

# Comped, a Web-based Competency Ontology Editor for Dynamic Geometry

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**Abstract.** The Intergeo project addresses the issue of sharing interactive geometry across Europe upon a competency ontology enabling semantic annotation of resources. Whereas ontology engineer and platform administrator can manage this ontology using standard ontology editing tools, it is not the case for other roles, usually taken by average teacher and curriculum experts. This paper describes CompEd, a dedicated tool providing online means integrated to the Intergeo platform to access and edit this competency ontology. It presents its functionalities and how it is linked and synchronised with other Intergeo components.

**Keywords.** Competencies, Topics, Ontologies, Learning-resources, Authoring.

## 1. Introduction

The Intergeo project, funded by the European Community, aims at providing teachers with means to share dynamic geometry resources across Europe. It has developed a platform (<http://i2geo.net/>) where they can add a new resource and search for existing one by subject, level, instructional type, etc.

A core element of that platform is a competency ontology, named GeoSkills, that provides a shared semantic to resources. This ontology contains as of this writing about 600 classes and 2,500 instances representing competencies from the mathematics education standards of Spain, Germany, France and United Kingdom.

After a first phase where curriculum experts of the project have edited GeoSkills using Protégé with the help of ontology experts [6], a web-based tool was needed to enable the wide community of mathematic teachers and curriculum experts to edit this ontology across Europe.

This article is focused on this web-based competency ontology editor, called CompEd. It starts with a brief description of GeoSkills and the roles that need to edit it. CompEd features are then presented followed by the specification of its architecture and how it synchronises with other software components. We conclude with the implementation status and perspectives on users manipulation of GeoSkills in Comped.

## 2. Editing GeoSkills ontology with roles.

In this section, we present the GeoSkills ontology and its rationale, and then the roles that need to edit it.

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### 2.1. The GeoSkills ontology and its rationale.

The GeoSkills ontology objective is to encode both a fine-grained mathematical semantics as well as names taken from various contexts (educational regions and languages). OWL-DL has been chosen to express GeoSkills for its well-defined semantics, its decidable knowledge representation and its interoperability over the WEB [3].

In order to provide to users names and descriptions of competencies they are used to, each elements of the OWL ontology (classes, instances and properties) can be described by names for each language. This is made using for instances, dedicated datatype properties, and for classes and properties, rdfs:label annotations.

GeoSkills essential ingredients are topics, competencies, pathways, levels and programs.

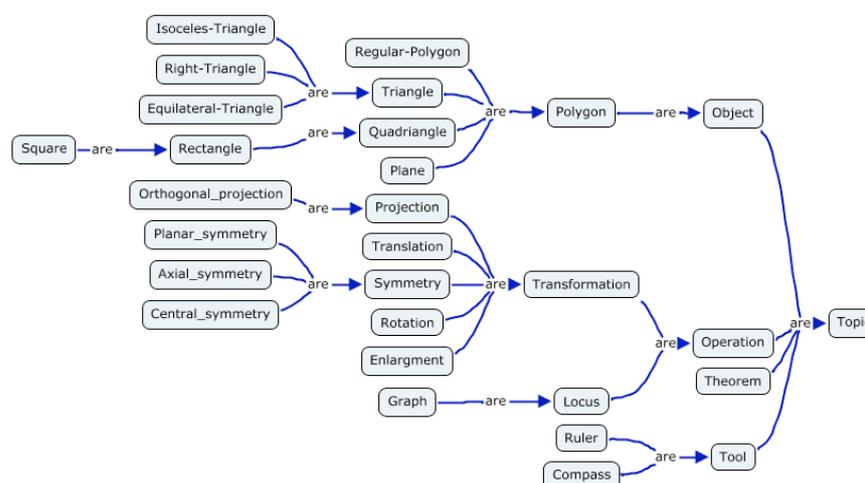


Figure 1. Extract of the topics hierarchy of GeoSkills

**Topics:** are made as a taxonomy (see figure 1), that is, a hierarchy of abstract classes each representing mathematical topics and objects. Multiple inheritance is possible thanks to OWL and is of great use in this case. Because OWL-DL properties only relate on instances, each class has a single representative individual. Properties on Topics are used to annotate resources with a topic or to relate a competency to topics

Examples of topics include [isosceles triangle](#) or [ApproximationProcess for roots](#).

