots (sometimes called roles or properties), and restrictions on slots (facets, sometimes called role restrictions). An ontology together with a set of individual instances of classes constitutes a knowledge base [1].

The most common components of ontologies are:

- Classes: sets, collections, concepts, types of objects, or kinds of things (for example, Vehicle, Car, Engine, etc.)
- Individuals: instances or objects (the basic or "ground level" objects) (for example, Ford Mondeo)
- Attributes: aspects, properties, features, characteristics, or parameters that objects (and classes) can have (for example, a Car such as Ford Mondeo can be described using the Model (Ford Mondeo), the Number-of-seats (5), the Color (white), the Type-of-transmission (automatic) etc.)
- Relations: ways in which classes and individuals can be related to one another (for example, a Car is\_a Vehicle, a Car has Engine, etc.)

Classes are the main components of ontologies. Classes represent important concepts in the domain that is being modelled by the ontology. For example, a class of wines represents all wines. Specific wines are instances of this class. The Bordeaux wine in the glass in front of you while you read this document is an instance of the class of Bordeaux wines.

A class can have subclasses that represent concepts that are more specific than the superclass. For example, the class of all wines can be divided into red, white, and rosé wines. Alternatively, a class of all wines can be divided into sparkling and non-sparkling wines. The two most common relations occurring between classes are:

- The subsumption (or generalization) relation (is-a): Class A is\_a Class B means that Class A is a subset of Class B (for example, Cat is\_a Mammal), therefore the instances of Class A inherit all the properties of the instances of Class B; if only this relation exists between entities of an ontology, then the ontology becomes a taxonomy,

- The mereology (or part-whole) relation (has): Class A has Class B means that an instance of Class A may contain one or more instances of Class B (for example, House has Window); this relation carries no implication regarding the properties of instances.

Attributes (or slots) describe properties of classes and instances: Château Lafite Rothschild Pauillac wine has a full body; it is produced by the Château Lafite Rothschild winery. We have two slots describing the wine in this example: the slot “body” with the value “full” and the slot “maker” with the value “Château Lafite Rothschild winery”. At the class level, we can say that instances of the class Wine will have slots describing their flavor, body, sugar level, the maker of the wine and so on.

Figure 1 shows another example for ontology-based metadata in the domain of higher education. The ontology features a concept (class) Person, with specializations (subclasses) such as MSc-Student, PhD-Student as well as Academic Staff. It can be seen that the ontology has five classes, ( MSc Student is a sub-class of Student and so on). Properties for each class can also be added. For example, Person has name, last name, birthday, etc., [12].

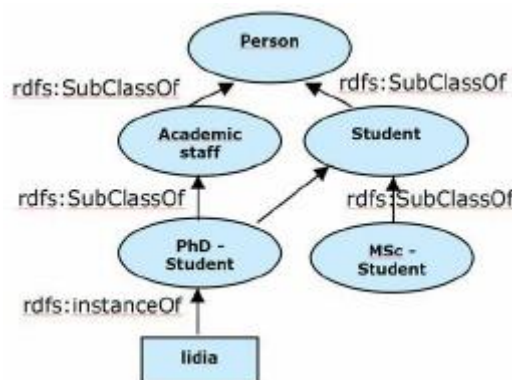


Figure 1. Example of ontology-based metadata in the domain of higher education

In this address <https://protegewiki.stanford.edu/wiki/Protege4Pizzas10Minutes> a fun tutorial on building an ontology using Protégé Ontology Editor can be found. Even if you do not plan to install and use the system, we advise to go quickly through it and look at the pictures in order to have an idea of what an ontology looks like.

## 3.2 Development of the STE(A)MonEdu Ontology

### 3.2.1 Ontology engineering methodology

The aim of the STE(A)M ontology is the representation of the knowledge needed by the STE(A)MonEdu project community regarding STE(A)M education. This document is a first attempt to design the STE(A)M ontology; unavoidably, this version of the ontology reflects the knowledge regarding the needs of the STEAMonEdu project that we have in the specific time that this report is written. The ontology, however, will be updated throughout the lifetime of the project in order to serve as a first step towards a “Europeana of STE(A)M”.

The software used for the development of the ontology was Protégé 5.5 Ontology Editor and Knowledge Acquisition System (OWL DL language). Protégé is a free, open source ontology

editor and a knowledge management system. It provides a graphical user interface to define ontologies. It also includes deductive classifiers to validate that the created models are consistent and to infer new information based on the analysis of an ontology. It was selected because its most powerful advantages over other tools are the user interface, plugin-based scalability and wide functionality provided either by using plugins or not. In addition, the large and active Protégé user community is highly engaged in Protégé code development, regularly contributing enhancements to the software<sup>10</sup>, as well as participating in online discussion groups devoted to modelling questions, technical-support issues, and requests for new features [13].

The ontology development was based on the iterative methodology “Ontology Development 101: A Guide to Creating Your First Ontology” [1]. Initially, a main structure with classes and subclasses was developed and the properties were inserted gradually. In addition, some instances were added in order to evaluate the ontology with the use of competency questions.

The basic steps followed for the comprehension and construction of the ontology are listed below:

- **Step 1:** Determine the domain and scope of the ontology
- **Step 2:** Consider reusing existing ontologies
- **Step 3:** Enumerate important terms in the ontology
- **Step 4:** Define the classes and the class hierarchy
- **Step 5:** Define the properties of classes
- **Step 6:** Define the data properties of the classes
- **Step 7:** Create instances
- **Step 8:** Evaluate the ontology by implementing DL Queries

#### ***3.2.1.1 Step 1: Determine the domain and scope of the ontology***

The scope of the STE(A)M ontology is to represent the knowledge needed by the STE(A)MonEdu project community regarding STE(A)M education. This ontology will be mostly used in the platform in order to create and access a structured repository of all the important elements (policies, practices etc.) of the STEAMonEdu project. That is why, we expect that it will contain mainly terms, concepts and items that will be used to index STE(A)M education-related resources, although we do not want to exclude other terms and relations that the project community will consider to be of interest.

