The Social Semantic Web in Intelligent Learning Environments
- State of the Art and Future Challenges -

Jelena Jovanović
(University of Belgrade, Belgrade, Serbia
jeljov@gmail.com)

Dragan Gašević
(Athabasca University, Athabasca, Canada
dgasevic@acm.org)

Carlo Torniai
(University of Southern California, Los Angeles, USA
torniai@usc.edu)

Scott Bateman
(University of Saskatchewan, Saskatoon, Canada
scott.bateman@usask.ca)

Marek Hatala
(Simon Fraser University, Surrey, Canada
mhatala@sfu.ca)

Abstract: Today's technology-enhanced learning practices cater to students and teachers who use many different learning tools and environments and are used to a paradigm of interaction derived from open, ubiquitous, and socially-oriented services. In this context, a crucial issue for education systems in general, and for Intelligent Learning Environments (ILEs) in particular, is related to the ability of leveraging these new paradigms for creating, maintaining and sharing the knowledge that these systems embed. This will enable ILEs to benefit from shared information from disparate systems, which is related to learning content and student activities, so that the overall complexity of system development and maintenance would be reduced while at the same time improving the capability of personalization, context-awareness, and interaction. In this paper, we investigate how the Social Semantic Web can be leveraged for enabling and easing this process. We first analyze each module of a typical ILE, showing how it can benefit from the Social Semantic Web paradigm and then proceed to investigate how this new paradigm can be leveraged for increasing interactivity level of ILEs.

Keywords: Intelligent Learning Environments, Adaptive Educational Hypermedia Systems, Semantic Web, Social Web, Ontologies, Folksonomies, Interactivity
Categories:

1 Introduction

Intelligent Learning Environments (ILEs) can be broadly defined as computer-based educational systems that rely on diverse Artificial Intelligence (AI) techniques to improve students' learning experience, and help them reach their learning objectives. There are a variety of ways that Artificial Intelligence technologies and techniques can be used for improving the learning process. Actually, there is a whole area of research, called Artificial Intelligence in Education (AIED) with a very active research community devoted to the exploration of these issues.

The primary advantage of ILEs over more traditional learning systems and tools lays in their ability to provide students with individualized interactions tailored to a student's personal traits (e.g., goals, tasks, knowledge, experiences, preferences, and individual traits), as well as the characteristics of the student's environment (e.g. location, computing platform, and bandwidth). To allow for adaptation of the learning content and/or the instruction process to fit the needs of each individual learner, ILEs make use of AI technologies, primarily knowledge modelling, rules, and reasoning[1].

However, today's technology-enhanced learning practices indicate that the education process of each particular learner is not limited only to one learning tool or environment (e.g., an ILE), but instead students are using many different learning systems and tools (e.g., Learning Management Systems or discussion forums). It is natural to assume that, for example, some knowledge and skills that students gain in other learning environments would be beneficial to bootstrap a student's model in an ILE. Moreover, the reuse of some of the best pedagogical practices (e.g., learning design) across different learning environments or learning content may also be useful for ILE developers.

Equally important is the fact that learning is not an isolated process, and it happens in parallel with the regular day-to-day activities, which students and educators may have. Students and educators now live in the world of Facebook, Wikipedia, MySpace, YouTube, del.icio.us, and SecondLife. Most of these technologies are collected in a common framework, of the so-called Social Web, where the notions of social interaction, human computing, and collective intelligence are major assets. Today's students have spent most of their lives surrounded by, and using, computers, videogames, digital music players, video cameras, cell phones, and the Web itself. By enabling ubiquitous access to the knowledge and data, social semantic technologies allow for leveraging learner activities performed using these popular gadgets and applications in ILEs (e.g., for creating more informed student models, or to increase the collaborative features of ILEs).

1.1 Research Objective One: Knowledge Capturing and Representation

Having the above examples in mind, the main question is how ILEs might be integrated with the aforementioned technologies. A potential approach could be to leverage learning technology standards such as the IEEE Learning Object Metadata and the IMS Learning Design definitions. However, those standards only provide a syntactical layer for the integration of different learning tools. What they do not provide are effective and reliable mechanisms for managing (i.e., capturing, representing, and evolving) various types of knowledge (e.g., domain, user, and pedagogical) which should be shared among various environments and ILEs. To enable such knowledge sharing, we present important conditions that should be satisfied by knowledge sharing solutions, to meet the requirements of ILEs:

- to represent formally the knowledge being shared, so that its semantics are fully preserved;
- to be a low-cost, or less expensive solution in terms of computational and development cost than the current mechanisms commonly used for knowledge capturing and maintenance in ILEs;
- to be in compliance with current Web and learning technology standards.

When it comes to formal and sharable representation of knowledge, Semantic Web technologies in general, and ontologies in particular offer a promising solution, since they guaranty high level of expressiveness, flexibility and extensibility of the represented knowledge (see Section 3). A lot of Semantic Web technologies, such as RDF (Klyne & Carroll, 2004), OWL (Bechhofer et al., 2004), and SPARQL (Prud'hommeaux & Seaborne, 2008) are already standardized by World Wide Web Consortium (W3C)[2], others are now passing the standardization process (e.g., GRDDL (Connolly, 2007) and RIF[3]), and the new ones are constantly emerging (e.g. RDFa (Adida et al, 2008)). However these technologies are still expensive in terms of ontology creation and maintenance, and as such cannot satisfy the second requirement listed above. This is where the Social Web can contribute: on Social Web, the process of knowledge creation is based on social activities and informal knowledge modelling and as such it is not expensive (see Section 3). Accordingly, in this paper, we suggest that by combining the best features of the Social Web (inexpensive knowledge creation) and the Semantic Web (structured and formalized knowledge), a solution for knowledge interchange in an e-learning eco-system can be developed. Specifically, we investigate a synergetic space built on top of formal ontology-based representations of shared knowledge and social computing mechanisms (e.g., collaborative tagging and folksonomies) in the context of ILEs.

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[1] This is just one example of applying AI for educational purposes; for more in depth look into these topics, we suggest proceedings of the AIED and ITS (Intelligent Tutoring Systems) international conferences which offer insight into a variety of approaches for applying AI technologies in learning for the learners benefit.

[2] http://w3.org

[3] http://www.w3.org/2005/rules/wiki/RIF_Working_Group

1.2 Research Objective Two: Interactivity

Another research issue that we want to tackle in this paper is how to improve the interactivity level of ILEs. Even though ILEs can be considered as advanced learning environments (since they provide students with personalized learning experience), the level of interactivity these systems provide is often unsatisfactory; they should allow for higher levels of interactivity along different dimensions, such as student-student, student-teacher, and student-content. In order to be broadly accepted by students and teachers, the solutions for enhancing the interactivity of today's ILEs should be based on the widely accepted online interaction paradigms and practices, such as bookmarking, tagging, commenting, communicating via short messages, status updating, and the like. Since these prevailing interaction practices are trademarks of the Social Web, a straightforward solution for increased interactivity would be to incorporate Social Web tools and services into ILEs. However, we believe that the integration of Social and Semantic Web technologies can offer even better solution. In order to provide support for this statement, we illustrate how Social Semantic Web technologies can be leveraged for improving interactions along each dimension of the "interactivity triangle" (Anderson & Garrison, 1998).

1.3 Research Approach

In order to analyze the benefits of the Social Semantic Web paradigm for ILEs, we use a bottom-up approach combined with the qualitative observations of features of the Social Semantic Web concepts, standards, and state of the art applications and systems.

Since Social Semantic Web is a new research area, there are still no precisely defined and broadly adopted methods for conducing research in that area. Therefore, we could not opt for a top-down approach - starting from a well defined model and analyzing the observed phenomena from the perspective of that model to be able to draw conclusions. Instead we had to take the opposite, bottom-up approach and start from observations aiming to infer some patterns in those observations that would eventually enable us to make generalizations and draw conclusions.

Our analysis is not exclusively based on the existing research publications covering the exact topic of the Social Semantic Web in ILEs, but we also refer to general-purpose solutions and research results that are leveraging the concepts of the Social Semantic Web. This is a natural decision, as the process of learning is not strictly bound to only one learning environment, but it is a continuous process spanning across different (social and/or learning) systems and contexts. Accordingly, throughout the paper we provide a number of examples which illustrate how Social Web and Semantic Web can facilitate integration of different learning systems, tools and services.

However, to have a coherent study of the identified features and their implications on ILEs, we decided to organize our analysis around two reference models, one for either research objective. First, for analysis of knowledge capturing and representation aspects, we use a typical architecture of Adaptive Educational Hypermedia Systems (AEHS) proposed in (Aroyo et al, 2006), as AEHSs are a representative example of advanced learning environments that leverage artificial intelligence techniques for the learners' benefit. The main premise of AEHS, which is the delivery of adaptive/personalized learning, is a common objective of all kinds of ILEs. Similar to their origin (Intelligent Tutoring Systems), AEHS are indented to be used as stand-alone learning environments on the Web, usually not interacting with other systems. As such, they are a suitable reference for our study that aims at showing the benefits of the combined usage of several (social and learning) systems based on the Social Semantic Web technologies. In Section 4 we briefly introduce the major components of an AEHS and explain how Semantic Web technologies and the Social Web paradigm can facilitate creation and sharing of knowledge that is relevant for each specific component; we have also presented examples of existing systems in order to illustrate the statements we make.

Second, for analysis of different forms of interactions in online learning settings, we base our study on the interactivity triangle model introduced by Terry Anderson and Terry Garrison in 1998. The interactivity triangle has students, teachers and content at its nodes; each node is related with the other two and with itself, so that, for example, students are in interactions with teachers and content, but they also interact among themselves. Since we use this model just as an instrument in our research, we do not present it in details; instead we refer interested readers to the publication (Anderson & Garrison, 1998) where the model is explained in details by its authors. We decided to use this model in our research because it provides us with a sound reference for investigation of the dimensions of interaction identified in current learning environments, and hence, enable us to draw conclusions generally applicable to broad range of ILEs. Moreover, our observations about interactivity can be referenced to the AEHS architecture used in the first part of the study, and thus we can draw conclusions that crosscut both aspects of our analysis.