**Competencies:** are becoming the major entity of assessment and learning-plans. In GeoSkills, just as in [7] or [4], competencies are made of a verb and a set of topics. The class hierarchy of competencies represents the specialisation hierarchy of verbs. Examples of competencies include [Calculate trigonometric ratio](#), [Reproduce an isosceles triangle](#), or [Identify square numbers](#). In the first case, calculate trigonometric ratio, the OWL individual is of the class [Calculate](#) and contains the topic [trigonometric ratio](#).

**Pathways:** are a series of educational contexts such as elementary-school, or [Secondaire de Qualification Technique Artistique](#).

**Levels:** are elements of a pathway, for example one of its year. For example [Gymnasium Saarland 7te](#), or [Bachillerato Ciencias y Tecnologia 2](#).

**Programmes:** a programme is the concrete plan of a level within a pathway; it is bound to curriculum standards. A programme is more a document than an individual, containing links to competencies where they are referenced.

The GeoSkills ontology is available under the Creative Commons Attribution ShareAlike and Apache Public Licenses; the current version can be downloaded from <http://i2geo.net/ontologies/current/GeoSkills.owl>.

With the Intergeo approach based on his ontology, searching through “Thales” competencies across European curricula provides also two types of competencies, obviously competencies having in one of their name or referring to topics whose name contain “Thales” but also to competency related to the “Intercept theorem” which is the English name of the French/Italian/Spanish “Thales Theorem”. And inferred knowledge can be used, for example to match [use binomial identities to solve equations](#)<sup>1</sup> with queries using “equality”, because *mathematically* an equality is a kind of identity.

## 2.2. Roles editing GeoSkills ontology

The Intergeo platform's main goal is to allow sharing of interactive geometry constructions and related materials. Overall, the usage of the platform is the execution of the following roles that access or edit the GeoSkills ontology:

- **The annotator** uses the editing front-end of the community platform in order to annotate resources as referencing the given competencies or topics, and a given educational-level, as well with many other information fields (such as authorship or license). Annotator needs a read-only access to the ontology, to check if the competencies chosen are the proper ones with the correct semantics.
- **The searcher** uses text-search, the ontology or curriculum-text browsing to identify the correct term so as to search through the platform's database to find relevant resources to use in teaching, to edit, or to evaluate. It also need a simple read-only access to GeoSkills, allowing her/him to browse through curricula, classes and instances of competencies and topics.
- **The curriculum encoder** identifies a curriculum-text of interest that could be shared among platform users, obtains an appropriate electronic version, browses through it and creates, in the ontology, the needed competencies and topics.
- **The competency translator** adds or edits competency or topic names or descriptions in one's own language. This does not require editing competency and topic classes or instance but only their denominations.
- **The ontology engineer**, together with the **platform administrator**, operates changes on the ontology for any facet, such as edition of the axioms or educational levels.

## 3. CompEd features

Whereas ontology engineer and platform administrator are able to us generic ontology editor such as Protégé, it is not the case of average curriculum encoders, competency translator furthermore annotators or searchers, roles usually played by average teacher or education experts but usually not semantic web experts.

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<sup>1</sup> Throughout this paper, we provide hyperlinks to the CompEd user-readable representation of the GeoSkills node when they are referenced.

We first tried to use of the Protégé client-server<sup>1</sup> which allowed team members to work synchronously on the ontology from remote places provided they are equipped with a very good network connection; only Universities met this challenge thus far. For other members, in particular companies involved in the Intergeo project, it was necessary to allow exclusive work on a local copy. Another limitation was met in the generic ontology-editor nature of Protégé, which makes it able to perform all sorts of changes, many of which should be reserved to ontology experts.

