

# Semantic CMS and Wikis as Platforms for Linked Learning

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## ABSTRACT

Although interoperability has always been a priority in e-learning, conventional Learning Management Systems are mostly geared towards the Standards for Learning Objects exchange and the integration among systems. The contingency for integration with other web applications and data is hardly foreseen. This prevents them, nowadays, from being flexible to adapt to the Linked Data standards emergence and the advent of Semantic Web in general, unless they radically change orientation. In contrast, Wikis, followed by Content Management Systems, proved to be more versatile in complying with the Semantic Web and Linked Data standards. These advancements, together with their modular architecture, turn Wikis and CMSs into a decent choice for modern e-learning solutions. MediaWiki and Drupal were customized and deployed in the Aristotle University of Thessaloniki to assess their potential in exposing the University's learning resources on the Web of Linked Data, in accordance with the Linked Universities Initiative. On the occasion of these two deployments, a thorough comparison of their platforms' potentials to function as Learning Management Systems took place and is presented on this paper.

## Categories and Subject Descriptors

J.1 [Administrative Data Processing]: Education

## General Terms

Documentation, Performance, Design, Reliability, Experimentation, Human Factors, Standardization

## Keywords

Linked Data, Linked Learning, Semantic CMS, Semantic Wiki.

## 1. INTRODUCTION

The challenge of exchanging learning objects, that has been present in web-based educational solutions early, led to the development of either standardized or proprietary approaches. Lately, advanced and also standardized technologies, like Linked Data and ontologies, have been used to facilitate the sharing of large datasets on the Web, but the e-learning standards seem reluctant to embracing them. Hence, they cannot be yet considered widespread, mainly due to the legacy systems'

difficulty to evolve rapidly and the cost related to the annotation of existing content. Nevertheless, these technologies are positively viewed in the educational field and have been successfully adopted in a handful of cases. Examples of early adoption are the British Open University's data hub<sup>1</sup> and the mEducator<sup>2</sup> project, which aims to analyze the use of existing standards and reference models in the e-learning field to discover, retrieve, share and reuse medical educational resources.

Lacking of conventional Learning Management Systems (LMS) with enhanced semantic features, a Semantic Wiki (henceforth abbreviated as SW) and a Semantic Content Management System (henceforth abbreviated as SCMS) were selected for the aforementioned reasons and were deployed to support different parts of the curriculum at the School of Mathematics at Aristotle University of Thessaloniki (AUTH). This paper aims at comparing their features regarding semantics and linking of Data, in the frame of the educational procedure. The comparison is focused on the adoption of semantic web for higher education institutes assessing their capability to expose the educational content as Linked Data.

In the following paragraph, assumptions are conducted on why LMS do not seem to yet follow the developments of Semantic Technologies and Linked Data. In the second and the third paragraph, it is presented how Content Management Systems (CMS) and Wikis may supplement LMS, and, afterwards, the prominent Semantic CMS technologies and Semantic Wikis are summarized. Next, follows the comparison between selected SCMS and SW and a comparative presentation of the Semantic Technologies used at the School of Mathematics at AUTH.

## 2. LEARNING MANAGEMENT SYSTEMS AND THE SEMANTIC WEB

Typical LMSs support the reuse of data and interoperability with other systems, by exploiting standards like SCORM, LOM, AICC or IMS (the most dominant). Although such standards clearly define how content may be packaged and transferred between the various LMSs, they essentially encourage content duplication.

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<sup>1</sup> <http://data.open.ac.uk>

<sup>2</sup> <http://www.meducator.net>

Actual linking of Data is not possible, as most of these systems neither support technologies such as RDF and SPARQL nor is such support planned for the near future, given the current orientation of the standards.

There have been suggestions regarding the future of these specifications in the Linked Data Web [2], although there are various reasons for not following closely their evolution. Most of these standards had approached their *slope of enlightenment* by 2005 and nowadays have reached their *plateau of productivity* according to Gartner Hype<sup>3</sup> Cycle. Consequently, the intense investment of vendors on implementing systems adherent to the aforementioned LMS standards and the difficulties rising on migration could be considered among the most significant.

As a result, traditional LMSs face the competition of other technologies, compliant with the Semantic Web standards, such as SCMS or SW. The latter, following the innovations of the Semantic Web, have evolved greatly in terms of linking and annotating the content and they succeed in providing their semantic offspring the opportunity to be linked not only among each other but to the whole Web of Linked Data.