Our analysis starts from the description of a typical architecture of an AEHS (Section 2). We then introduce the fundamental concepts of the Social Semantic Web (Section 3). Next, we examine possible implications of integrating Social Semantic Web technologies into each component of the AEHS architecture (Section 4). Subsequently we focus on the interactivity issues and discuss how the application of Social Semantic Web technologies can increase interactivity of today's ILEs (Section 5).

2 Adaptive Educational Hypermedia Systems

An adaptive hypermedia system (AHS) has been defined as a hypertext or hypermedia system which reflects some features of the user in the user model and applies this model to adapt various visible aspects of the system to the user (Brusilovsky, 2001). AHSs have been present in the e-learning domain for over a decade under the name Adaptive Educational Hypermedia Systems (AEHS).

The first generation AEHSs were stand alone systems with adaptation rules and content entwined in a single model. They used this model together with the user model to offer personalised content. Typical representatives of this generation are AHA! (De Bra & Calvi, 1998) and ELM-ART (Brusilovsky, 1996). However as adaptation rules and content were intertwined, there was little scope for reuse or the use of externally developed content.

The second generation of AEHSs attempted to overcome some of the problems encountered in the first generation AEHSs by pursuing a multi-model approach. This approach assumed decoupling of content and the adaptation rules of the system. In these systems (e.g. KnowledgeTree (Brusilovsky, 2004), various prototype systems based on the AHA! architecture and KBS-Hyperbook (Henze & Nejdl, 2000)) the adaptation engine is more generic and relies upon separate knowledge models to adapt the system for each individual.

The latest, or third, generation of AEHS is moving towards a service-oriented architecture and complete decoupling of different kinds of knowledge. These systems are attempting to support personalisation through the use of individual services for the sourcing of learning content, the personalisation of learning offerings, and the presentation of such offerings (Henze & Herrlich, 2004). In addition, a typical architecture of the state-of-the-art AEHSs is fully decoupled and consists of five complementary models (Aroyo et al, 2006):

- the domain model – specifies what is to be adapted,
- the user (student) and context models – tell according to what parameters the content could be adapted,
- the instructional (teaching) and adaptation models – express the pedagogical approach the learning process should be based on as well as the forms of adaptation to be performed.

In what follows, we briefly present each of these models in turn in order to contextualize our position on how Social Semantic information can enrich these models (discussed in Section 4). We are particularly interested in pointing out what kind of "knowledge" each model embeds or relies upon since Social Semantic Web addresses ways in which this knowledge can be much more easily and cost effectively created, updated, shared and reused.

Domain Model. This model integrates the content to be used during the learning process (also known as 'hyperspace') and the knowledge about the domain to be thought (known as 'knowledge space'). Due to the level of details required in defining the model, it is usually designed by a small group of people or even by a single person with a high level of expertise in the domain of interest. The attention to detail in designing knowledge space is essential to ensure the desired levels of adaptation, learning path definition and feedback provisioning. For this reason, the process of creating such a knowledge is time consuming and in general considerably expensive.

Student Model. The purpose of the Student Model is modelling knowledge that is related to the student's characteristics, so that the process of instruction can be adapted accordingly. This model contains all the necessary information about the student, such as his/her learning goals, learning history, learning style, and current level of topic/course mastery.

Context Model. In AEHSs, context is often related to the characteristics of the environment where the learning is taking place. Context models usually deal with issues like automatic acquisition of context (meta)data or contextualized delivery of content, activities, and services (Kravcik & Gasevic, 2007).

Instructional (Teaching) Model. This model embeds formally represented knowledge about different teaching strategies. Its role is to specify how to teach the content defined in the Domain Model by leveraging the knowledge defined in the Student and Context models. Usually, each teaching strategy embodies one particular pedagogy theory or method, and defines, accordingly, the sequences of activities and relevant learning content to be presented to a learner.

Adaptation Model. This model describes the specific adaptation semantics which are usually represented as rules embedded in AEHSs, stored in system-specific formats or represented in well-known rule-based languages (e.g., Jess, Lisp).

In addition to the above brief description of AEHS modules, for the sake of our discussion, it is important to say that the architecture of traditional AEHSs can be considered 'closed', since it lacks mechanisms for interacting with external systems and sharing the knowledge captured in its components. All the components are tightly linked together, so that changes in one of them affect all the others. For instance, modifying the Domain Model will affect the teaching strategies specified in the Teaching Model, which in turn is affected by the student's mastery of the topics defined in the Student Model. Moreover, the ability of the knowledge models to evolve is limited by their implementations, "(which) tend to be unique in the features they provide, contain hand-crafted ontologies developed by a small group of developers, and lack interoperability between one another" (Brooks et al, 2006).

Finally, we need to point out the low level of interactivity of most AEH systems: learning activities in the large majority of these systems are reduced to content consumption and doing assessments, often in the form of tests. In the last couple of years there has been an increasing trend towards improving interactivity of AEHS by providing support for collaborative learning. This was especially due to the initial successes of the Computer Supported Collaborative Learning (CSCL) community. However, evaluations of CSCL systems have shown that many of the expected benefits, such as increased motivation and participation, have not been realized. Studies repeatedly revealed problems such as low participation and communication rates, satisfaction, and limited learning (Lane, 2006). In Section 5, we present how the collaborative nature of the Social Web can be leveraged for increasing the interactivity of AEHSs.

3 The Social Semantic Web

The Semantic Web has been introduced as the evolution of the current Web in which "information is given well-defined meaning, better enabling computers and people to work in cooperation" (Berners-Lee et al. 2001). The building blocks of the Semantic Web are *ontologies*. Ontologies are formally described conceptualizations of shared domain knowledge. They are expressed through standard languages (such as RDF and OWL), which allows them to be combined, shared, easily extended and used to semantically annotate different kinds of resources, such as web pages, documents, and multimedia content, to name a few. By leveraging such ontological infrastructure, various different *intelligent* services can be built such as semantic search engines that provide more relevant and fine grained results than traditional search engines through *i)* inferring new knowledge based on relationships that can be derived from ontologies and *ii)* correlating Web content according to its semantic annotations, and thus interpreting meanings with respect to the underlying ontologies. Despite the many promising aspects that we have described, the Semantic Web is still not widely adopted yet. This is mainly due to the difficulties in ontology creation and maintenance, and the process of semantic annotation. The development of ontologies is difficult and strenuous for domain experts who typically lack the required knowledge engineering expertise. Despite current efforts to increase the availability and reusability of ontologies, through the development of online ontology libraries (e.g., Swoogle) or (semi-)automatic ontology development tools, the usage of these libraries and tools still require a high level of technical knowledge (Gašević et al, 2007)

A new wave of so-called *social* applications has emerged as a culmination of technology and interaction techniques, and has been labeled the Social Web or Web 2.0 (O'Reilly, 2005). While much hype has surrounded these recent innovations, the uptake and trends of the software has been significant. The Social Web transforms the "old" model of the Web – a container of information accessed passively by users - into a platform for social and collaborative exchange; in which users meet, collaborate, interact and most importantly create content and share knowledge. Popular social websites, such as Facebook, Flickr and YouTube, enable people to keep in touch with friends and share content. Other services such as blogs, wikis, video and photo sharing that together enable what recently has been defined as "lifestreaming"[4] allow novice users to easily create, publish and share their own content. Further, users are able to easily annotate and share Web resources using social bookmarking and tagging; thus creating metadata for web content commonly referred to as "folksonomies". However, Social Web technologies in general, and collaborative tagging in particular, suffer from the problems of ambiguity of meanings. For instance collaborative tags are often ambiguous due to their lack of semantics (e.g., synonymous meanings for a tag). Moreover, they lack a coherent categorization scheme, and require significant time and a sizeable community to be used effectively (Mikroyannidis, 2007).

Despite the initial perception that the Social Web and the Semantic Web oppose each other, the two efforts are jointly being used to create a common space of semantic technologies. In fact, the Semantic Web can not work alone. It requires society-scale applications (e.g., advanced collaborative applications that make use of shared data and annotations) (Breslin & Decker, 2006). Moreover, the paradigm of knowledge creation derived from the Social

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[4] According to WordSpy (http://www.wordspy.com/words/lifestreaming.asp) lifestreaming is "an online record of a person's daily activities, either via direct video feed or via aggregating the person's online content such as blog posts, social network updates, and online photos."

Web can be effectively used to refine/update ontologies generated according to Semantic Web standards and best-practices. At the same time the Social Web can benefit from the paradigm of structured knowledge, represented with standard languages adopted in the Semantic Web vision. Such standards will make it easier for collective knowledge to be shared and to interoperate with any sort of application.

The idea of merging the best of both worlds has converged in the concept of the Social Semantic Web, in which socially created and shared knowledge on the Web leads to the creation of explicit and semantically-rich knowledge representations. The Social Semantic Web can be seen as a Web of collective knowledge systems, which are able to provide useful information that is based on human contributions, and which improves as more people participate (Gruber, 2008). We have summarized key features of the Semantic, the Social, and the Social Semantic Web in Table 1.

Table 1. Comparison between the key features of the Semantic, the Social and the Social Semantic Web.

Semantic Web	Social Web	Social Semantic Web
Structured Knowledge	Semi-structured/ unstructured knowledge	Structured or Semi-structured knowledge
Standardized and machine understandable knowledge representation and annotations	Knowledge and annotations not expressed in standard forms	Standardized and machine understandable knowledge representation and annotations
Knowledge creation process requires engagement of experts for knowledge provision and formal modeling: expensive	Knowledge creation process based on social activities and informal knowledge modeling: inexpensive	Simplified creation/refining of formalized knowledge based on social software sources
Complex interaction: tools for knowledge authoring/maintenance are still overly complex for end users; require background in knowledge engineering	Effortless interaction: authoring tools (wikis, blog platforms) enable seamless creation of knowledge as well as knowledge augmentation through 'peer-review' (tagging, commenting, blog trackbacks)	Simplified interaction patterns for generating structured knowledge through novel methods for enhancing semantically informal knowledge.
Semantic annotation (annotation with ontological concepts): expensive	Annotation based on social tagging /bookmarking, knowledge sharing/agreement in wikis: inexpensive	Annotation based on inexpensive social sources of knowledge creation

Specific examples of the Social Semantic Web are being undertaken in a wide number of projects. For instance, DBpedia[5] is a large-scale semantic knowledge base, which structures socially created knowledge on the Wikipedia, a wiki-based encyclopedia. DBpedia takes advantage of the common patterns and templates used by Wikipedia authors to gather structured information into a knowledge base of socially created structured knowledge. The result is a huge database of shared knowledge which allows "intelligent" queries such as: "List the 19th century poets from England" (Auer et. al., 2007). With its capability of answering very specific queries, DBpedia can serve as a very handy learning tool and is an excellent example of the advantages that Social Semantic Web paradigm brings to the educational domain. Throughout the paper we provide a lot of additional examples of the benefits that the Social Semantic Web brings to education.