Then a platform to edit the ontology was needed, a web-based editing tool that allows every people from the dynamic geometry community to contribute and use aside of the Intergeo platform. As explained in [5], the GeoSkills ontology has been developed using an approach close to that described in MI2O. We propose a web-based tool that corresponds to the last phase of that methodology, the deployment, with iterations through the validation and refinement phases. This editing tool is called CompEd (Competency Editor). Its objective is to edit topic and competency individuals of GeoSkills as well as the topic and competency sub-classes and individuals. Editing includes altering names and relation properties (such as the generalisation/specialisation, instantiation relationships, or the involvement relationship of a topic in a competency).

### 3.1. Web based navigation

Even before the editing actions, a first important aspect is to allow web-based navigation of nodes of the ontology to allow the annotation of curriculum texts and textbooks: both of these features are to be done by having topics, competencies, and levels addressable through URLs which can also be presented in a browser. The annotations edited in the Intergeo platforms use these links as part of their presentation as in the figure 2 aside from this paragraph.

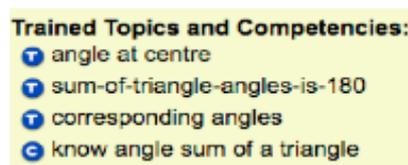


Figure 2. Rendered annotations of a resource.

### 3.2. CompEd Features

CompEd offers the browsing and editing of individual topics, competencies, and competency processes. Individuals can be reached by tracking recent activity; by browsing the alphabetic list view or hierarchical tree view; by navigating the relationships; by keyword searching; or by an external URL.

Items are displayed in a consistent way. As depicted by figure 3, which is an example for the "[solve similarity problems](#)" competency individual, the display is divided into three parts:

- The first part provides general information, which includes the name of the URI, the URI itself, the created and the modified dates. Below, the names in the user's language for the particular item are displayed. Names are grouped by type (common, uncommon, rare, false-friend). If wished, the user can click on the "more languages" link to get the other languages names.

<sup>1</sup> The Protégé client-server setting is based on Java RMI and is documented at [http://protegewiki.stanford.edu/index.php/Protege\\_Client-Server\\_Tutorial](http://protegewiki.stanford.edu/index.php/Protege_Client-Server_Tutorial)

- The topic part just provides a list of topics that are connected to the competency item. The list items are links, which simplifies the navigation to the topic. Note there is no topic part in the view for topic items (only competencies are linked to topics).

The screenshot shows the I2Geo CompEd web interface. At the top, there is a navigation menu with links for 'Main Menu', 'Competencies->', 'Topics', 'Edit Profile', and 'Logout'. The main content area is titled 'Competency Information' and includes the following details:

- Created: 08/29/2008, Last modified:08/29/2008
- Solve similarity problems**
- URI: [http://www.inter2geo.eu/2008/ontology/ontology.owl#Solve\\_similarity\\_problems](http://www.inter2geo.eu/2008/ontology/ontology.owl#Solve_similarity_problems)
- Names [\[Add\]](#)
- Common names [\[More languages\]](#)
- use similarity [\[Edit\]](#) [\[Delete\]](#) [\[translate\]](#)
- résoudre des problèmes mettant en jeu des formes [\[Edit\]](#) [\[Delete\]](#)
- resolver problemas de figuras semejantes [\[Edit\]](#) [\[Delete\]](#)
- No uncommon names available
- No rare names available
- No false-friend names available
- Topics
- [Similar](#)  
[similar triangles](#)
- Structural Information
- Competency
  - TransversalCompetency
    - Solve
      - Solve graphically
      - Solve in geometry
      - Solve similarity problems**
- No similar items

Figure 3. Presentation of a competency in CompEd (for curriculum encoder role)

- Finally, the structural part shows a hierarchical tree, which represents the generalisation/specialisation/instantiation path down to the competency item. In the case of competency classes (called *Competency processes* in the English GUI and *Catégories de compétences* in the French one), the tree will have all super-classes, subclasses, and individuals that are on the path through the competency process node.