#### ***3.2.1.2 Step 2: Consider reusing existing ontologies***

In order to find any existing ontologies that could be reused, we searched the following ontology libraries [14] for similar ontologies: BioPortal, Ontology Design Patterns.org, OLS the Ontology Lookup Service, OntoSelect, ONKI ontology server. We searched for similar ontologies with the use of the following key words: “STEAM education”, “STEM education”, “STE(A)M education”. At the time of research, no existing ontology that would satisfy the specific requirements of the project was located. However, the ontology structure and development will follow the metadata profiles that have been developed (see chapter 2).

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<sup>10</sup> <http://protege.stanford.edu/community/wiki.html>

### 3.2.1.3 Step 3: Enumerate important terms in the ontology

The main important terms in the ontology were formed based on the needs of the STEAMonEdu project. At first, important terms for the STEAMonEdu project are the different **STEAM disciplines** and both **Policies** and **Practices** that the community of the STEAMonEdu project will collect, alongside with their available **Resources**. The Audience and the **Role** of the different stakeholders is also an important term. Other important terms based on the outcomes of the project are the **Educators Competence Framework** which will detail the competences necessary to design and implement STE(A)M education activities and the **Educators competences profiles** that will be designed on the principles of ESCO (European multilingual classification of Skills, Competences, Qualifications and Occupations). In addition, during the second year of the project a two-stage training program for the professional development of educators will be developed (**STEAM Course**), based on a specific designed **curriculum**, while **educational recourses** (learning objects, educational activities etc.) will be created and used in order to meet the course's learning outcomes.

### 3.2.1.4 Step 4: Define the classes and the class hierarchy

Based on the important terms on the ontology in this step, we defined the classes and subclasses that are included in the first version of the STE(A)M Ontology. These are:

- The class **Policy**: This class represents policies for STE(A)M education.
- The class **Practice**: This class represents the STE(A)M educational practices.
- The class **Resource**: This class represents the different recourses that are needed in order for a practice to be implemented. Class "Resource" has three sub-classes, each of which represents the different resources based on the meta-data schema that was implemented for the collected STE(A)M practices. There are: Hardware, Software, Other Resource.
- The class **STEAM discipline**: This class represents the different disciplines that the STEAM includes. It has five sub-classes: Science, Technology, Engineering, Arts and Mathematics. Each one of these five sub-classes has sub-classes based on the major subjects for each discipline<sup>11</sup> (see Fig. 3).
- The class **Educators Competence Framework**: This class represents a set of necessary competences to design and implement STE(A)M education activities.
- The class **Educators Competence Profile**: This class represents the competence profiles based on the Educators Competence Framework.
- The class **Role**: This class represents the different roles of the involved persons in STEAM education. Class "Role" has seven sub-classes (not shown in the table), each of which represents the different roles based on the meta-data schema that was implemented for the STE(A)M policies and practices. These sub-classes are: Adult education manager or director, Author-Creator, Educator, Formal education manager or director, Learner, Policy maker, School Director-Manager.

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<sup>11</sup> For the Arts discipline we adopted the perspective that the "A" represents the integration of Arts/Humanities and Social Sciences to broaden STEM integration into STEAM. (Boon Ng, S. (2019). Exploring STEM competences for the 21st century. UNESCO.)



- The class **Educational Resource**: This class represents all the necessary resources that are needed for the implementation of a course. It has four sub-classes: Learning Object, Educational Activity, Activity template, Other educational resource.
- The class **STEAM Course**: This class represents a set of classes or a plan of study on a STEAN subjects, usually leading to an exam or qualification
- The class **Curriculum**: This class represents the curriculum of each course.

In Figure 2 and Figure 3 the taxonomy of the classes and subclasses as they have been created using Protégé are presented. Note that “Thing” is a root class always added by default by Protégé. Some of them have sub-classes (is\_a relation). For example, class “Resource” has three different sub-classes which are: Hardware, Software and Other\_Resource.