The implications of such technologies are significant for the educational domain, where students can find immediate answers to their detailed questions. Further than finding answers to questions, though, is the possibility of the "Education Social Semantic Web", where pedagogically focused learning materials and activities are easily created, shared, and used by students and teachers; without the need for detailed knowledge engineering skills or know-how of advanced technologies. Specifically, for the field of AEHS, we see several immediate benefits of incorporating the current capabilities of the Social Semantic Web. Our discussion in sections 4 and 5 describes how the traditional AEHS stands to benefit.

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[5] http://dbpedia.org

4 Bringing Social Semantic Web to AEH Systems

Semantic Web and Adaptive Hypermedia came from different backgrounds, but it turned out that they can benefit from each other, and that their integration can result in synergistic effects (Cristea, 2004). The Semantic Web is designed to enable (among other things) integration and interoperability on a web-wide scale between applications. AEHSs, in contrast, tend to be designed as closed systems. Semantic Web technologies can lead to the opening of AEHSs, by allowing the sharing of learner interactions and of knowledge embedded in their modules. While some work has investigated the promise that Semantic Web technologies offer for 'opening' AEHSs (e.g. (Dolog et al, 2003), (Henze & Herrlich, 2004)), the trend of closed systems continues. A common point of note between the Semantic Web and AEHSs is that neither of them is widely adopted, due to their complexity. The Social Web paradigm is enabling a gradual acceptance of the Semantic Web among both developers and end users – hopefully, leading to its wider adoption. In the same way, we see the Social Web paradigm as potentially promoting broader acceptance of AEHSs.

There are several challenges in the AEHS field which can either fully or partially be addressed with technologies offered by the Social Semantic Web. In the rest of the section, we look at each component of AEHS systems and investigate possible implications that can stem from the inclusion of the Social Semantic Web paradigm.

4.1 Domain Model

Our discussion about domain models of AEHS covers two aspects: i) knowledge space – the definition of the domain knowledge; and ii) hyperspace – textual and multimedia content to be adapted.

4.1.1 Knowledge space

One of the main problems with the development and maintenance of the domain model of traditional AEHSs stems from the fact that despite the significant effort put into the definition of the domain knowledge model (i.e., knowledge space), this model often cannot be reused or shared with other systems. Moreover, the process of its definition or evolution, even within the same AEHS, can be accomplished only by domain experts. This problem can be addresses by expressing such models in a standard and interoperable format, which would enable the reuse of these models as well as facilitate sharing and combining models from different AEHSs focused on the same domain; thus easing the process of model evolution.

The Semantic Web offers technologies (e.g. RDF) to address these needs. In addition, it provides means for formally specifying the semantics of the represented data (i.e., defining ontologies as sharable and machine-processable knowledge representation formats).

In the last five years researchers in the AEHS field have been on the road of using ontologies for domain knowledge modelling and representation (Cristea, 2004) (Henze & Herrlich, 2004). However, the problem is that these first endeavours were restricted to local ontologies that were usable only in systems for which they were developed, and did not allow for seamless knowledge sharing among AEHSs covering the same or similar knowledge areas. In order to allow for automatic knowledge exchange among AEHSs covering the same or similar domains, mappings had to be defined between the ontologies formally representing their domain models. With such mappings in place, two AEHS systems from the same or a similar domain would be able to communicate and exchange knowledge stored in their domain models. Therefore, the major challenge was to facilitate the creation of those mappings (they still cannot be created automatically, but humans have to define them) and thus enable (semi-)automatic knowledge sharing, reuse, and exchange among several different AEHSs covering the same or similar domain. One of the primary obstacles for fulfilment of this goal was the fact that at the time when these first solutions were proposed (in 2003 and 2004), the Semantic Web infrastructure was not mature enough to provide the required support. Since those first proposals, Semantic Web technology has made significant progress, and the next generation of Semantic Web applications (Motta & Sabou, 2006) can now take advantage of the vast amount of semantic data and ontologies available online. For instance, there are now infrastructures (such as Watson[6] or SWSE[7]) for the collection, indexing and provision of access to semantic data and ontologies on the Web.

Another problem related to the usage of ontologies for representing domain models is the constant need for ontology evolution (maintenance and updating). This is not a trivial task, because current approaches and tools assume a background in knowledge engineering, or familiarity with ontology languages; this is true even when a

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[6] http://watson.kmi.open.ac.uk

[7] http://swse.org/

(semi-)automatic approach is proposed. In general, tools are too complex to be used by most teachers. The social side of the Social Semantic Web paradigm offers a possibility to simplify the evolution (the update and maintenance) process of ontology-based domain models. Student activities, which can be enabled within AEHSs, such as annotating, chatting, tagging, and the like, can be leveraged for the maintenance of a domain model. Further, intrinsic motivation and trust of students in a system that derives knowledge from their activities is certain to increase, since they are aware that they are contributing to the system and that their contribution 'counts'.

In our latest work, we have suggested a novel method of interactive visualizations that provide an intuitive and practical way for instructors to incorporate the implicit feedback available from student folksonomies for evolving domain ontologies (Torniai et al, 2008a). In addition, we have developed a method which leverages algorithms for computing the semantic relatedness to further facilitate the teacher's task of ontology maintenance by suggesting him/her the tags that are relevant for any particular ontology concept. The method is based on the idea that the ontology itself defines a 'context' for its concepts. So, when computing the relatedness between a concept and a tag, the surrounding concepts (forming the 'context' of the concept in question) must also be taken into account. The initial evaluation has shown that our method is particularly useful in situations where (i) the chosen semantic relatedness measure can not relate a high number of concept-tag pairs and (ii) fine grained domain ontologies are available (Torniai et al, 2008b). The tasks of ontology refinement are constant, and in order to efficiently address them we combine several approaches that leverage student contributions. This combined approach allows support to be given which is consistent with the course content, and with the conceptualizations that instructors and students have of that content.

The Social Web paradigm as a mean for facilitating ontology development and maintenance has been receiving a constantly increasing interests of the Semantic Web research community. For example, Hepp et al (2007) have suggested Wikis' infrastructure and culture as an environment for constructing and maintaining domain ontologies and using the Wikipedia URIs as unique identifiers for ontology concepts. This seams to be an appealing solution from the perspective of end-users (i.e. teachers and instructors) as it would provide them with an easy-to-use working environment. However, this solution produces an "informal ontology", that is, a collection of named conceptual entities with a natural language definition, and such an ontology can not address specific requirements of e-learning environments. Another solution, del.icio.us Brainlet (Tummarello & Morbidoni, 2007), enables a user to import tags from his/her del.icio.us account into a local RDF store, transform them into ontology classes and insert them in the class hierarchy. Even though it is originally aimed at supporting the DBin Semantic Web platform for personal knowledge and information management, the idea behind del.icio.us Brainlet can be used to facilitate teachers' tasks of ontology maintenance in ILEs. Actually, this solution is highly related to our work mentioned above. However, the interaction in our approach is more powerful for two reasons: 1) we provide teachers with hints about the relevancy of a tag for a given concept in the context of the given ontology (based on the calculated relatedness between ontology concepts and tags); 2) tags are not presented in the form of a flat list (as in del.icio.us Brainlet), but in the form of tag cloud, so that the user can spot the popularity of each tag, its relevancy to the selected domain concept, and how it compares to other tags used to describe concept-related content.

4.1.2 Hyperspace

The second aspect of our consiteration of domain models is related to the hyperspace, that is, a set of textual and multimedia content that is to be adapted. Almost all traditional AEHSs work with closed corpus set of documents assembled together at design time and fully known to the system. However, this approach does not go along with the open nature of the Web. The major challenge is to empower AEHSs, so that they can extract some meaning from an open corpus of documents and work with the open Web without the help of a human indexer (Brusilovsky & Nejdl, 2005). Technologies such as RDFa (Adida et al, 2008), eRDF[8] and microformats[9] offer a part of the solution since they allow for embedding semantic annotations in Web (e.g., XHTML) documents in a standardized way. There are already tools for extracting semantics (i.e. RDF data) from Web pages enriched with the RDFa/eRDF markup (e.g., Gleaning Resource Descriptions from Dialects of Languages - GRDDL (Connolly, 2007)). Even thought these technologies still require humans in the loop (to embed semantic markup in Web pages), there are more and more incentives for human participation[10] and tools that facilitate the process (such as SearchMonkey[11] API).

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[8] http://getsemantic.com/wiki/ERDF

[9] http://microformats.org/

[10] Yahoo has recently announced a new search engine that will index pages with embedded semantics (http://www.ysearchblog.com/archives/000523.html)

[11] http://searchmonkey.sourceforge.net/

Some initial research work has been done on leveraging the above technologies in the e-Learning domain. For example, DERI Galway has developed a framework for extracting useful knowledge published online in an informal way (e.g. wikis, blog posts, forum posts), structuring the acquired knowledge and putting it into use within LMSs (Jankowski et al, 2008). The first implementation of this framework is IKHarvester, a web service capable of capturing RDF data from Social Semantic Information Sources (such as semantic blogs, and semantic wikis), and resources with semantics embedded in the form of microformats. In addition, by scrapping HTML pages, IKHarvester can generate RDF descriptions from non-semantic information sources, such as Wikipedia[12]. The harvested resources together with their semantic descriptions are available for use in LMSs. IKHarvester has already been used within the Didaskon learning framework (Jankowski et al, 2007) and the initial evaluation of this service has provided positive results; a full usability survey of the service is on the way.