Adding and editing of names as in the picture above includes the provision of a textual name, a language, and a type. The type can be one of: common, uncommon,

rare, or false friend. While the latter pieces of information have a default value to be displayed in Intergeo tools (common name and the native language of the user), the validation through OWL axioms guarantees that a name is provided.

Editing of competencies includes:

- changes, additions, and deletions of competencies,
- alterations on the competencies' URI,
- making connections to competency processes,
- referencing to topics.
- provision of a default common-name in any language

Editing of competency classes is very similar except that connections are established to other competency classes (which denotes a subclass relation) and to competencies instances (which denotes a membership relation). CompEd supports the user in altering data as much as possible, i.e., it suggests default values and signals errors in a user-friendly way.

The remaining input that is not covered in the CompEd usage is left for the ontology experts which includes adding or deleting extra properties, defining a class with a necessary and sufficient restriction, adding or deleting axioms about the ontology. Currently, edition of educational levels is also left to them, basically by using Protégé editor. They work informed by the curriculum encoding community based on a public forum where users of the curriculum knowledge, curriculum encoders, and ontology experts discuss.<sup>1</sup>

#### 4. CompEd Architecture

The CompEd server software has been designed with high-usability in mind based on web-technologies that are widely spread. Thus the AppFuse framework<sup>2</sup> is at its core and its memory management is supported by the RDBMS persistence engine MySQL through the widespread java persistence framework Hibernate.<sup>3</sup> These choices make CompEd a long-lasting responsive edition framework.

The decision not to use an OWL persistence engine is due to the apparently still lacking persistence framework for this technologies which scale long term and the ongoing need to load the complete ontology in RAM for most forms of reasoning.

#### 5. CompEd synchronisation with other components

##### 5.1. Editing tools

Two tools, CompEd and Protégé, can edit the GeoSkills ontology. Protégé 3.3.1 has been the first editing tool for creating a GeoSkills first version, used by two curriculum experts. It offers all the possible OWL expressivity. The normal tool to be used by curriculum experts is CompEd, but it offers an expressivity reduced to instances, hyponymy (is-a relation), links between competency and topics, and names. Because CompEd is unaware of axioms that have been expressed in OWL with Protégé, violations and new statements appear once the reasoning is invoked, nightly.

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1 The curriculum encoders' online community is being built at <http://curriculum.i2geo.net/>

2 See <http://www.appfuse.org/>

3 See <http://www.hibernate.org/>

The Pellet classifier [1], on a dedicated server, makes these ontological consistency checks. This classifier provides also automatic classification of Competency classes between them, and of Competency instances into classes.

### 5.2. Accessing tools: SkillsTextBox

To allow users to identify the competencies, topics, or levels they mean, we extend the familiar auto-completion paradigm: users can type a few words in the search field, these are matched to the terms of the names of the tokens; the auto-completion pop-up

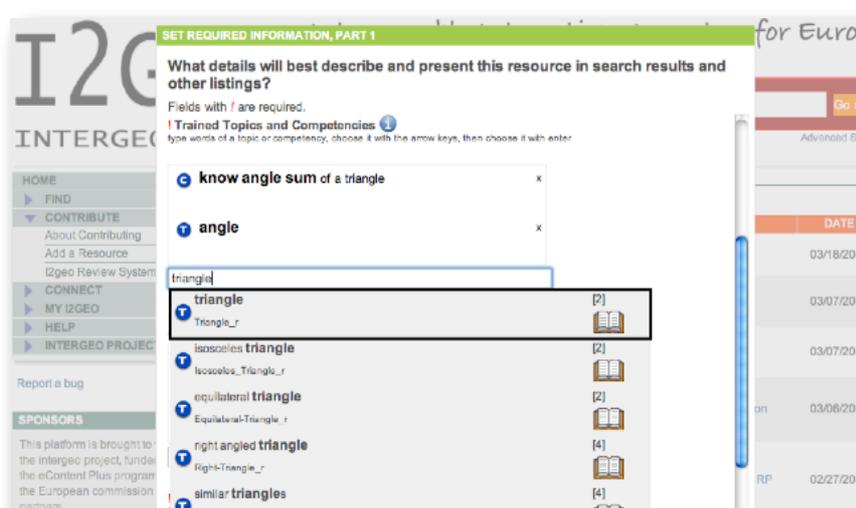


Figure 4: skilltextbox matching.