### 3. STATE OF THE ART

Modern LMSs are able to provide educational organizations with a broad range of features for administration, time scheduling, and, basically, content delivery, sharing and personalization. The LMSs that are content-centric are called Learning Content Management Systems (henceforth abbreviated as LCMS) and can greatly enhance the educational process, because learning resources may be centrally managed, searched and assembled to support custom, personalized learning paths.

There are currently three significant players in the LMS industry. The first of them are the established commercial vendors that often provide their LMS solutions together with authoring tools. The established developers compete with new entrants that provide innovating solutions and with the open source community. While open source LMSs are, generally, more immature at the beginning of their development, they can be customized, hosted and supported by third parties, providing an inexpensive solution. Most of the LMSs that are currently under active development are SCORM compliant or certified, so content exported from any of them can be re-imported to any of the others, providing a typical layer of file interoperability.

#### 3.1 CMSs and Wikis for Learning Resource Management

LMSs and their content-centric alternatives (i.e. LCMSs) are usually combined to offer planning, delivering and managing of learning events together with gathering, organizing and repurposing content features. This combination could also be achieved with CMSs and Wikis, carefully fined-tuned for learning and education.

While the early CMSs were able to manage a restricted set of content types and allowed minimum customization, today's implementations are flexible enough to adapt in most business situations without any in-house development needed. In a typical CMS, the domain can be modeled into discrete classes, such as Person, Course, Session, Department and others. Each class will then contain a set of properties. This representation can model

<sup>3</sup> [http://www.gartner.com/it/docs/reports/asset\\_154296\\_2898.jsp](http://www.gartner.com/it/docs/reports/asset_154296_2898.jsp)

flexibly the educational environment and be an ideal choice for large institutions. If flexible enough, a plain CMS can become the core of a customized CMS repurposed for learning [11]. Even though LMS capabilities cannot be entirely substituted by CMS equivalents (with the Learning Path feature to be the most difficult to implement in a traditional CMS), their resource management functionality can be replaced with a combination of alternatives, currently available on most typical CMSs.

Wiki engines, on the other hand, are collaborative software running websites whose users can view and edit their content. In Wikis, the articles are not automatically generated belonging to a certain class. It is up to the users to edit the pages in order to classify them under a certain category. Hence, they succeed in offering functionality equivalent to the one found in CMSs, but an article may belong to more than one category. Therefore, Wikis can be an excellent solution for self-contained learning environments that change constantly and require collaboration out-of-the-box.

#### 3.2 Semantic CMS and Semantic Wikis Usage as Semantic LMS

In order to benefit from Semantic Web and Linked Data advances, and be worthy alternatives for the still missing SLMSS, SCMSs need to also support a broad range of Web 3.0 specifications. Among the most popular CMSs, only Drupal has got advanced support for Semantic features. Other solutions, including Talis Aspire<sup>4</sup>, FreshKnowledge<sup>5</sup> and Webnodes<sup>6</sup>, are mostly proprietary and certainly lack the community contribution that Drupal enjoys.

In the field of SWs, there are more alternative choices offering intelligent semantic solutions. SW engines can be distinguished into two categories [9], the “Wikis for ontologies” and the “ontologies for Wikis”. The first category includes OntoWiki<sup>7</sup>, which is mostly technical-oriented rather than user-friendly and Platypus Wiki<sup>8</sup> which has a corresponding “Metadata page” for each article page. The other category includes Semantic MediaWiki (SMW)<sup>9</sup>, which is more user friendly and supported by a loyal community that provides ongoing development and, finally, KiwiWiki<sup>10</sup> which is currently discontinued.

Both SWs and SCMSs proved to be pedagogically efficient for e-learning[15]. Both of them expose learning content objects on the Web as linked resources and allow users to discover, connect and aggregate content, creating new, value-added resources. Using existing tools, SWs and SCMSs can provide context-related suggestions and also actively support the learners with plain personalization, based on their semantically annotated interests.

A notable realization of such system is the mEducator3.0 Drupal-based site<sup>11</sup>, which allows users create, upload, repurpose, describe, share and search for resources, also exploiting SPARQL

<sup>4</sup> <http://www.talisaspire.com/>

<sup>5</sup> <http://www.freshknowledge.net/>

<sup>6</sup> <http://www.webnodes.com/ontology-engine>

<sup>7</sup> <http://ontowiki.net/Projects/OntoWiki>

<sup>8</sup> <http://platypuswiki.sourceforge.net/>

<sup>9</sup> <http://semantic-mediawiki.org/>

<sup>10</sup> <http://www.kiwi-project.eu/>

<sup>11</sup> <http://www.meducator3.net/drupal/>

queries. On the mEducator project, the Moodle LMS was also semantically enhanced<sup>12</sup>, by extending the database, creating mappings between the new schema and the mEducator ontology [13] and serving the data using a D2R instance. Although sufficient for the mEducator case, this implementation might still be a bit complex for other institutions considering deploying it, as it was tied with the project's requirements and it is not packaged as a redistributable plugin, easy-to-fit in any case, with little effort spent for its configuration [3].