An important source of semantic markup are tags. Even though they are mainly used as descriptive metadata (i.e., tags often describe the content of the tagged resource), they can also be used as administrative metadata (e.g. "creative-commons" to identify licence issues), or can identify the source/author of the tagged resource (e.g., "w3c" tag to identify a document from the w3 website, or "byTBL" tag to identify Tim Berners-Lee as the author) (Kim et al, 2008). In the last couple of years, the Semantic Web research community has made a significant effort to disambiguate and formalize tags, that is, to bridge the gap between the needed level of semantic richness and the level offered by tags. For example, the work presented in (Van Damme et al, 2007) offers an interesting and comprehensive approach for semi-automatic generation of ontologies out of folksonomies. In particular, the authors suggest combining multiple online resources (such as, on-line lexical resources, existing ontologies and other Semantic Web resources) and techniques (e.g. basic text processing techniques, statistical analysis and social network analysis). Besides being beneficial for improving semantic richness of tags, the considered techniques could also be applied for analyzing students' tags to identify students sub-communities based on shared interests: annotated lessons and/or tags used for annotation.

Another relevant approach presented in (Specia & Motta, 2007) is oriented towards generating groups of highly related tags corresponding to elements in ontologies, thus producing knowledge structures which can be thought of as faceted ontologies, that is, partial ontologies conceptualizing specific facets of knowledge. Even though they can not be reasoned over like regular ontologies, those faceted ontologies can be beneficial for deducing the semantics of learning content. The Meaning Of A Tag (MOAT)[13] project takes a different approach: instead of trying to disambiguate and semantically enrich tags after their creation, MOAT aims to empower users to define meaning(s) of their tag(s) – by relating them to the URIs of existing concepts from Semantic Web knowledge bases (such as DBpedia and GeoNames) – while they are annotating web resources (Passant & Laublet, 2008). While users can still benefit from the simplicity of free-tagging when annotating content, the linking to existing concepts (i.e. URIs) offers a way to solve tagging ambiguity. Moreover, the relationships between concepts that tags are linked to can be leveraged for deducing additional relationships among tags themselves, as well as among tagged resources. There is also the MOAT ontology for formal representation of tags, their meaning and the tagging context.

Besides MOAT, Social Semantic Cloud of Tags (SCOT)[14] is another relevant project aimed at semantically representing the tagging data and enabling their share and reuse across different tagging systems. A comprehensive overview of existing efforts at representing tagging data semantically is given in (Kim et al, 2008). Besides presenting and comparing existing tag ontologies, the authors have also investigated mapping possibilities between those ontologies and suggested a method for their federation with the ultimate goal to allow for preserving the meaning of tagging data when shared across different tagging systems.

Finally, let us mention the project entitled Semantic Document Management (SDM) that provides a content model for ontology-based representation of learning objects (Nešić et al., 2008). Thus, content authors can search for and reuse parts (e.g., paragraph, table, or figure) of learning objects. Each part of learning objects is also annotated with domain ontology concepts and collaborative tags. In addition, each learning object part has metadata about the authors (i.e., author profiles) where the FOAF ontology is used to describe social relations among content authors. These social relations are then leveraged in a recommender service of add-ins for the Word and Power Point authoring tools. The recommender service consider the authors preferences in terms of social relations, where the authors may explicitly state the "friend" authors whose learning objects they prefer most to reuse.

Table 2 presents a summary of the solutions that the Social Semantic Web paradigm can offer for the Domain Model of AEHSs, and state the main challenges for full adoption of those solutions.

***Table 2**. A summary of solutions for Domain Model offered by the Social Semantic Web paradigm*

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[12] http://www.wikipedia.org/

[13] http://moat-project.org

[14] http://scot-project.org/

Issues to be addressed	**SSW solutions**	**Challenges**
Allowing for domain knowledge sharing, reuse, and exchange among several different systems covering the same or similar domains.	Using ontologies for domain knowledge modeling and representation (e.g., [Cristea, 2004], [Henze & Herrlich, 2004])	Low usability of tools not only for end users (teachers, students), but also for software developers: - Tools are still overly complex for end users; - Require background in knowledge engineering
Facilitating the tasks related to the maintenance and evolution of the domain knowledge models	Leveraging data about students' collaborative tagging activities to facilitate the teacher's task of the domain model maintenance (e.g., [Torniai et al, 2008a], [Tummarello & Morbidoni, 2007].	Tool support still at the level of research prototypes; further studies are needed for testing the scalability of the software solutions. Further (massive) evaluation studies within real world settings are needed for testing the research hypothesis. Tends to work well for relatively small lightweight ontologies; does not address the problem of maintenance of complex (heavy-weight) ontologies.
	Using Wikis' infrastructure and culture as an environment for constructing and maintaining domain ontologies [Hepp et al, 2007].	This solution produces an "informal ontology" (a collection of topics with a natural language definition), which can not address specific requirements of an AEHS system.
Making systems able of extracting meaning from an open corpus of documents and work with the open Web without the help of a human indexer	Embedding semantic markup in Web resources in a standardized way, using technologies such as RDFa, eRDF and microformats; the semantics embedded in this way can be automatically extracted using standard technologies, such as GRDDL. This solution would also make relevant knowledge published online in an informal way (e.g. blogs, wikies, fora) accessible from AEHSs [Jankowski et al, 2008].	Further investigation of the support needed by mainstream tools for web content authoring such as Office tools. Still require humans in the loop to embed semantic markup in Web pages. Thus, low usability for content developers. Improvement of services for automatic extraction of semantics from web content.
	Disambiguation and formalization of tags so that they can be used for semantic annotation of web resources. Present solutions: - semi-automatic generation of ontologies out of folksonomies (e.g., [Van Damme et al, 2007], [Specia & Motta, 2007]); - empowering users to define meaning(s) of their tag(s) while annotating web resources (e.g., [Passant & Laublet, 2008]); - tag ontologies for semantically representing the tagging data and enabling their share and reuse (with preserved meaning) across different tagging systems (e.g., [Kim et al, 2008])	Development of tools that implement the suggested research solutions. Evaluation studies in real world settings for testing the research hypothesis.

4.2 Student Model

The reliance on shared/interoperable student models would enable AEHSs to construct and update these models using information coming from different systems students interact with. This would lead to an increased capability and consistency of personalization in these systems.

A lot of research effort has already been put into development of interoperable ontology-based user models that can be shared among different systems. For example, Dolog et al. (2005) have proposed an ontology-based framework for manipulating and maintaining sharable learner profiles. Niederee et al. (2004) have introduced a metaphor of a 'context passport' that accompanies users on their travel through the information space. When interacting with a system, the relevant "context-of-use" is extracted from this context passport and is used for improved support of related activities. There is also a proposal for an RDF-based user model exchange language, called UserML, aimed at enabling decentralized systems to communicate through their user models (Heckman et al, 2005). The same research group has developed GUMO – the General User Model Ontology – which allows for the uniform interpretation of decentralized user models. However, none of these suggestions has yet received wider acceptance.

The Friend of a Friend (FOAF) ontology (Brickley, & Miller, 2005), also known as an ontology of social networks, provides a unified way for describing people and their relations. Due to its popularity and wide acceptance among Web users and communities (the number of FOAF profiles on the Web already counts in tens of millions), this ontology has become the basis for building domain/application specific ontologies for user and group modeling. For example, Ounnas et al (2007) has proposed a semantic learner model based on the FOAF ontology and aimed at supporting automation of the process of grouping students while preserving the individual's personal needs and interests. They have actually extended the FOAF ontology with a set of student-properties, which are relevant for the formation of different types of learning groups. Since it presents a common part of many of the application-specific user models commonly used, the FOAF ontology serves as a good base for sharing user models among diverse learning systems. Moreover, in the context of AEHSs, it offers potentials to allow for seeking peer-support while studying certain topics, as well as for leveraging successful learning paths of the fellow students.

Student models that can be enriched with data coming from diverse systems students interact with and that can be easily shared and exported (since expressed in standard formats) will lead to yet another kind of important benefits for students. In fact, if student models can be 'pulled out' from AEHSs and expressed in a sharable format, students will be given the possibility of having their knowledge - deduced from learning activities in many different systems – available for all of their learning activities. For instance, students would be able to export information about their achievements in an AEHS environment into their e-portfolio. In this way, a user-centered profile management can be enabled allowing students to benefit from personalization, feedback provisioning and interaction while moving across different learning systems.

An increasingly important ontology for user-centered profile management on Social Semantic Web is the Semantically-Interlinked Online Communities (SIOC) ontology (Bojãrs & Breslin, 2008). SIOC is an open-standard machine readable format for expressing the information contained both explicitly and implicitly in Web discussion methods such as blogs, forums and mailing lists. It thus enables the gathering of data about all kinds of interactions a student has had on the Web, and allows for the inference of additional knowledge about the student that can be beneficial for improving his/her student model. For example, an ILE could analyze online discussions a student participated in, and relate messages that the student exchanged with his/her peers to the topics of domain ontologies in order to infer the student's level of mastery of some of the domain topics. In addition, this offers an additional knowledge base of the *unofficial* content that can potentially be referred to while studying certain concepts. This will be possible, as that unofficial content can semantically be annotated by the domain ontology which is used for the description of the subject domain in the Domain Model. Moreover, some of that content can be recommended to educators while maintaining current content in the hyperspace.

The recent work of Carmagnola et al (2007) provides yet another example of how user activities on the Social Web can be beneficial for the enrichment of user models. Their research was aimed at understanding how users' tags can be leveraged for increasing and improving the knowledge that an adaptive system has about its users. The suggested approach is based on performing semantic analysis of tags, and some simple (heuristics-based) reasoning on them in order to infer new knowledge about a specific user. Knowledge that can be inferred in this manner can be beneficial for AEHS systems since it encompasses, for example, student knowledge level of tagged content, his/her interest in that content, and knowledge on levels of a student's creativity, group conformance, and (self-)organization. Besides being useful for enriching existing student models, this approach can also be used for creating the initial student model for students starting to use an ILE. In particular, the tags produced by a student can be mapped to the topics of domain ontologies (of the AEHS's domain model) to reflect his/her interest in and maybe even knowledge of the domain. Here, of course, the major research challenge is related to the development of heuristics and/or mapping mechanisms that would facilitate accurate disambiguation of the student's tags.