presents, as the user types, a list of matching tokens as seen on figure 4. This list presents, for each candidate, the default-common-name, the name found to match the user's input, the number of related resources, an icon of the type, and a link to browse about the ontology at the node and around it. When chosen using either a click, or a few presses of the down key followed by the return key, the choice action either triggers a search or the addition of the node in a list, or for annotations.

SkillsTextBox uses a simple HTML form equipped with a GWT script [2]. This script submits the fragments typed to the index on the server, which uses all the retrieval matching capabilities (stemming, fuzziness through edit distance or phonetic matching) to whose names start with the typed input, first in the languages supported by the user than in any language. The index returns the 20 best matching tokens and the script renders as an auto-completion list. More information about it is at <http://www.activemath.org/projects/SkillsTextBox/>.

### 5.3. CompEd, OWL, and the Term Index: Synchronisation

The competency-editor, the Protégé editor, the Skills-text-box' term index all are places which store a representation of the GeoSkills' ontology; in this section we explain how the OWL ontology file is at the centre of the synchronisation with incremental updates and regular resets.

The architecture of these pieces is depicted in figure 5: CompEd stores the contents of GeoSkills in a way made for massive collaborative edition; it cannot allow edition of all facets of the ontology; on the other side, Protégé allows full edition of the OWL ontology but is not suitable for such collaborative edition; the ontology server stores the ontology in RAM and performs the reasoning but it only receives the updates done by the CompEd users through update XML documents which are then incorporated into the OWL file. Finally, the term index contains an index of the names, ready for retrieval in the auto-completion and search functions.

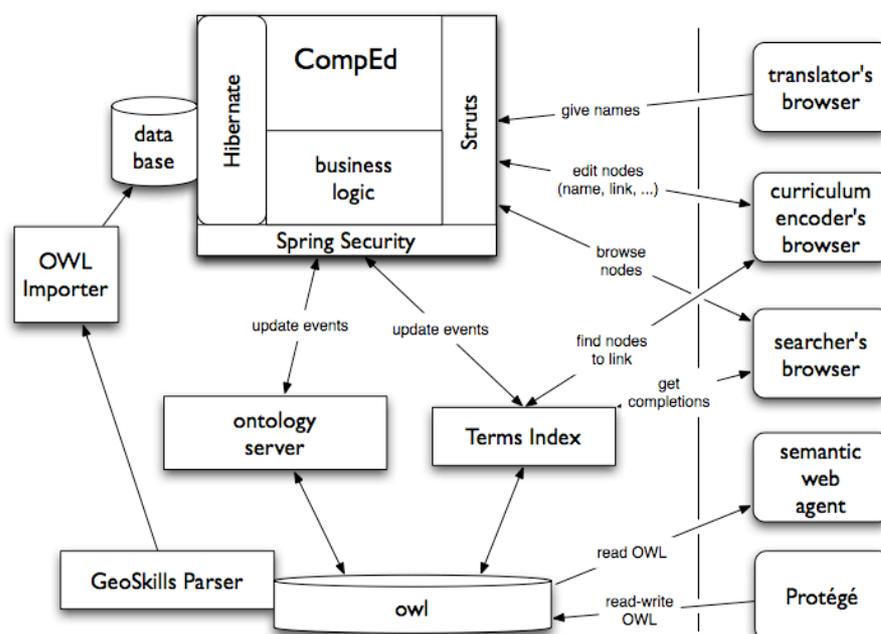


Figure 5. Architecture of the usages of the GeoSkills ontology

The communication flows between the pieces are as follows:

**CompEd updates:** following the actions of a curriculum-encoder or curriculum-translator, CompEd modifies his RDBMS storage and also sends an update document to the ontology server and to the term index. The latter update their representations following these updates.