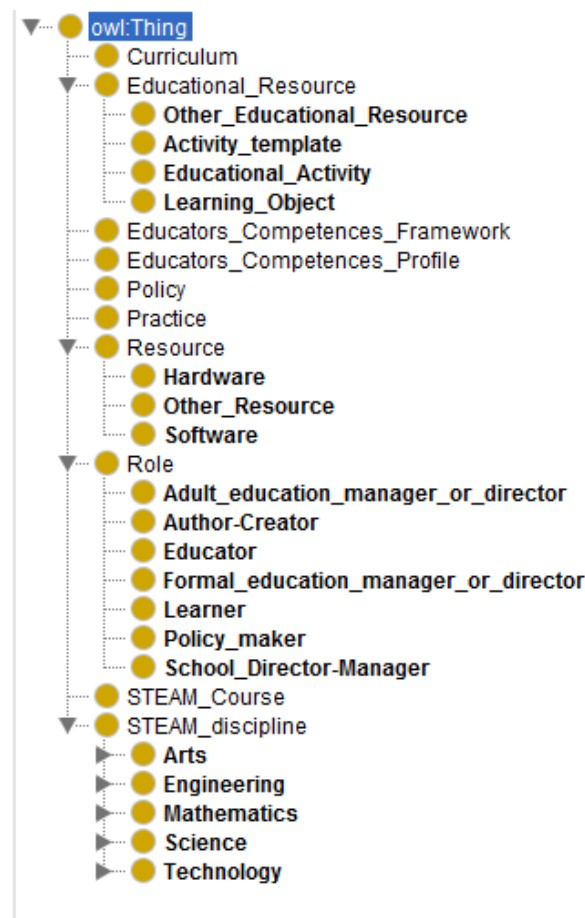


Figure 2. Classes and sub-classes of the STE(A)M ontology

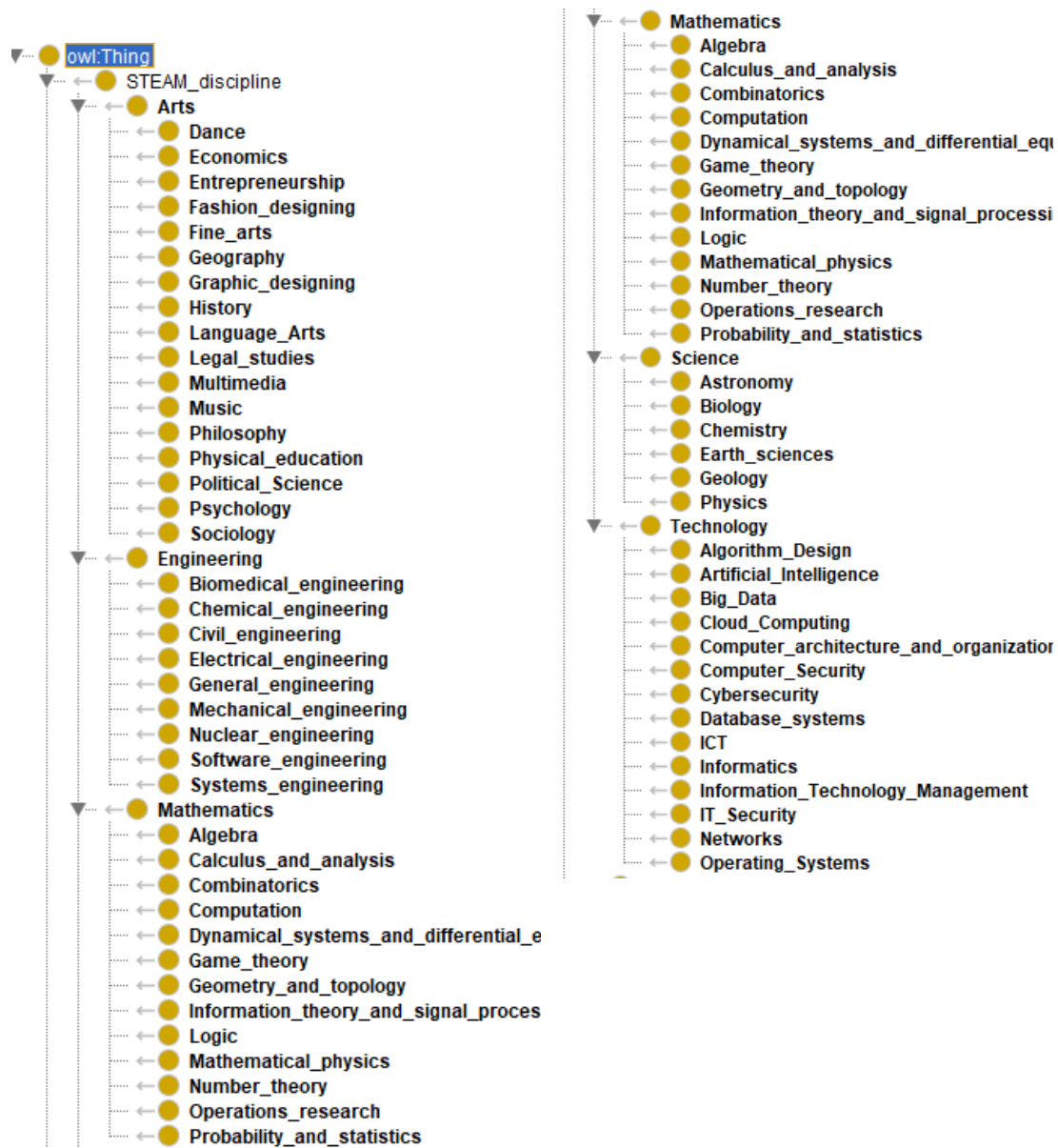


Figure 3. Classes and subclasses of the STEAM disciplines

### 3.2.1.5 Step 5: Define the properties of classes and Step 6: Define the data properties of the classes

The abovementioned classes and sub-classes were connected and characterized with properties. In Figure 4 the graphical representation of the classes, sub-classes and their properties is provided. The yellow items represent classes and subclasses, the green items represent the properties, while the arrows that connect two classes (yellow items) represent relations (called also object properties); note that relations are directional.