In Table 3, we summarize the above discussed issues related to the Student Model of AEHSs, the solutions offered by the Social Semantic Web technologies, as well as the challenges for full adoption of those solutions.

***Table 3**. A summary of solutions for the Student Model based on the Social Semantic Web paradigm*

Issues to be addressed	**SSW solutions**	**Challenges**
Sharing student models across different systems that students interact with	Ontologies based on official specifications for student modeling (e.g., [Dolog et al, 2005])	Addressing the problem of low acceptance: - providing guidelines and best practices of use; - better connection with learning technology standard; - examples on the widely adopted systems.
	General user model ontology allowing for alignment of user models from heterogeneous systems [Heckman et al, 2005]	
	Leveraging the popular FOAF ontology [Brickley, & Miller, 2005] as the basis for building domain/application specific ontologies for user and group modeling (e.g., [Ounnas et al, 2007])	Mapping user traits that cannot be represented with the FOAF ontology between student models used by heterogeneous systems.
Enriching the student model with additional knowledge inferred from diverse kinds of interactions a student has had on the Web	Leveraging users tags for inferring new and/or improving existing knowledge about a specific student (e.g., [Carmagnola et al, 2007]).	Development of heuristics that would facilitate accurate disambiguation of the student's tags.
	Inferring additional knowledge about a student from data contained both explicitly and implicitly in Web discussion methods, such as blogs, forums and mailing lists (e.g., [Bojārs & Breslin, 2008]).	Development of rules and heuristics that would allow for the interpretation of the interaction data and inference of relevant knowledge about students. Enabling creation of learners' portfolios based on the knowledge artifacts produced in diverse tools used in the learning process.

4.3 Context Model

The term "context" has been interpreted in different ways in different domain areas and different approaches have been applied to capture and utilize the contextual information. The areas of mobile and ubiquitous learning rely on two underlying contexts, namely the learning context and the mobile/ubiquitous context. The notion of learning context is mostly characterized by the learners, learning objects and learning activities which are performed in accordance with a specific pedagogical approach (Jovanovic et al, 2007). The mobile/ubiquitous context is mainly about spatial and temporal aspects of the user's situation.

To represent context in today's learning environments with the goal of providing personalized and context-aware learning content/activities to the learners, concise yet comprehensive representation methods are required which, not only are expressive and extendable, but also have the potential to be reasoned over. Due to their flexibility, expressiveness and extendibility, ontologies can be considered as the most suitable candidates for context representation. They ensure that different entities that use the context data have a common semantic understanding of that data. They also come with reasoning mechanisms over the available context data, making it possible to extract inferred knowledge out of the implicitly stated situations. In our previous work (Jovanovic et al, 2007), we have developed the LOCO (Learning Object Context Ontologies) ontological framework to allow for formal representation of the notion of learning context – a specific learning situation, determined by the learning activity, the learning content, and the student(s) involved. Accordingly, the framework integrates a number of learning-related ontologies, such as a user model ontology, a content structure ontology, and domain ontologies.

The notion of context and context modelling, have been mostly explored in the fields of mobile and ubiquitous computing. In these fields ontologies are used for uniquely describing context, and hence ensuring a common understanding of the contextual information being shared. For example, in the work of Ranganathan et al. (2003), context is represented through a set of predicates, where the name of the predicate is the type of context that is being described (e.g., location, temperature or time). Ontologies essentially define the vocabulary and types of arguments that may be used in the predicates. On the other hand, Preuveneers and his associates (2004) proposed a generic context ontology that can be considered as a metamodel for context modeling and not as a vocabulary. Lessons learned from these and other related work in the fields of mobile and ubiquitous computing can be leveraged for capturing, representing and utilising context in mobile learning environments. For example, we have proposed an extension of the LOCO framework in order to allow for capturing and representing contextual data in ubiquitous learning environments (Siadaty et al, 2008). The extended framework, called m-LOCO should allow for capturing the contextual data in a generic ubiquitous learning environment and effectively leveraging this data in different use case scenarios to support an over-all personalization for the learners.

The notion of context as an aggregate of spatial and temporal aspects of a user's situation is becoming increasingly important with the constantly growing usage of smart phones and emergence of mobile social networks. This nascent but constantly growing trend of location-based social networking is empowered by GPS technology and platforms like Yahoo!'s FireEagle[15] which enables one to share his/her location online. There are already a number of services that leverages this public location-data to allow users find their friends who are nearby, to discover and share what is happening in the vicinity or to get contextualized search results. These kinds of services can be highly beneficial for educational purposes as well. Of course, online sharing of one's location and other context data has important privacy implications. To deal with them, for example, Yahoo! allows users to turn FireEagle off when they want to keep their location private. However, this could be considered just as initial solution since more fine grained management of private data should be enabled (e.g., to enable one to define with whom he/she is willing to share his/her location data).

The above issues are calling for the use of various ways for regulating the access to private data. To date, the most relevant solutions are based on the use of policy languages such as Ponder, KAoS, Rei, PeerTrust, and XACML (Bonatti et al., 2006). Typically defined over ontologies, the policy languages provide a reliable mechanism for (rule-based) reasoning in the open environments where the use of roles and institutions the users may belong to is not possible (De Coi et al., 2008). Rather, the current policy languages allow for context-based reasoning where one can only leverage the knowledge coming from the shared vocabularies (i.e., ontologies) used by different communities and reputation of individuals gained in different communities. However, management of policies today requires a lot of technical knowledge, which in general disables wide adoption of policy-based approaches for privacy protection. Moreover, we can not expect that end-users will define a policy for each possible threat that may arise, but we need to develop mechanism for detection of privacy threats by leveraging the ontology-based definitions of contexts. Similarly to the relations between ontologies and folksonomies, there is a need to investigate policy languages in terms of folksonomies.

We summarize the above discussed issues and the suggested solutions in Table 4.

Table 4*. A summary of solutions for the Context Model based on the Social Semantic Web paradigm*

Issues to be addressed	**SSW solutions**	**Challenges**
Capturing and representation of the context data in such a way that different entities which use the context data have a common semantic understanding of that data	Ontology-based frameworks for capturing and representation of learning context data (e.g. [Jovanovic et al, 2007], [Siadaty et al, 2008])	Effective device independent solutions Common infrastructure for context-aware information exchange
Securing privacy of the context data	Languages and systems for management of privacy policies.	Development of user interfaces for policy management. Development of engines for context-aware detection of possible privacy threats. Developing policy languages that can reason over socially constructed knowledge in addition to the formally defined ontologies.

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[15] http://fireeagle.yahoo.net/

4.4 Teaching Model

Design of teaching strategies and their representation in a computer executable form is a challenging task, and requires the engagement of both pedagogical experts (having knowledge of instructional and learning theories as well as best teaching practices) and knowledge engineers (capable of representing pedagogical knowledge in machine executable form). Therefore, it is highly important to enable sharing and reuse of the pedagogical knowledge as much as possible.

One approach towards the reuse and the exchange of pedagogical knowledge is based on the reliance on standards and official specifications. The most relevant standard is the IMS Learning Design[16] (IMS LD) specification. The primary aim of IMS LD is to provide a common information model for representing pedagogy that is conceptually abstracted from context and content, so that proven pedagogical patterns can be shared and reused across instructional contexts and subject domains; as well as shared among different learning systems. Still, this specification can be improved by using ontologies. Giving a formal definition of semantics for such information models provides a stronger basis for integration into different systems. For example, Amorim et al (2006) developed an OWL ontology based on the IMS LD information model in order to address the limited expressivity of the official specification.

Not only are semantics of learning designs more precise by the use of ontologies, but it is possible to relate elements of learning designs with various aspects characterizing specific contexts of their use. For example, learning design activities can be connected with the domain knowledge, learning content, and learner models of the previous learners who participated in those learning activities. In fact, the LOCO framework exactly address this problem by providing a set of ontologies for defining learning context as an interplay of learning activities, learning content (and concepts), and users (Jovanović et al., 2007). It provides the firsts steps toward materialization of the ecological approach (McCalla, 2004) to the learning environments by fully leveraging formal semantics of ontologies and collective experiences of the learning content usage in previous learning contexts. For AEHSs, this offers a tremendous potential to evaluate the quality of the shared learning designs as well as all other shared learning resources (e.g., as it is shown in the LOCO-Analyst tool (Jovanović et al., 2007)). For example, AEHS developers may benefit from integration of an existing learning design into the teaching module. The teaching module itself may have heuristics and rules that reason over such shared learning designs for generating an instructional plan (e.g., to refer students to how their friends (FOAF) successfully completed learning activities on a certain topic).

In our recent work (Torniai et al, 2008a), we have also shown how folksonomies resulting from the students' collaborative tagging activities can be used for providing teachers with feedback about students' conceptualisation of the course content. The assumption is that the tags that a student has used for annotating the learning content reflect his/her perception (or even comprehension) of that content. We have extended our LOCO-Analyst tool (Jovanović et al., 2007) to provide teachers with visual clues which help them easily spot all parts of the course that the tags were used with, so that they can more easily reveal some of the students' misconceptions. We are currently working on some additional visual indicators that should point out the level of agreement between the teacher's and the student's conceptualization of the learning content. To accomplish this, we make use of the (semantic) annotations of the course content with concepts of the domain ontology, students' tags and our context-based measure of relatedness between ontology concepts and tags. Since the domain ontology reflects (or at least should reflect) the teacher's conceptualization of the course content, by using our measure of relatedness between ontology concepts and tags, we can identify where the teacher's and the student's conceptualizations overlap and where they diverge. We believe that this kind of information can be very valuable for teachers as it can help them improve the design and/or the content of the courses they teach.

Not are all research efforts aimed at developing ontological representations of instructional knowledge based on IMS LD. Mizoguchi et al (2007) have developed a comprehensive ontology which covers different theories and paradigms about instructional and learning design. The ontology came as a result of the researchers ten year commitment to providing a comprehensive and sharable model of instructional design knowledge. It is built based on the philosophical consideration of all the necessary concepts for understanding learning, instruction and instructional design, and as such should enable increased theory-awareness in authoring tools. The first tool that leverages the OMNIBUS ontology to support the design of instructional scenarios is called SMARTIES (Hayashi et al, 2008). SMARTIES understands instructional theories based on the OMNIBUS ontology and supports authors in designing scenarios that conform to those theories.