In the same context but in a narrower perspective, the team worked on the integration of SMW with Moodle. In this case, the learner may access SMW with Halo extension through Moodle and the Wiki within this context serves only for collaborative knowledge construction. It does not function as a complete support tool for the overall educational procedure; as a consequence, not all SMW's features were well exploited [8].

In the following paragraph SCMS and SW are presented in a comparative way, offering an insight on their Semantic features that can be used for learning and education.

#### 4. SELECTED SEMANTIC CMS AND SEMANTIC WIKI COMPARISON

As mentioned above, SCMSs and SWs may be used as alternatives to SLMSs. SMW with the community version of the Halo extension and Drupal with its set of Semantic modules were selected as the most promising solutions among their alike. A comparison between the two of them, in the frame of the educational procedure, follows. Table 1 summarizes the most significant semantic features found in the two platforms.

In order to annotate the content, ontologies have to be manually imported on both systems. The loaded ontologies are not automatically updated, so the web applications' administrators have to manually keep them current. In the Drupal CMS, the content types are mapped onto ontology classes and the content fields are mapped onto corresponding ontology properties, using the rdx module user interface. Equally, in a SMW, articles are mapped to one or more categories which are, in turn, mapped to ontology classes while context semantic annotations are mapped to the corresponding ontology properties. On SMW, properties have their own namespace and each single property has its own page, summarizing the pages having this property within their content, similarly to Classes pages in the Category namespace.

In addition to ontologies, Drupal provides, via a contributed module, the ability to load a SKOS classification in its taxonomy system. Instead, SMW does not offer the possibility to include taxonomies separately, as Drupal does; SKOS is handled as other ontologies. It only supports ontologies and as a consequence, SKOS classifications are imported into SMW, as raw ontologies.

Both MediaWiki and Drupal are able to expose machine-readable annotations and export their content in RDF format. They are also able to expose their data using SPARQL Endpoints. The SPARQL endpoint functionality is provided by the underlying ARC2 PHP library, in both of the platforms. Besides, Drupal can query external SPARQL endpoints to include data from remote datasets within its content. In contrast, SMW cannot query external endpoints and embed their content within its articles, as its function is limited on exposing its own data. There are other

Extensions offering limited functionalities compared to the Halo extension, but being able to integrate data coming from queries to external SPARQL endpoints. Their conflict with Halo extension inhibits their simultaneous use, though.

**Table 1. Semantic features overview for SMW Halo and Drupal's semantic modules.**

| Feature   | SMW (Halo extension) | Drupal (semantic modules) |
|---|----------------------|---------------------------|
| Exposes machine readable annotation (RDF)                       | ✓                    | ✓                         |
| Ontologies import & reuse                                       | ✓                    | ✓                         |
| Taxonomies  | ✗                    | ✓                         |
| Exposing Learning Objects                                       | ✗                    | ✓                         |
| Context annotation  | ✓                    | ✓                         |
| Content reuse based on Semantic Annotations                     | ✓                    | ✗                         |
| Context-Sensitive Learning Paths Construction                   | ✓                    | ✗                         |
| Personalization based on Semantics                              | ✓                    | ✗                         |
| SPARQL endpoint for contained data                              | ✓                    | ✓                         |
| external SPARQL endpoint querying for external data composition | ✗                    | ✓                         |
| Semantic Mappings   | ✓                    | ✓                         |
| Semantic Queries  | ✓                    | ✓                         |
| Semantic Search   | ✓                    | ✗                         |
| Reasoning   | ✓                    | ✗                         |
| Semantic Rules  | ✓                    | ✗                         |

SMW reuses its own previously semantically annotated content to create more composite pages, via its semantic queries, exploiting that way its semantic annotations to the greatest extent. Drupal, on the other hand, does not directly support local content composition based on semantics. Instead, it provides similar, non-semantic, functionality using relationships between nodes and semantic analysis of the content, using the OpenCalais service<sup>13</sup>. Drupal's SPARQL Views module can also be used for that purpose, but it is still missing the flexibility available in SMW.