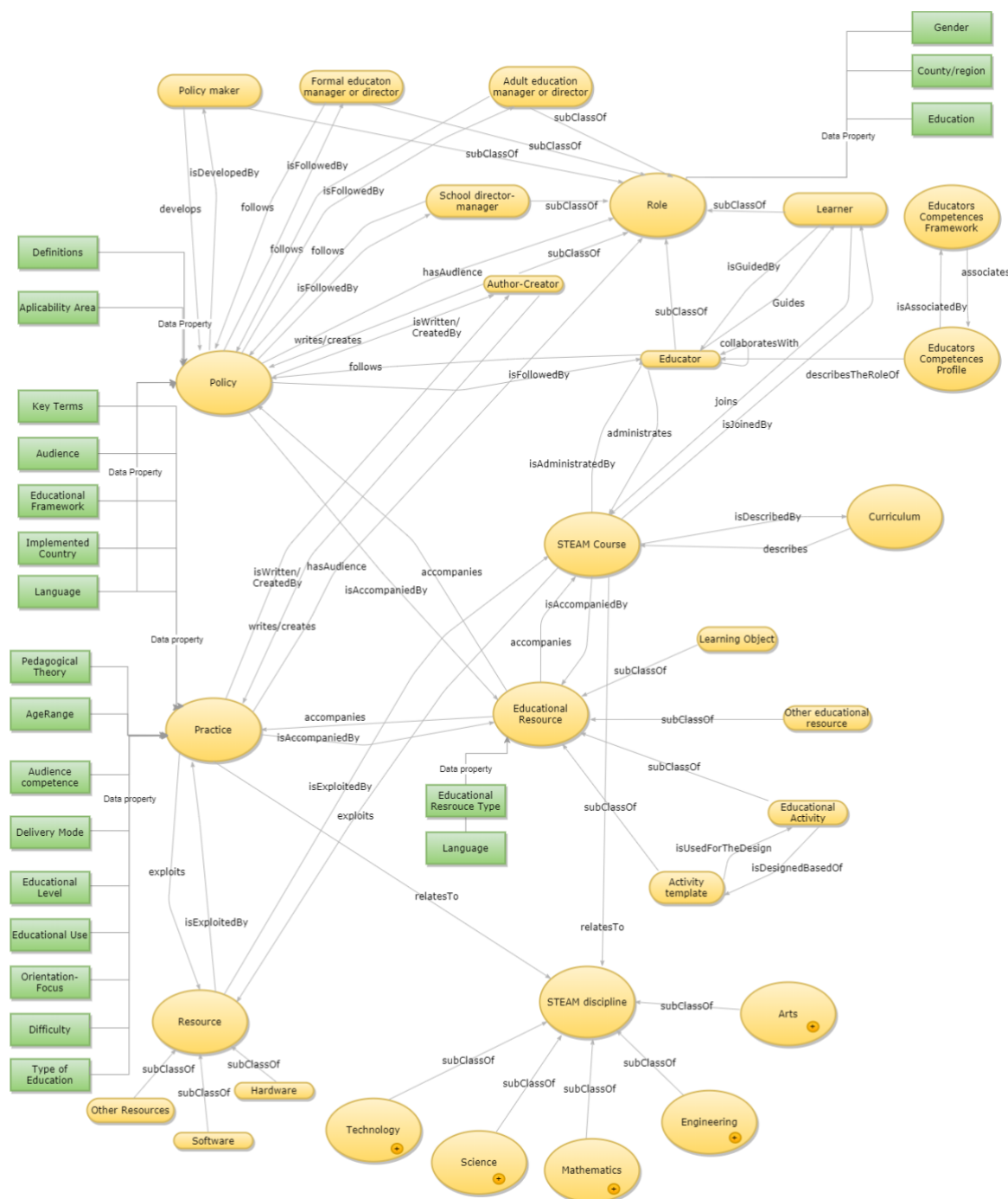


Figure 4. The graphical representation of the STEAM Ontology

All the properties are described in more detailed in the following tables. In each table, we write first the properties that describe relations (object properties) other than is\_a between classes (from Domain class to Range class) and then the properties that describe data sets (data properties). Where applicable, the inverse relation is also mentioned (in this case, the relation is from Range to Domain). Also, a brief description of each entry is given.

Property	Domain	Range	Description
<b>hasAudience</b>	Policy	Role	The Policy has specific Audience
<b>Aplicability_area (datatype:string)</b>  Values: { "European"^^xsd:string , "Institutional level"^^xsd:string , "Local"^^xsd:string , "National"^^xsd:string , "Regional"^^xsd:string , "School level"^^xsd:string }	Policy	-	The applicability area of this policy
<b>Definition (datatype:string)</b>	Policy	-	Unique terms that, by being defined, would add to the reader's understanding of the basic policy
<b>Educational Framework (datatype:string)</b>  Values: { "Adult education"^^xsd:string , "College - University"^^xsd:string , "Elementary"^^xsd:string , "Further education"^^xsd:string , "High school"^^xsd:string , "Kindergarden"^^xsd:string , "Middle school"^^xsd:string , "Other"^^xsd:string }	Policy	-	The educational framework of the policy
<b>Implemented Country (datatype:string)</b>	Policy	-	The Country that the policy implemented.
<b>Language (datatype:Language)</b>	Policy	-	The language that the policy was written
<b>Keyterms (datatype:string)</b>	Policy	-	The key terms of the policy

Table 6: Properties of Class "Policy"

Property	Domain	Range	Description
<b>exploits (isExploitedBy)</b>	Practice	Resource	The Practice exploits recourses
<b>HasAudience</b>	Practice	Role	The practice has audience
<b>RelatesTo</b>	Practice	STEAM discipline	The practice relates to STEAM disciplines
<b>Keyterms (datatype:string)</b>	Practice	-	The key terms of the practice
<b>PedagogicalTheory (datatype:string)</b>	Practice	-	The pedagogical theory of the practice
<b>AgeRange (datatype:string)</b>	Practice	-	The age range of the learners of the practice
<b>Audience competence (datatype:string)</b>  Values: { "beginner"^^xsd:string , "capable"^^xsd:string ,	Practice	-	The audience competence

Property	Domain	Range	Description
"expert"^^xsd:string , "proficient"^^xsd:string , "starter"^^xsd:string}			
<b>Delivery Mode</b> (datatype:string)	Practice	-	The delivery mode of the practice
Values: {"blended"^^xsd:string , "facetoface"^^xsd:string , "online"^^xsd:string}			
<b>Educational Level</b> (datatype:string)	Practice	-	The educational level of the practice
<b>Educational Use</b> (datatype:string)	Practice	-	The educational use of the practice
<b>Orientation-Focus</b> (datatype:string)	Practice	-	The orientation-focus of the practice
Values: {"acquire new knowledge"^^xsd:string , "attain attitudes"^^xsd:string , "develop new skills"^^xsd:string}			
<b>Difficulty</b> (datatype:string)	Practice	-	The difficulty of the practice
Values: {"difficult"^^xsd:string , "easy"^^xsd:string , "medium"^^xsd:string , "very difficult"^^xsd:string , "very easy"^^xsd:string}			
<b>TypeofEducation</b> (datatype:string)	Practice	-	The type of education of the implemented practice
Values: {"formal learning"^^xsd:string , "informal learning"^^xsd:string , "non- formal learning"^^xsd:string}			
<b>Educational Framework</b> (datatype:string)	Practice	-	The educational framework of the practice
Values: {"Adult education"^^xsd:string , "College - University"^^xsd:string , "Elementary"^^xsd:string , "Further education"^^xsd:string , "High school"^^xsd:string , "Kindergarden"^^xsd:string , "Middle school"^^xsd:string , "Other"^^xsd:string}			
<b>Implemented Country</b> (datatype:string)	Practice	-	The Country that the practice implemented.
<b>Language</b> (datatype:Language)	Practice	-	The language that the practice was written

Table 7: Properties of Class "Practice"

Property	Domain	Range	Description
<b>associates</b> (isAssociatedBy)	Educators Competence Framework	Educators Competence Profile	The Educators Competence Framework associates with the educators competence profile

Table 8: Properties of Class “Educators Competence Framework”

Property	Domain	Range	Description
<b>describesTheRoleOf</b>	Educators Profile	Educator	The Educators Competence Profile describes the role of educators.