Table 5 presents a summary of the solutions that the Social Semantic Web paradigm can offer for the Teaching Model of AEHSs, and state the main challenges for broader adoption of those solutions.

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[16] http://www.imsglobal.org/learningdesign/

Table 5. A summary of solutions for Teaching Model that leverage the Social Semantic Web paradigm

Issues to be addressed	SSW solutions	Challenges
Sharing and reuse of the pedagogical knowledge stored in the teaching model	Ontologies based on standards and official specifications for representing pedagogy abstracted from content and context. (e.g., [Amorim et al, 2006])	Inadequate tool support – today's tools require: - detailed knowledge of the standards/specifications they rely upon, - understanding of ontologies and ontology engineering Low usability not only for end users (teachers, students), but also for developers.
	A comprehensive ontology covering numerous theories and paradigms of instructional and learning design; the ontology serves as a shared reference model for development of instructional scenarios [Mizoguchi et al, 2007]	Low usability: to be able to use such an ontology one needs competence both in domain of pedagogy and knowledge engineering.
Improvement of the stored pedagogical knowledge based on the real-world experiences	Ecological approach [Mc Calla, 2004] combined with a comprehensive ontological framework for capturing and usage of learning context data [Jovanović et al., 2007]	Further evaluation studies are needed for testing some of the research hypothesis. Tool support still at the level of research prototypes: - large-scale experiments in real-world settings - higher scalability of the employed technologies (e.g. RDF repositories, inference engines)
	Leveraging students' collaborative tagging activities for providing feedback about students' conceptualization and comprehension of the course content. [Torniai et al, 2008a]	
Facilitating development of (pedagogy) theory-aware course design	Course authoring tool built on top of a comprehensive ontology of instructional design knowledge. (e.g. [Hayashi et al, 2008])	Low usability: currently the tool usable only for individuals who are experts both in pedagogy and knowledge modeling.

4.5 Adaptation Model

Based on a student's current learning context and the system's knowledge about the student stored in his/her student module, the adaptation module can schedule content selection and presentation, tutoring feedback, and other adaptation actions. This means that the adaptation module stores procedural knowledge that describes the dynamics of the system. This knowledge often takes the form of different kinds of rules, which are typically represented in well-known rule-based languages (e.g., Jess, Lisp). Recently, some researchers have been proposing the use of Semantic Web Rule Language (SWRL) (Horrocks et al, 2004) for designing a system's dynamics. For example, Carmagnola et al (2005) have proposed a Semantic Web framework for AHS which exploits SWRL for definition of adaptation strategies.

The major problem with the present practice of representing adaptation rules and strategies in AEHSs is the lack of interoperability among AEHSs based on heterogeneous rule representation formalisms. This problem can be addressed by the use of Rule Interchange Format (RIF) (Ginsberg, 2006). RIF is an initiative of the W3C RIF Working Group aimed at addressing the problem of interoperability between existing rule-based technologies. Its usage in AEH systems has already been discussed in details in (Kravcik & Gasevic, 2007). In a nutshell, by providing a common model for representing rules, RIF allows for reuse and repurposing of existing adaptation strategies and thus leads to the reduction of AEHS development costs.

If domain, user and context models of an AEHS are represented in a structured way, adaptation rules can be expressed in SPARQL (Prud'hommeaux & Seaborne, 2008), the official query and transformation language for the Semantic Web. For example, using SPARQL CONSTRUCT queries one can restrict the domain model to only those domain concepts that are suitable for a specific student interacting with the AEHS. This query would provide an adapted or personalized 'view' over the domain model for that particular student. SPARQL ASK queries can be applied for checking, for example if a student is ready to take the next lesson (i.e. has acquired all prerequisite knowledge) or if a specific learning content can be delivered to the students mobile device. Finally, SPARQL SELECT query can be leveraged for different kinds of personalization scenarios as suggested in (Siadaty et al, 2008). Being the defacto standard for querying the data on the Web, SPARQL has a continually increasing number of adopters as well as applications/tools that supports it. Therefore, it can also serve as a reusable and interchangeable format for expressing adaptation rules.

Recently, there has been an increasing interest in using dynamic composition of Web services for achieving dynamic adaptation to different learning contexts and requirements of individual learners. Ontologies for describing Web services, such as OWL-S, and ontology-based frameworks, such as Web Service Modeling Ontology (WSMO), are supposed to facilitate the automation of Web service tasks including automated Web service discovery, execution, composition and interoperation (Sheth et al., 2006). For example, Dietze et al (2007) have presented an innovative semantic web service-oriented framework aimed at fulfilling learning objectives based on a dynamic supply of services. Their approach is based on abstract and reusable learning process models describing a learning process semantically as a composition of learning goals. Similar approaches can be applied in AEH systems to enable advanced levels of adaptation and context-sensitive learning experience.

All the above ideas promote sharing different types of knowledge among different learners. However, as this may also affect privacy of learners, it is also important to explore how policies can be integrated in the adaptation module. For example, policies can be used for defining access rights to certain resources based on the student's current context and/or role or by negotiating trust (e.g., PeerTrust used in the ELENA project) (Bonatti & Olmedilla, 2007). This is especially relevant for mobile learning contexts, where a certain context of learners (e.g., in a classroom) may be used by the teaching module to collaborate or share experiences with some peers.

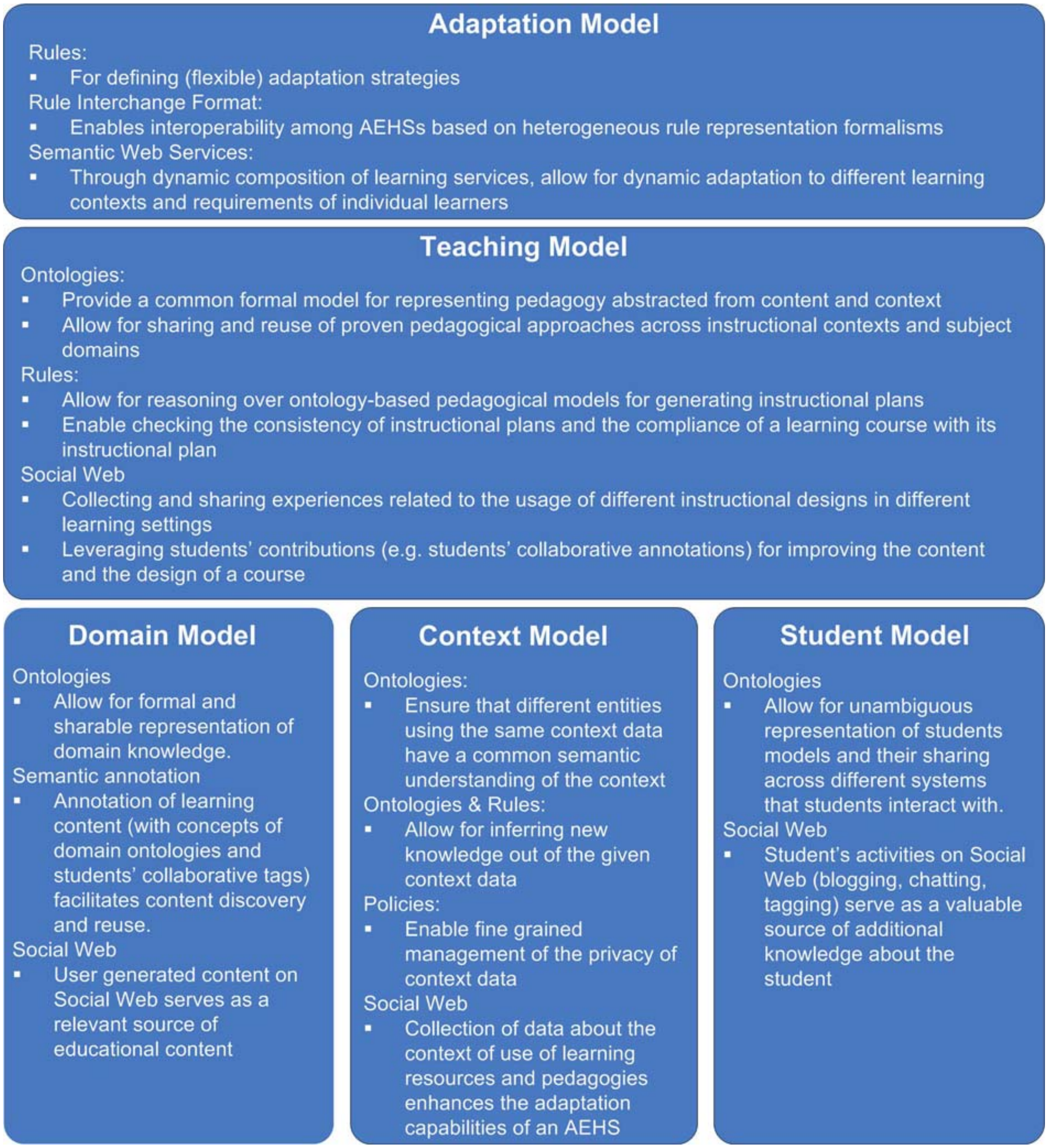
In Table 6, we present a summary of the still open problems related to the Adaptation Model of AEHSs, the solutions offered by the Social Semantic Web technologies, as well as the challenges for broad adoption of those solutions.

Table 6. A summary of solutions for Adaptation Model offered by the Social Semantic Web technologies

Issues to be addressed	SSW solutions	Challenges
The lack of interoperability among adaptation models of different AEHSs	Rule Interchange Format (RIF) [Ginsberg, 2006] for dealing with interoperability issues of adaptation knowledge expressed using heterogeneous rule representation formalisms	Inadequate tool support – complex not only for end users but also for software developers. Frameworks for end-user educational service composition (e.g., mash-ups) that address context specific learning objectives. Reusability and exchange of end-user produced mash-ups with other educators, students, and software developers (Since mash-ups comprise data, user interface, and software services, this challenge is also related to domain and teaching models).
	Expressing adaptation knowledge in the form of SPARQL [Prud'hommeaux & Seaborne, 2008] queries over user, domain and context models; being a W3C standard, SPARQL guaranties interoperability of adaptation knowledge.	
	Ontologies and ontology-based frameworks for describing Web services: for exchanging adaptation knowledge among ILE's which provide adaptation through dynamic composition of Web services.	