**Regular resets:** because the intent of the competency editing process is the GeoSkills ontology, the ontology is used to replace the contents in RDBMS. This is done through a conversion from the OWL file, read through the reasoner, to the tabular format. These resets are applied every night and are the key to receive the reasoner results (such as the axioms that add properties or classes).

**Ontology adaptation:** from time to time, having concerted themselves, the ontology engineers will request to work at the ontology level, for example to add axioms, to add particular new classes or to perform clean-up operations. In order to do so, the CompEd server is taken read-only and the work on the OWL file in a text-editor or using Protégé can happen. It is followed by the regular reset, which re-imports the OWL file in the RDBMS.

## Conclusion

The CompEd ontology editing tool has been developed to help standard users to collaboratively edit the GeoSkills ontology. It is linked with the other Intergeo platform tools and thus offers a standardised way of accessing and editing this ontology on the web. A synchronisation mechanism is the basis that enables that the ontology is consistently handled.

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Because of its collaborative aspect, CompEd seems to be one of the sole tools in the world to undertake the encoding of a multilingual and multicultural pool of educational competencies and topics.

The public deployment of CompEd and the opening of the curriculum-encoders group to users which have never seen Protégé has happened early 2009: the group now contains also encoders of the Czech, German, Dutch, Russian mathematics curriculum standards.

## *Perspectives*

The commitment to encode the curriculum standards of mathematics of many European countries seems to be novel at least by its great diversity and start on the strong basis of a usable editing tool and internationalisation infrastructure. The perspective of such a large coverage may uncover new cross-lingual issues, which such an enterprise as Academic Benchmarks<sup>1</sup> seems not to have met yet.

The curriculum encoders' work includes the annotations of curriculum standards, or other texts for this purpose, by the additions of hyperlinks from sentences of the texts till the nodes of the ontology. Currently, encoders' are requested simply insert links to CompEd URLs. However this curriculum-linking task is only easy for HTML documents which are also the easiest documents to post-process to make actionable, allowing a reader to click on sentences to choose annotations. Most educational ministries, however, deliver the curriculum standards in PDF form, which has the advantage to be very close in appearance to the paper form, which a reader may well be used to. It is not yet clear whether this format will be acceptable for curriculum linking or to become actionable.

Among the avenues to be explored deeper is a more synthesised and complete exploitation of the conclusions of the reasoner. While inherited property values are easily handled by the parsing infrastructure which uses the reasoner, the automated classification results have been ignored thus far because it would make any parent class a direct subclass of the node: at least in the competency editing process, this is wrong as it would flatten the whole tree of inheritance (e.g. as in figure 3). We have to explore

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<sup>1</sup> Academic Benchmarks Inc. is an american corporation providing services of matching curriculum standards to content resources.  
See <http://www.academicbenchmarks.com/>.

such avenues as taking parent-classes inferred by the reasoners and removing the asserted ancestor parent-classes.

An issue we encountered together with the curriculum encoders of the Intergeo project is the readability of URIs. On the one hand, this characteristic is good, creating, for example, URLs and annotations that are more readable hence easier to manage. On the other hand a readable URI carries a textual semantic and several times we encountered the wish to adjust that URI to resembles better the semantic of the node. Changing a URI, however, would need a richer infrastructure e.g. resulting in redirects or the adjustment of all the links. One of the safest approaches could be to have unreadable URIs, as safe randoms. More experience is required to decide on best practice.

Beyond parsing, there should also be the possibility of the ontology server to feedback on changes done in the curriculum editing process, including indicate inconsistencies that have appeared. The XML encoding of the updates could be of use for this purposes displaying errors.

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