Table 9: Properties of Class “Educators Competence Profile”

Property	Domain	Range	Description
<b>Gender</b> (datatype: string)  Values: { "I dont want to say"^^xsd:string, "female"^^xsd:string, "male"^^xsd:string, "other"^^xsd:string }	Role	-	Gender of the person.
<b>Country/region</b> (datatype:string)	Role	-	The Country/Role of the person.
<b>Education</b> (datatype:string)	Role	-	The educational level of the person.

Table 10: Properties of Class “Role”

Property	Domain	Range	Description
<b>collaboratesWith</b>	Educator	Educator	Educator collaborates with other educators
<b>Guides</b> (isGuidedBy)	Educator	Learner	Educator guides learner.
<b>administrates</b> (isAdministratedBy)	Educator	STEAM Course	Educator administrates STEAM courses.
<b>follows</b> (isFollowedBy)	Educator	Policy	Educator follows policies.

Table 11: Properties of sub-Class “Educator”

Property	Domain	Range	Description
<b>joins</b> (isJoinedBy)	Learner	STEAM Course	Leaner is joins STEAM Courses

Table 12: Properties of sub-Class “Learner”

Property	Domain	Range	Description
<b>writes/creates</b> (isWritten/CreatedBy)	Author-Creator	Policy or Practice	Author-Creator writes policies or/and practices

Table 13: Properties of sub-Class “Author-Creator”

Property	Domain	Range	Description
<b>follows</b> (isFollowedBy)	School director-manager	Policy	School director-manager follows policies.

Table 14: Properties of sub-Class “School director-manager”

Property	Domain	Range	Description
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<b>follows (isFollowedBy)</b>	Formal education manager or director	Policy	Formal education manager or director follows policies.
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Table 15: Properties of sub-Class "Formal education manager or director"

Property	Domain	Range	Description
<b>follows (isFollowedBy)</b>	Adult education manager or director	Policy	Adult education manager or director follows policies.

Table 16: Properties of sub-Class "Adult education manager or director"

Property	Domain	Range	Description
<b>develops (isDevelopedBy)</b>	Policy maker	Policy	Policy maker develops policies.

Table 17: Properties of sub-Class "Policy maker"

Property	Domain	Range	Description
<b>accompanies (isAccompaniedBy)</b>	Educational Resource	STEAM Course	Educational resource accompanies STEAM Courses
<b>Educational Resource Type</b>	Educational Resource	-	Educational resource has specific type  Values: { "diagram"^^xsd:string , "exam"^^xsd:string , "exercise"^^xsd:string , "experiment"^^xsd:string , "figure"^^xsd:string , "graph"^^xsd:string , "handout"^^xsd:string , "lecture"^^xsd:string , "presentation"^^xsd:string , "questionnaire"^^xsd:string , "simulation"^^xsd:string }
<b>Language (datatype:Language)</b>	Policy	-	The language that the educational resource is.

Table 18: Properties of Class "Educational Resource"

Property	Domain	Range	Description
<b>isDesignedBasedOf (isUsedForTheDesign)</b>	Educational Activity	Activity Template	Educational activity is designed based on activity templates

Table 19: Properties of sub-Class «Educational Activity»

Property	Domain	Range	Description
<b>exploites (isExploitedBy)</b>	STEAM Course	Resource	STEAM Course exploits resources
<b>RelatesTo</b>	STEAM Course	STEAM discipline	The practice relates to STEAM disciplines

Table 20: Properties of Class "STEAM Course"

Property	Domain	Range	Description
<b>describes (isDescribesBy)</b>	Curriculum	STEAM Course	Curriculum describes the STEAM Course

Table 21: Properties of Class "Curriculum"

In Figure 5 and Figure 6, we present all the properties that at this time have been linked to the classes and sub-classes of the STE(A)M Ontology. At the left side of the screenshot, the list of the created properties is shown while at the right side the connections between the classes

for the selected properties are presented. For example, Figure 6 shows the description of the object property “accompanies”, the domain of which is class “Educational Resource” and its range are the classes “Policy” or “Practice”; note that in OWL Syntax the “or” is not exclusive.

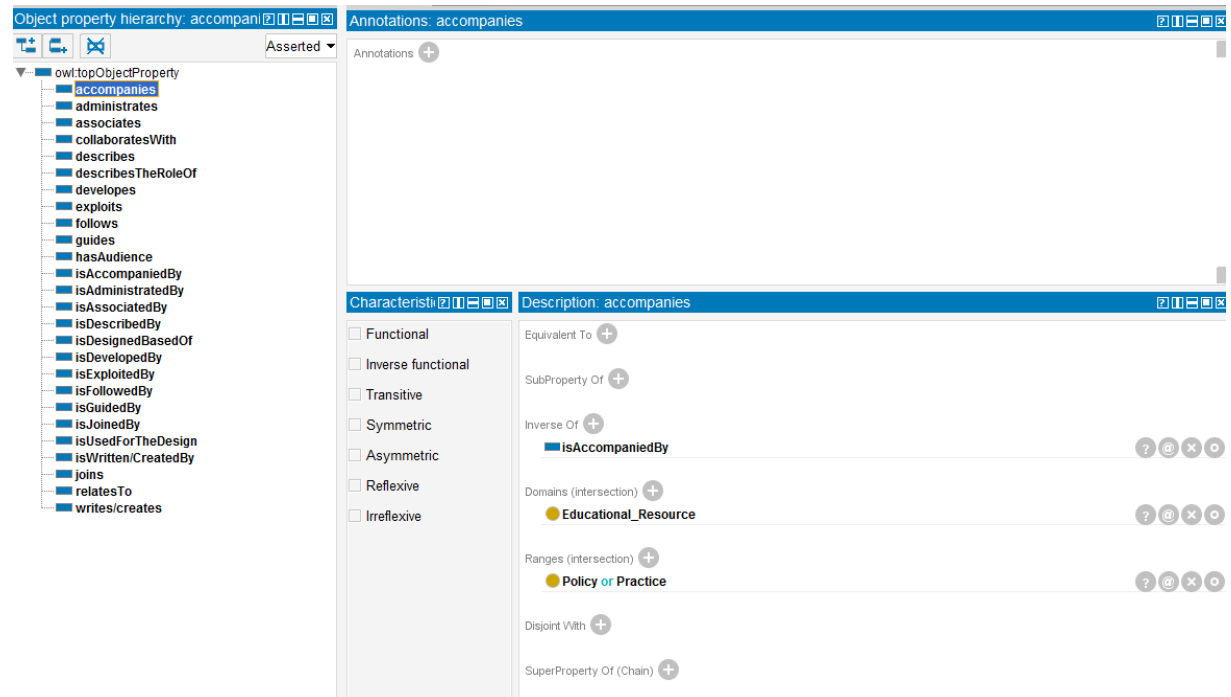


Figure 5: Screenshot from protégé with the list of object properties of the STEAM ontology