SMW, compared to Drupal, is not ideal for exposing complete Learning Objects, based on its semantic functions. An article may belong to one or more categories, namely classes, which can act, to a certain extent, as Learning Objects, but this does not belong to the SMW's strong points. On the other hand, Drupal, annotates the whole Content Item based on its fields, making it a preferable choice on exposing larger amounts of learning resources as complete Learning Objects. Figure 1 demonstrates the RDF graph that can be created for a Course object.

Nevertheless, SMW is more suitable for annotating the content, rather than exposing larger amounts of data as solid Learning Objects. By semantically annotating the content, new navigation

<sup>12</sup> [www.meducator3.net/moodle](http://www.meducator3.net/moodle)

<sup>13</sup> <http://www.opencalais.com>

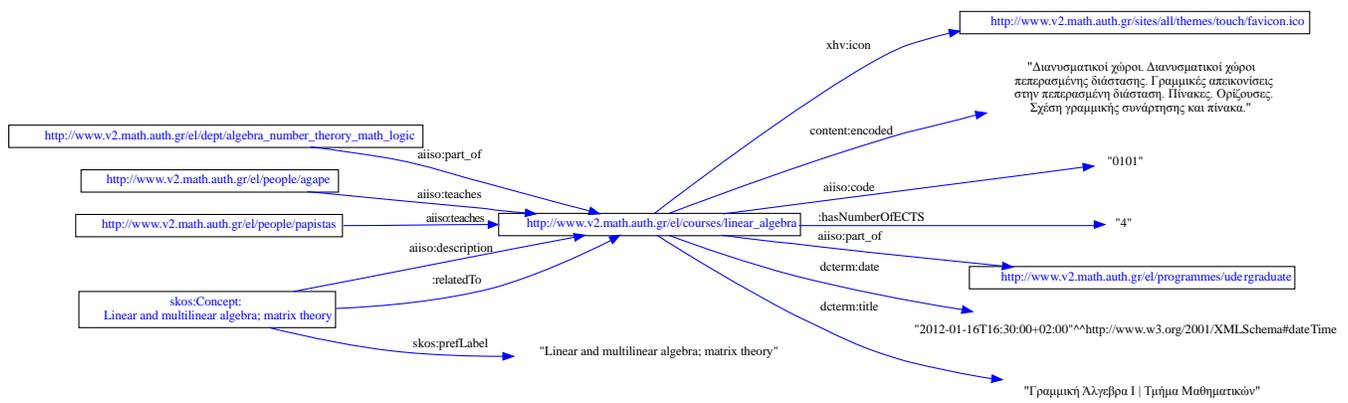


Figure 1. RDF Graph of a Course in Mathematics School website

opportunities emerge, which may turn into alternative Learning Paths, feature impuissant on Drupal. These new, alternative Semantic Learning Paths offer to the users / learners the opportunity to navigate through its content and construct new knowledge. Drupal does not support semantic annotation within its own context, limiting the potential to offer innovative Semantic Learning paths.

Combining SMW's editing feature and content semantic annotation, high potentiality for personalization opportunities appears. Users / learners have the opportunity to create their own pages, not only to add extra content, but to recapitulate the already existing content based on its semantic annotations. The new pages can summarize the content fragments which interest them the most and introduce their perspective. In general, they can add their personal touch to every SMW's article.

SMW thanks to Halo extension can offer extensive search functions based on SMW's semantics and some basic query reasoning. For this purpose, it claims to have a user friendly query interface which can be used to create, edit, load and reuse existing queries. Search results are easy to handle due to multiple query formats available. Drupal does not currently support semantic reasoning neither into its core nor with any contributed module.

Finally, SMW also offers Rule Knowledge extension which is a graphical editor for creating logical rules. Using its triple store, SMW uses this extension to assist its users / learners to exploit inferring knowledge and logical dependences. It supports authoring calculations, definitions and priority chain rules.

According to the above, with some enhancements, SMW and Drupal can be used to create web sites and applications suitable for education and capable to play the role of LCMSs. They can also expose learning objects to the rest of the Web of Data, and, in the case of Drupal, federate external resources based on the current context. The two platforms were applied in practice at the AUTH and these cases are presented in the following paragraph.