4.6 A Summary

We conclude our discussion on the advantages that can stem from leveraging the Social Semantic Web paradigm in AEHSs by providing a figure (Figure 1) which illustrates the basic architecture of an AEHS and summarizes the major benefits that the Social Semantic Web paradigm brings to each component of an AEHS (domain model, student model, etc).



Adaptation Model

Rules:
- For defining (flexible) adaptation strategies

Rule Interchange Format:
- Enables interoperability among AEHSs based on heterogeneous rule representation formalisms

Semantic Web Services:
- Through dynamic composition of learning services, allow for dynamic adaptation to different learning contexts and requirements of individual learners

Teaching Model

Ontologies:
- Provide a common formal model for representing pedagogy abstracted from content and context
- Allow for sharing and reuse of proven pedagogical approaches across instructional contexts and subject domains

Rules:
- Allow for reasoning over ontology-based pedagogical models for generating instructional plans
- Enable checking the consistency of instructional plans and the compliance of a learning course with its instructional plan

Social Web
- Collecting and sharing experiences related to the usage of different instructional designs in different learning settings
- Leveraging students' contributions (e.g. students' collaborative annotations) for improving the content and the design of a course

Domain Model

Ontologies
- Allow for formal and sharable representation of domain knowledge.

Semantic annotation
- Annotation of learning content (with concepts of domain ontologies and students' collaborative tags) facilitates content discovery and reuse.

Social Web
- User generated content on Social Web serves as a relevant source of educational content

Context Model

Ontologies:
- Ensure that different entities using the same context data have a common semantic understanding of the context

Ontologies & Rules:
- Allow for inferring new knowledge out of the given context data

Policies:
- Enable fine grained management of the privacy of context data

Social Web
- Collection of data about the context of use of learning resources and pedagogies enhances the adaptation capabilities of an AEHS

Student Model

Ontologies
- Allow for unambiguous representation of students models and their sharing across different systems that students interact with.

Social Web
- Student's activities on Social Web (blogging, chatting, tagging) serve as a valuable source of additional knowledge about the student

Figure 1. A summary of the major benefits that the Social Semantic Web paradigm brings to each component of an AEHS

5 Social Semantic Web Paradigm for Increasing the Interactivity

In this section, we concentrate on the second research challenge this paper aims to address, namely, how to improve the interactivity level of ILE. We first explain why interactivity is important for successful learning and then proceed to discuss how the Social Semantic Web paradigm can increase the interactivity level along each dimension of the "interactivity triangle."

5.1 Why is interactivity important?

In the context of learning, interactivity implies 'doing' as opposed to 'being' (present) (Downes, 2007); it assumes active participation in the learning process, rather than passive consumption of the content server by instructors (O'Connell, 2007). In other words, in the context of learning, interactivity can be equated with social and creative engagement, that is, communication, collaboration and authoring. Here we look into why interactivity is so important for successful learning and prove its relevancy both from practical and theoretical points of view.

According to a Pew Internet and American Life Project report[17], 87% of kids between the ages of 12 and 17 are online. They are using the Internet for research, to communicate, play games, get news, shop, and much more. 57% of these teens could be considered content creators–they have created a blog or webpage, posted original artwork, photography, stories or videos online or remixed online content into their own new creations. Other similar studies, such those reported in ('New Global Study', 2007) and (NSBA, 2007), on students social and education related activities confirm these findings. Today's kids, often referred to as digital natives (Prensky, 2001), need higher level of social and creative engagement in order to learn; they will not be passive consumers of the predefined learning content. For these kids, highly interactive learning environments are a must.

In addition, modern learning theories stress the importance of interactivity in learning and call for social and creative engagement of students. For example, the Conversation theory argues that learning is a continual conversation; with the external world and its artefacts; with oneself; and also with other learners and teachers. The most successful learning comes when the learner is in control of the activity, able to test ideas by performing experiments, ask questions, collaborate with other people, seek out new knowledge, and plan new actions (Naismith et al, 2004). Collaboration and community also offer a potential for increasing learner motivation, and thus leading to the improved learning results (Greer, 2006). Likewise, the portfolio approach, which is individual-centred and enables individuals to keep their own objectives and control over their learning process (even when learning in a group), also leads to increased learning motivation (Osterloch, 2007). It allows users to plan and document their personal learning processes, to store personal reflections, self-produced artefacts and other evidences of competence.

5.2 Social Semantic Web for Increased Interactivity

Social Web has already proven itself as a platform for social interaction and collaboration. Online social networks have become the place where people meet, communicate, create and exchange information and knowledge. A huge number of students and teachers actively participate in at least one of such networks, while a significant proportion of them are active members of many online networks. A recent comprehensive survey on social and education related activity patterns of American students (NSBA, 2007) has revealed that beyond basic communications, many students, who use social networking, talk online about education topics (60%) and that, surprisingly, more than 50% talk specifically about schoolwork.

In this section we provide detailed explanations of how the Social Semantic Web paradigm supports interactivity in learning environments. We also provide a number of examples which illustrate the statements we make.

5.2.1 Social Networking as a Rich Source of Interaction Data for Adaptation and Personalisation

Besides being members of general social networks, like Facebook, MySpace and YouTube, many students are also participants of online social networks specifically focused on their studies, like stud.icio.us, NoteMesh[18] and CollegeRuled[19]. These networks typically allow students of the same class to share notes with each other; offer a message board and/or a discussion area where students discuss assignments with classmates, ask questions, work in groups, and the like. There are also online social networks aimed primarily at teachers and instructors, for their professional development, as well as collaborative creation and exchange of learning content and instructional practices; examples include Curriki[20], EdTechTalk[21] and Yahoo!Teachers[22]. Finally, some online social networks are aimed at connecting students and teachers, like Schoopy[23] and BuddySchool[24].

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[17] http://www.pewinternet.org/index.asp

[18] http://www.notemesh.com/

[19] http://collegeruled.com/

[20] http://www.curriki.org/

[21] http://www.edtechtalk.com/

[22] http://teachers.yahoo.com/ (still in beta)

[23] http://www.schoopy.com/

[24] http://www.buddyschool.com/

The use of these and similar tools and services can significantly facilitate interaction along student-student, student-teacher and teacher-teacher dimensions. Furthermore, the data about users (students and teachers) interactions via these (social) tools and services can be leveraged by an AEHS for generating recommendations and adapting the learning process of each particular student. For example, the interaction data can be mapped to the learning context ontologies of the Context Model (see Section 4.3), thus, providing the AEHS with knowledge about the student's learning situation; adaptation rules expressed in the form of SPARQL queries (as suggested in Section 4.5) can be applied on top of the acquired learning context data in order to generate recommendations for the student that address his/her current learning needs (as suggested in (Siadaty et al, 2008)). In addition, the interactions data can be used for enhancing user models (not just of students but also of teachers) with knowledge about their social relations, expressed using the FOAF ontology (see Section 4.2). Similarly, this data can be used for inferring a user's reputation, that is, how he/she is perceived by the other members of the community (e.g., how competent a particular student is in a particular subject area according to his/her peers). This knowledge can be represented using the FOAFRealm ontology (Kruk, 2004) – an extension to the FOAF ontology which allows users to express how well one person knows, or trusts, another – and leveraged by an AEHS for providing recommendations. Furthermore, by leveraging semantic frameworks, such as the one suggested in (Jankowski et al, 2008), useful knowledge can be extracted from the informal content exchanged online among users of social networks, and used as a part of the AEHS's hyperspace.

Having recognized the importance of online social networking for education, traditional e-learning environments, like Learning Management Systems (LMS), have recently started to incorporate well known social networking tools. Currently, the best example of this practice is Haiku LMS[25] which already has over 80 social networking tools ready to embed with just a simple drag-and-drop. In a similar manner, through inclusion of social networking tools and services (via their public APIs), intelligent learning environments can increase their level of interactivity along all dimensions of the interactivity triangle (see Table 7). Since both students and teachers are used to interacting via those tools and services in their daily practices, there will be no barriers for adoption. In addition, the interaction data could be captured internally (i.e., by the system itself), and then mapped to the AEHS's context model and used for adaptation purposes and/or for enrichment of the student model – as already suggested above. However, AEHSs can go even a step further, by leveraging the integration of Social Web and semantic technologies, as will be explained below.

5.2.2 Socially-constructive and User-centred Knowledge Management

Currently, one of the major obstacles for collaborative creation and sharing of knowledge on the Social Web is the fact that online social networks are like isolated islands – knowledge can be exchanged within the island (i.e. network) but not across them, at least not without a lot of effort (i.e. manual copy-and-paste activities). For example, let us consider a student who is studying a certain domain topic and wants to acquire the knowledge on that topic by leveraging the resources gathered by an expert or his/her peers. Unfortunately, resources maintained by those people can be located on many different social networks; our student would spend significant amount of time on manually importing these resources, or may even abandon the operation in favour of using other, potentially less relevant or less trustworthy sources of knowledge.

The integration of the Semantic Web technologies into the Social Web paradigm promises to solve this problem. For example, Social Semantic Collaborative Filtering (SSCF) (Kruk et al, 2006) allows users to easily share their knowledge with others within and across online social networks. For example, one could easily import friends' bookmarks and utilise their expertise and experience in specific domains of knowledge. In addition, SSCF allows users to set fine grained access rights for their resources; access control is based on the distance and the friendship level (expressed using FOAFRealm) between users. SSCF exemplifies how Social Semantic Web technologies can be leveraged for surpassing the paradigm of "walled garden" learning environments (typical for traditional e-learning systems, like LMSs) and replacing it with the novel paradigm of Personal Learning Environments (PLEs). The idea behind PLEs is to provide learners with their own personal learning environment, which they could use to interact with diverse systems, tools and services to access content, assessment, collaborate with peers and the like (Wilson & Milligan, 2007). In a nutshell, the idea is to 'empower' learners by giving them greater control over their learning experience. This new paradigm of online learning, facilitated by the Social Semantic Web technologies, assumes high level of interaction along student-student, student-content and student-teacher dimensions of the interactivity triangle. In this paradigm, AEHSs will be just one of a number of systems and tools that students interact with; this will require from AEHSs to communicate with those other tools and services and exchange with

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them the data about students' interactions. This data can further be used for adaptation purposes, generation of feedback for teachers (as suggested in (Jovanovic et al, 2007)) and/or for enrichment of the student model – as already being discussed above.