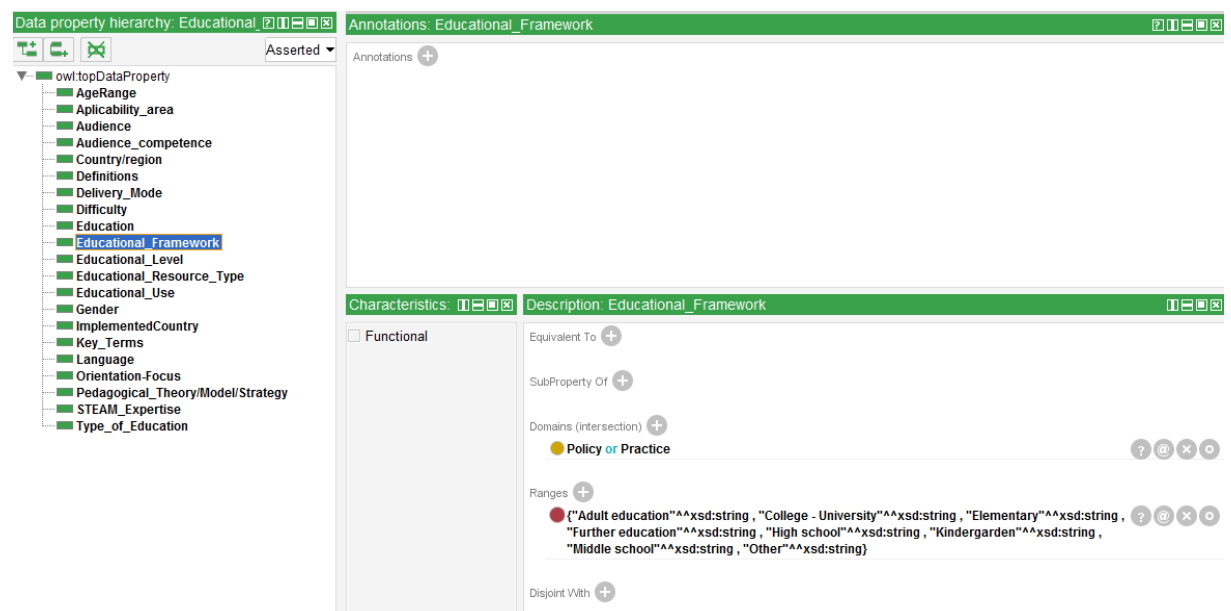


Figure 6: Screenshot from protégé with the list of data properties of the STEAM ontology



### 3.2.1.6 Step 7: Create instances

At this point, some individual instances were created and connected with specific classes, sub classes and connections. For example, in Figure 6 the individual instance named “Practice 5” is presented. This individual instance represents a specific practice.

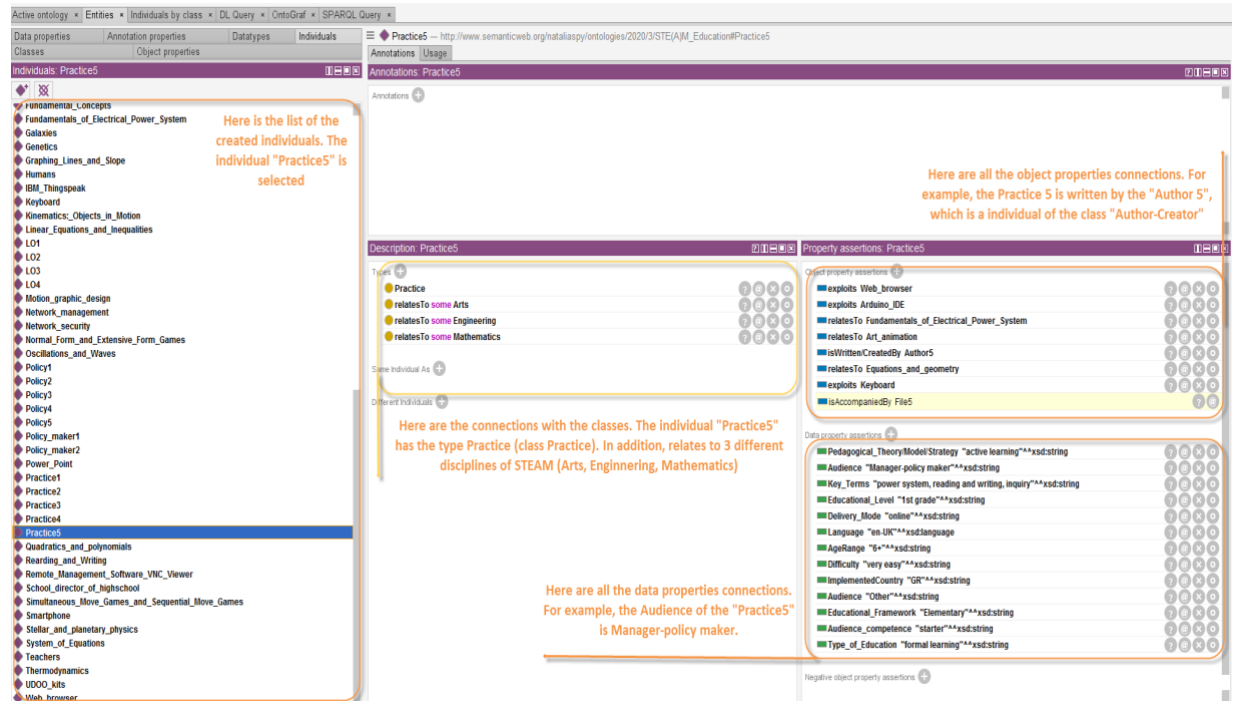


Figure 7: Screenshot from protégé with individuals

### 3.2.1.7 Step 8: Evaluate the ontology by implementing DL Queries

One way to determine the scope of the ontology is to sketch a list of competency questions that a knowledge base based on the ontology should be able to answer. These questions will serve as the litmus test later: Does the ontology contain enough information to answer these types of questions? Do the answers require a particular level of detail or representation of a particular area? These competency questions are just a sketch; the list does not need to be exhaustive [1].