## 5. SEMANTIC TECHNOLOGIES AT SCHOOL OF MATHEMATICS, AUTH

The Web Science's Semantic Wiki (henceforth abbreviated as WS-SW)<sup>14</sup> and the School of Mathematics' Semantic Content Management System (henceforth abbreviated as SM-SCMS)<sup>15</sup>

<sup>14</sup> <http://webscience-class.web.auth.gr/WebScienceWiki2>

<sup>15</sup> <http://www.math.auth.gr>

were built with similar objectives in mind. They aimed to not only abet the educational procedure, but to use the latest semantic technologies and expose their public data to the Linked Data cloud as well.

Among the different SWs, Semantic MediaWiki (SMW) presented the best performance by the time of selection and better fulfilled the requirements set. A thorough documentation regarding WSSW is available at [7]. On the other hand, Drupal was chosen as the leading CMS, concerning its semantic features. It features a powerful taxonomy system, which allowed the import of the MSC 2010 taxonomy to further annotate and link its content nodes.

### 5.1 Web Science's Semantic Wiki

WSSW was the result of a project carried out by the graduate students at the Web Science Master Program at Mathematics Department of AUTH. Its enhanced functionality and its innovative features turned the project into the Wiki used by the Master Program in order to coordinate its educational procedure. WSSW was presented last year at LiLe2011 [7] and received positive acknowledgements.

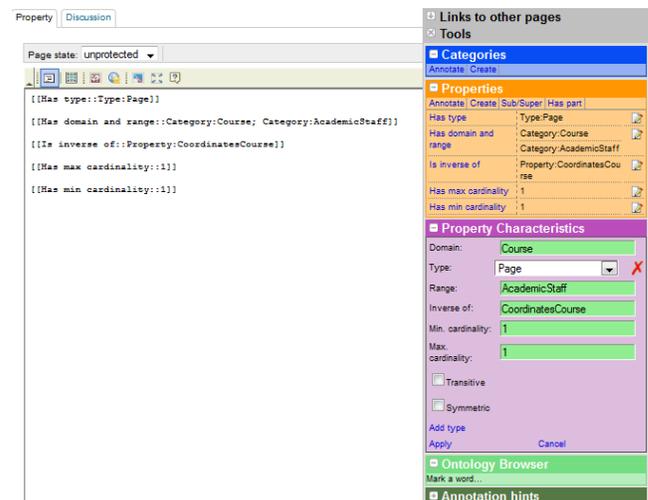


Figure 2. Context annotation on a SMW's article with Semantic Toolbar

It is built on top of MediaWiki with Semantic MediaWiki extension and a set of other accompanying extensions of SMW+ community package. Semantic Gardening extension was used to

upload and maintain the imported ontologies. Semantic Results Formats extension was installed for the bundle of different results formats it offers for the inline queries. The Tree View extension was installed to support alternative navigation while SMW User Manual extension was installed to offer users immediate access to context-sensitive selection of articles and direct interaction with the online community. Finally, Triple Store connector was used to interface remote queries and forward them to a local triples store.

## 5.2 School of Mathematics Semantic Content Management System

Given the successful application of the Semantic Wiki to the Master Program, the School of Mathematics gathered feedback and built its main website from the ground-up, using semantic technologies. SM-SCM System was designed using the leading technologies in the field of semantics nowadays. Although the outdated legacy Web 2.0 website could still cover the needs of the School, the transformation of the Mathematics Subject Classification (MSC)<sup>16</sup> into SKOS [12] acted as the springboard. There were major challenges during the deployment; on one hand, the use of cutting edge and at the same time untested technologies on semantics, in order to annotate the content using SKOS MSC and other ontologies, and on the other hand, the challenge to follow the flow as expressed by the Linked Universities initiative<sup>17</sup>, exposing the department's public data as Linked Data.

To implement the required features a set of modules was used. Namely, RDFx and SPARQL offered the main functionality of annotating and querying and the Taxonomy XML Import module was used to import the MSC SKOS classification.

## 5.3 Ontologies for Description and Linking

In the presented AUTH case studies, the content was annotated using both generic and domain-specific ontologies. Describing content with common ontologies makes it possible to link it to other data on the Web. Both in the Semantic Wiki and the semantic CMS, the ontologies were loaded locally and stored in the web application database. That means, any updates on the online version will not be reflected to the local ontologies. Table 2 outlines the ontologies used on each of the deployed platforms.

The FOAF [10] ontology was used in both platforms to represent faculty, staff and students. Online community features, such as content authors and comments, were annotated using the SIOC [16] ontology.