Semantically-enhanced social networks represent another solution that leverages the Social Semantic Web paradigm to allow for advanced forms of social interactions, as well as knowledge creation and exchange. These are emerging systems, among which the most representative one is Twine[26], a knowledge networking site where users are encouraged to connect with other people, create, organize and share information and knowledge. Twine integrates facilities currently available in different Social Web tools, but also uses Semantic Web technologies to enable sophisticated services, such as recommendation of relevant content and people. Users can create topic-oriented communities, called twines; they can be members of different twines and exchange knowledge with other users both within a twine and across twines. It is expected that by the end of this year (2008), users will be able to easily pull their information and knowledge from Twine to make them available in other systems and tools. Twine and similar systems, like the forthcoming Qitera[27], can be leveraged for increasing the interactivity of online learning environments – students and teachers can create communities around course topics; develop and exchange knowledge within and across those communities; meet peers studying/teaching the same or similar subjects; get recommendations about relevant resources (both human and digital). In the PLE paradigm, AEHSs should communicate with these systems (via open APIs and/or data exchange protocols) in order to acquire the interaction data that they can further leverage for improving students learning experience within AEHSs.

5.2.3 Improved User Experience

Some emerging software solutions that rely upon Social Semantic Web paradigm promise not only to improve end-users interaction with the content, but also to introduce new forms of interaction that was previously not possible. For example, Parallax[28] offers a new way of browsing and exploring data stored in Freebase[29] – an open, semantically structured database of information of general interest. The tool leverages the faceted browsing paradigm to allow for seamless exploration of data. It also enables one to browse from one set of things to another related set of things (e.g., find the architects of skyscrapers in New York and all the structures that they have designed) – a novel and powerful mechanism for exploring the data, much more efficient than the ability to browse from one single thing to another single thing.

The Social Semantic Web technologies has also facilitated the emergence of mash-ups – web applications allowing users to combine and integrate different types data, often originating from different sources. Mapping mash-ups, in which maps are overlaid with information, may be the best known example of this rapidly growing genre. Tools, such as Google's Mashup Editor[30], or Yahoo Pipes[31] allow individuals to mix up data, find new meaning, and present it in interesting ways. The suit of tools developed in the scope of the MIT's SIMILE[32] project (such as Exhibit (Huynh et al, 2007a), Potluck (Huynh et al, 2007b), and PiggyBank (Huynh et al, 2007c)) facilitates the creation of Semantic Web mash-ups – by leveraging Semantic Web technologies (primarily RDF and SPARQL) these mash-ups are more dynamic and flexible. Maybe the most distinctive among those tools is Potluck, a tool that lets casual end-users (i.e. non-programmers) easily make mash-ups of structured, semantically reach data, often expressed in RDF or JSON[33] format. Potluck acknowledges the fact that the real-world RDF is messy, "broken perhaps not just in syntax but also in semantics" (Huynh et al, 2007b), and empowers users to deal with this problem by providing them with visual editing facilities. In particular, the tool assumes an iterative process of data integration in which the user leverages the tool's rich visualisation capabilities to explore the data, identify data of interest as well as merge, align and/or clean up the data – all that in an easy and intuitive manner.

Educationally, tools like Potluck can be extremely valuable by helping students integrate previously disparate types of information, explore them from different perspectives and in more depth. Mash-ups not only improve the interactivity along student-content and teacher-content dimensions, but also introduce a novel form of content-content interaction: the mash-up resulting from the integration of disparate sources of data brings in a new quality (e.g., a new point of view, or a better understanding of some phenomenon) that is often more valuable than the pure

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[26] http://www.twine.com
[27] http://www.qitera.com/
[28] http://mqlx.com/~david/parallax/index.html
[29] http://www.freebase.com
[30] http://code.google.com/gme/
[31] http://pipes.yahoo.com/pipes/
[32] http://simile.mit.edu/
[33] http://json.org/

sum of the integrated parts. In addition, mash-ups can be semantically annotated (e.g. using ontologies of the LOCO framework) with the data about the context of their creation (who created them, using which data sources, for what purpose) and used as learning content, i.e. become part of the hyperspace used by an AEHS.

Table 7. An overview of different forms of interaction typical for Social Semantic Web and tools/services that support them

	Student	**Teacher**	**Content**
Student	**Forms of interaction**: - Status update - Commenting on status - Discussions via chats and forums - Social browsing - Content sharing and co-authoring - Content/peers recommendations **Relevant tools/services:** - Special focused learning groups within general online social networks, like Facebook, YouTube, del.icio.us - Specialized online social networks, such as stud.icio.us, NoteMesh, CollegeRuled - Social browsing tools, such as Kiobo[34] and Browzmi[35] - Tools for exchanging opinions and ratings, such as RateMyProfessor[36] - Semantically enhanced social networks, like Twine	**Forms of interaction:** - Feedback provisioning (teachers to students and vice versa) - Status update - Social browsing - Content co-authoring / refinement - Content/peers recommendations **Relevant tools/services:** - Special focused learning groups within general online social networks, like Facebook, YouTube, del.icio.us - Specialized online social networks, such as Schoopy, BuddySchool - Social browsing tools, such as Kiobo and Browzmi - Semantically enhanced social networks, like Twine - Tools for providing teachers with feedback, such as LOCO-Analyst	**Forms of interaction:** - Tagging - Commenting - Highlighting - Visualization - Content browsing and exploration **Relevant tools/services:** - Social bookmarking and annotation tools, such as del.icio.us, diigo[37], magnolia - Visualization tools, such as Exhibit, ManyEyes [Viegas et al, 2007][38] - Data exploration tools, such as Freebase Parallax and Potluck
Teacher		**Forms of interaction:** - Status update - Content sharing and co-authoring - Exchange of best practices - Content recommendations **Relevant tools/services:** - Specialized online social networks, such as Curriki, Yahoo!Teachers, EdTechTalk - Semantically enhanced social networks, like Twine	**Forms of interaction:** - Tagging - Commenting - Highlighting - Visualization - Content browsing and exploration - Content authoring **Relevant tools/services:** - Social bookmarking and annotation tools, such as del.icio.us, diigo[39], magnolia - Visualization tools, such as Exhibit, ManyEyes[40] - Data exploration tools, such as Freebase Parallax and Potluck - Collaborative authoring tools, such as Google Apps, wikis

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[34] http://www.kiobo.com/

[35] http://browzmi.com/

[36] http://www.ratemyprofessors.com/

[37] http://www.diigo.com

[38] http://services.alphaworks.ibm.com/manyeyes/home

[39] http://www.diigo.com

[40] http://services.alphaworks.ibm.com/manyeyes/home

Content	▨	▨	**Forms of interaction:** Aggregation of content from different sources and services **Relevant tools/services:** - Tools for creating mash-ups, such as Google's Mashup Editor and Potluck - Tools for manipulating RSS feeds (e.g. Yahoo! Pipes), and RDF-based Web content (e.g., DERI Pipes[41]) - Services providing data for creating mash-ups, such as Wikipedia, DBpedia, Freebase

6 Conclusions

The Social Semantic Web offers new approaches and technologies for leveraging user contributions in the systems they use. This is achieved by means of structured information expressed with standard formalisms that can be collaboratively created, updated and enhanced through user activities. We have shown how the computational and development costs of knowledge engineering and maintenance can be decreased for ILEs across all their components, including, domain, student, context, teaching, and adaptation models. It is very important to point out that, in order to be fully viable (in general, and for ILEs in particular), a technical solution based on the Social Semantic Web paradigm has to provide a sound paradigm of interaction (in terms of effectiveness and consistency with user interaction behaviour). The capability of solving technical issues related to data and knowledge integration, reuse and exchange has to be complemented by the capability of delivering innovative and yet intuitive interaction forms. In this paper, we have shown how this can be achieved through the synergic use of social and semantic technologies in ILEs. In particular, we have shown how all dimensions of the interactivity triangle can be improved by leveraging the Social Semantic Web paradigm, as well as how those interactions (i.e. the interactions data) can be leveraged by various models of the ILE's architecture. However, a significant challenge still remains for the next generation of ILEs: developing advanced capability of delivering solutions that merge knowledge creation, integration and exchange capabilities with innovative and effective interaction paradigms.

Given that social technologies have appeared as a global phenomenon recently, the research community has not yet provided sound methodological frameworks for exploring and evaluating it. The provision of such frameworks is an additional challenge for synergic use of the Semantic Web and Social Web technologies in the domain of ILEs. Thus, our research, based on qualitative observations, is one of the first attempts toward developing a sound methodological framework for evaluation of such technologies in the context of ILEs. We have also demonstrated that the focus on AEHSs is quite effective, as it covers aspects that most ILEs have, and as such creates a general enough framework for drawing generally applicable conclusions in the area. Combined with the interactivity triangle, this builds a promising research framework for future investigating the implications and potential benefits of the Social Semantic Web paradigm for ILEs. We believe that the qualitatively identified set of features in this paper, spanning across the ILE's constitutional models and interactions dimensions will serve as a useful point for

- researchers starting their investigation of the use of the Social Semantic Web paradigm;
- researchers trying to either compare their solutions with related works done or describe the scope of their work; and
- educational technology managers trying to identify the features that can best suit to the needs of their institutions.

Of course, there are many issues to be addressed to further validate and improve the proposed framework. First, we need to develop sound criteria for evaluation of social technologies, inducing but not limited to, technical, social, pedagogical, and economical criteria. These should help us in answering the questions such as how significantly does the application of those technologies in learning settings contribute to better performance of students and/or better learning experience (in the sense learning is less a burden for students, that is, perceived qualitative benefits).

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[41] http://pipes.deri.org/

Second, the identified set of features has to be further improved trying to identify more quantitative criteria for description and analysis of Social Semantic Web based ILEs. Finally, the identified list of features is not exhaustive, as the use of the Social Semantic Web paradigm is just in the early stages of its investigation in the domain of ILEs.

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