The following list contains some of the competency questions that were created in order to design and evaluate the STE(A)MonEdu ontology.

- What are the submitted practices?
- Which practices are implemented for elementary level?
- Which practices are implemented for elementary or kindergarten?
- Which practices include arts and science subjects?
- Which practices include all STEAM subjects except arts?
- Which practices are delivered using blended learning?
- Which practices are in English?
- In which countries the submitted practices were implemented?
- Which practices were submitted by “Author1”?
- Which practices are implemented in European level and are written in English?

- Which practices are addressed to policy makers?
- What is the accompanying material in “Practice1” practice?
- What software and hardware resources are needed for the submitted practices?
- Which STEAM subjects were addressed in the submitted practices?
- What are the submitted policies?
- Which policies include all STEAM subjects?
- Which policies are addressed to educators and are written in English?
- Which policies have expert audience competence?
- Which policies are addressed to kindergarten educational framework?
- What are the required resources for “Practice1” practice?
- What policies were implemented in Italy and had application area at European level?

In order to evaluate the ontology, we present in the following screenshots examples of the DL queries and their results.

*Query 1: What are the submitted practices?*

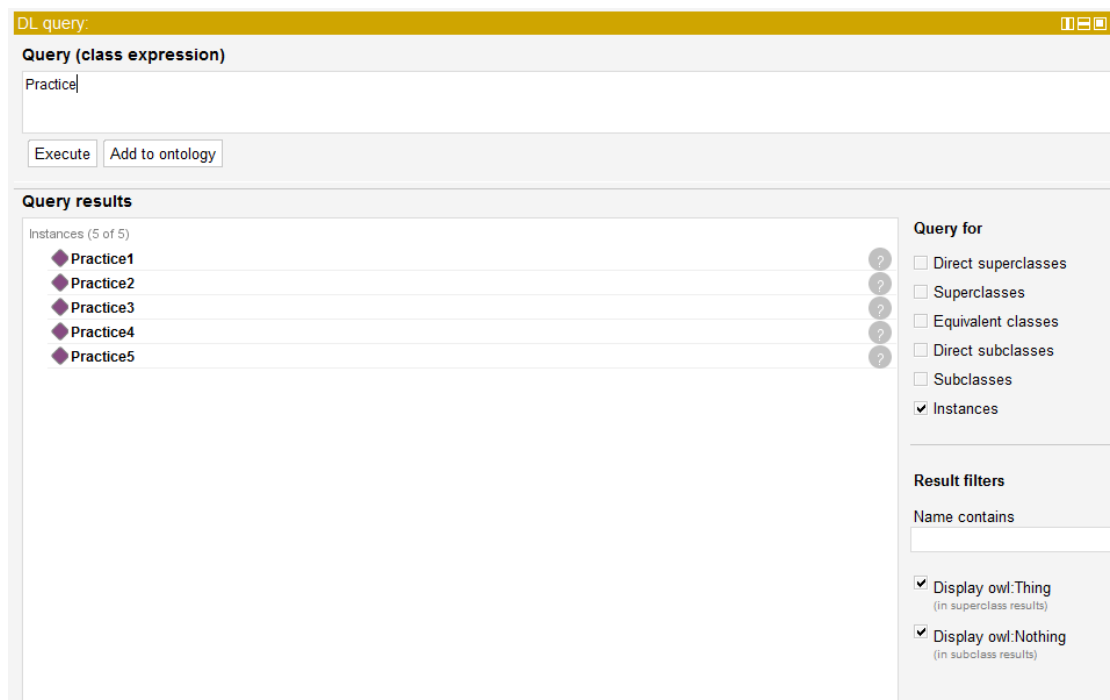


Figure 8: Screenshot from protégé with query 1 results

Query 2: Which practices are implemented for elementary level?

DL query:

**Query (class expression)**

Practice and Educational\_Framework value "Elementary"

Execute Add to ontology

**Query results**

Instances (3 of 3)

- Practice2
- Practice4
- Practice5

**Query for**

- ☐ Direct superclasses
- ☐ Superclasses
- ☐ Equivalent classes
- ☐ Direct subclasses
- ☐ Subclasses
- ☒ Instances

**Result filters**

Name contains

- ☒ Display owl:Thing (in superclass results)
- ☒ Display owl:Nothing (in subclass results)

Figure 9: Screenshot from protégé with query 2 results

Query 3: Which practices are implemented for elementary or kindergarten?

DL query:

**Query (class expression)**

Practice and (Educational\_Framework value "Elementary" or Educational\_Framework value "Kindergarden")

Execute Add to ontology

**Query results**

Instances (4 of 4)

- Practice1
- Practice2
- Practice4
- Practice5

**Query for**

- ☐ Direct superclasses
- ☐ Superclasses
- ☐ Equivalent classes
- ☐ Direct subclasses
- ☐ Subclasses
- ☒ Instances

**Result filters**

Name contains

- ☒ Display owl:Thing (in superclass results)
- ☒ Display owl:Nothing (in subclass results)

Figure 10: Screenshot from protégé with query 3 results

Query 4: Which practices include arts and science subjects?

DL query:

**Query (class expression)**

Practice and (relatesTo some Arts and relatesTo some Science)

Execute Add to ontology

**Query results**

Instances (1 of 1)

- Practice2

**Query for**

- ☐ Direct superclasses
- ☐ Superclasses
- ☐ Equivalent classes
- ☐ Direct subclasses
- ☐ Subclasses
- ☒ Instances

**Result filters**

Name contains

☒ Display owl:Thing (in superclass results)

☒ Display owl:Nothing (in subclass results)

Figure 11: Screenshot from protégé with query 4 results

Query 5: Which practices are in English?