The learning content was also described using two education-related ontologies, proposed by Linked Universities, in the SM-CMS. The Academic Institution Internal Structure Ontology (AIISO) [1] ontology was used to describe the internal organizational structure of the Mathematics School, which is divided in departments, offers different programs for its students and supports research groups. The Bowlogna ontology [6] not only describes the School in administrative terms, but also models its curriculum, following the Bologna Process for European Higher Education institutes. On the other hand, WS-SW, since it started as a project, it was required to use an ontology implemented and customized for the Master's needs; for that reason, none of the renowned ontologies for learning content was used.

Regarding bibliographic references, two ontologies were used, the Bibliographic Ontology, known as BIBO [5] and the BIBTEX [4] ontology. Publications of the faculty members and suggested readings for each course can be represented and linked using the properties provided by these ontologies.

Table 2. Ontologies used in AUTH applications.

| Ontology                    | WS-SW | SM-SCMS |
|-----------------------------|-------|---------|
| DC                          | ✓     | ✓       |
| FOAF                        | ✓     | ✓       |
| SIOC                        | ✗     | ✓       |
| AIISO                       | ✗     | ✓       |
| Bowlogna                    | ✗     | ✓       |
| BIBO                        | ✗     | ✓       |
| BIBTEX                      | ✗     | ✓       |
| SKOS MSC                    | ✗     | ✓       |
| proprietary Master Ontology | ✓     | ✗       |

WS-SW was implemented earlier, when the notion of Linked Data was not so widely known and accepted. As a consequence, WS-SW lacks regarding linkage compared to SM-CMS. On the other hand, the SM-CMS is well advanced regarding Linked Data standards. Apart from reusing standard ontologies or learning oriented ontologies, it also uses MSC SKOS, which is exactly the key to link its content with the rest of the Web of Data. SM-CMS is not only focused on linkage with other learning oriented semantic applications, but also expands its potential linkage beyond education, providing its users unique learning opportunities for constructive knowledge discovery.

Throughout the website, every course, department and person can have research fields/interests annotated with SKOS MSC classification ontology, using a suitable ontology property. That way, an interested party can access the SPARQL endpoint and submit a query for courses that are related, for example, to Linear Algebra, without the need to be aware of the local representation of the mathematical term, as each term has a standardized GUID in the MSC2010 classification. The SKOS MSC was just released, so WS-SW does not support it yet.

## 6. CONCLUSIONS

In the AUTH cases, SMW and Drupal have proven sufficient in terms of annotating content, providing additional, context-related resources and exposing their resources to the Web of Data, according to the Web 3.0 principles. Still, both platforms need time and effort to mature and support semantic web features more transparently both for the administrators and the end users.

While the presented systems can adequately support a University website with semantic technologies, they currently lack enhanced personalization features for the students. Ideally, students would have a personal space where they would collect learning objects and construct their own learning path, a feature common in most LMSs.

<sup>16</sup> <http://msc2010.org/>

<sup>17</sup> <http://linkeduniversities.org>

## 7. FUTURE WORK

Going forward, a semantic web-enabled LMS would be able to integrate with semantic Wikis and CMSs, discovering and composing their content, based on learner's semantically annotated profile.

In order for the LMSs to gain ground in the Web of Data, their developers need either to rush the evolution of the standards their products are tied to, or consider the possibility to adopt Semantic technologies along with the existing standards. In either case, the LMSs should, eventually, be able to expose their resources as linked data through standard HTTP APIs [14].

In that sense, a personal learning space could greatly benefit from the linked nature of these technologies and allow the students and teachers to collect learning resources from other institutions, reuse or repurpose content or even get qualifications. Such a federation of learning objects from different sites could happen in a single personal learning space, independently from any particular institution and it could greatly enhance the collaboration of European Universities.

As far as the AUTH specific real-world cases are concerned, many improvements are expected for the WS-SW. Taking into consideration that semantic technologies advance rapidly and on the occasion of the of SKOS MSC release, WS-SM needs to be upgraded to follow the current trends and also expand its function towards integrating scientific knowledge, annotated with the SKOS MSC. This will be succeeded only if SMW provide the community with an extension able to accomplish what Halo extension currently offers, but with the additional feature of integrating content fetched by SPARQL queries. This addition can touch off SMW in general and set SMW among the leading technologies in the Linked Data age.

In the SM-CMS, the next steps would be to integrate content from external sources, like bibliography on Mathematics and link it with the existing learning resources. As a later development and since it is just released, it uses the pioneer Semantic technologies at the moment and it is expected to be flexible to adapt to the near feature needs and also operate as a reference point for other educational institutes. In both cases improvements could be identified based on per-platform evaluation and a corresponding comparative assessment of the platforms, focused on their semantic features.

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