DL query:

**Query (class expression)**

Practice and Language value "en-UK"

Execute Add to ontology

**Query results**

Instances (5 of 5)

- Practice1
- Practice2
- Practice3
- Practice4
- Practice5

**Query for**

- ☐ Direct superclasses
- ☐ Superclasses
- ☐ Equivalent classes
- ☐ Direct subclasses
- ☐ Subclasses
- ☒ Instances

**Result filters**

Name contains

☒ Display owl:Thing (in superclass results)

☒ Display owl:Nothing (in subclass results)

Figure 12: Screenshot from protégé with query 5 results

*Query 6: Which practices are addressed to policy makers?*

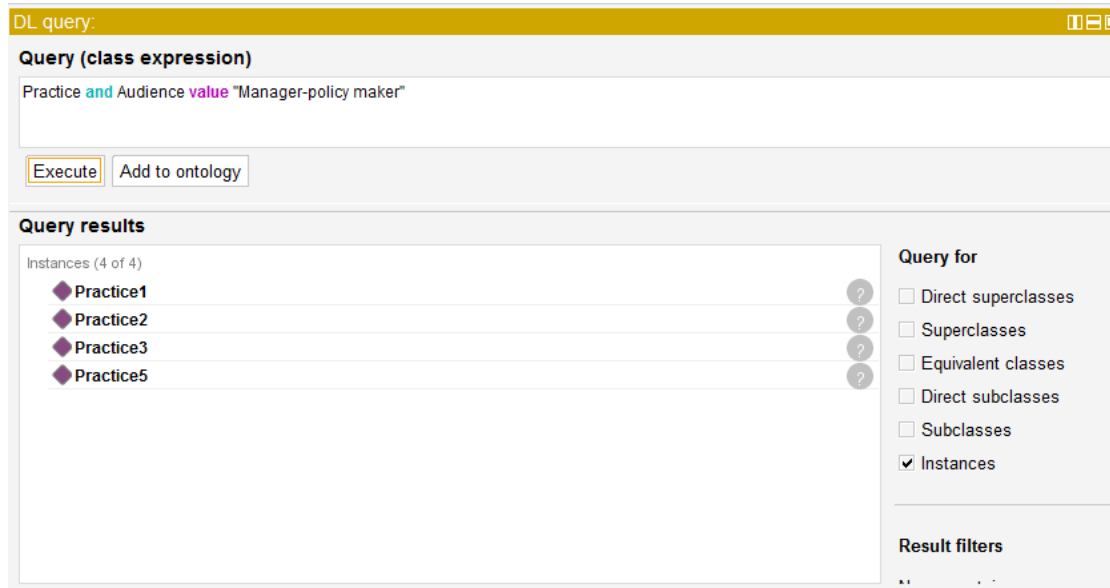


Figure 13: Screenshot from protégé with query 6 results

*Query 7: Which policies are addressed to educators and are written in English?*

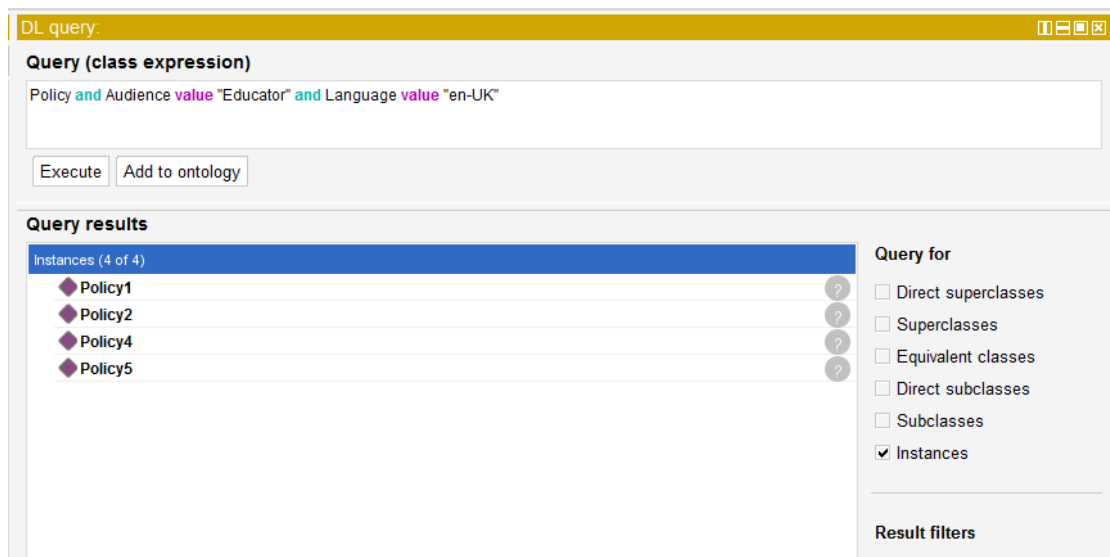


Figure 14: Screenshot from protégé with query 7 results

Query 8: What is the accompanying material in “Policy1” policy?

DL query:

**Query (class expression)**

Educational\_Resource and accompanies value Policy1

Execute Add to ontology

**Query results**

Instances (2 of 2)

- File1
- File5

**Query for**

- ☐ Direct superclasses
- ☐ Superclasses
- ☐ Equivalent classes
- ☐ Direct subclasses
- ☐ Subclasses
- ☒ Instances

**Result filters**

Name contains

☒ Display owl:Thing (in superclass results)

☒ Display owl:Nothing

Figure 15: Screenshot from protégé with query 8 results

Query 9: What are the required resources for “Practice1” Practice?

DL query:

**Query (class expression)**

Resource and isExploitedBy value Practice1

Execute Add to ontology

**Query results**

Instances (2 of 2)

- Keyboard
- UDOO\_kits

**Query for**

- ☐ Direct superclasses
- ☐ Superclasses
- ☐ Equivalent classes
- ☐ Direct subclasses
- ☐ Subclasses
- ☒ Instances

**Result filters**

Name contains

☒ Display owl:Thing (in superclass results)

☒ Display owl:Nothing (in subclass results)

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