Unlocking Serendipitous Learning by Means of Social Semantic Web

Matteo Gaeta[1], Vincenzo Loia[2], Giuseppina Rita Mangione[1], Sergio Miranda[1]
and Francesco Orciuoli[1]
[1]*DIEM, University of Salerno, Via Giovanni Paolo II, 132, Fisciano (SA), Italy*
[2]*DI, University of Salerno, Via Giovanni Paolo II, 132, Fisciano (SA), Italy*

Keywords: Serendipitous Learning, Social Semantic Web, SKOS, SIOC.

Abstract: Serendipitous Learning is the learning process occurring when hidden connections or analogies are unexpectedly discovered, mostly during searching processes (for instance on the Web) which are typical for informal learning activities, especially accomplished in the workplace context. Moreover, serendipitous processes have high probability to occur in the contexts where learners have high autonomy, more chances to intervene in different activities and to interact with resources and people. This paper proposes an approach, based on the Social Semantic Web, to sustain and foster Serendipitous Learning. The proposed approach considers two connected ontology layers to model knowledge by using several Semantic Web vocabularies like SIOC, Dublin Core, SKOS, and so on. The SKOS role is particularly relevant because it allows connections among heterogeneous resources, also across multiple communities. The proposed approach models the above-mentioned connections at the conceptual level in order to facilitate learners to discover relevant links, concepts and to follow unexpected useful paths.

1 INTRODUCTION AND RELATED WORKS

Technologies and, in particular, ICTs (Information and Communication Technologies) influence the educational practices as well as the redefinition of the concepts of learning and teaching. This phenomenon asks educators to review their practices in order to face new learning/teaching situations in which learners can access alternative learning resources in addition to those defined in structured curricula. The availability of new learning resources is mainly due to the Web, intended as a boundless field of information. The increasing number of learning resources (on the Web) and the decreasing of teacher presence require higher autonomy and regulation to learners in order to master both formal and informal learning environments. Autonomous and self-directed interactions with available content foster *"[...] unexplored and unplanned discoveries and fortunate incidents in the process of exploring something else [...]"* (Kop, 2012). In this context, the term *serendipitous learning* was coined to point out the learning processes related to the *"[...] unexpected realization of hidden, seemingly unrelated connections or analogies [...]"* (Kop, 2012).

This paper describes how *Social Semantic Web*, if opportunely deployed, is able to effectively sustain *serendipitous learning*. *Social Semantic Web* (Breslin et al., 2009) is defined as the synergistic application of Semantic Web and Social Web that tries to get and combine the advantages of both. The work provides a scalable approach to manage knowledge and contents created in a specific environment. It mainly focuses on both the formal description of relevant resources (e.g. Web resources) in the environment and the modelling of conceptual connections among the above-mentioned resources. The approach proposes a knowledge representation architecture based on two integrated layers of ontologies in order to foster the emergence of relevant connections among resources and the agile provisioning of these connections to the learners, helping them to play a serendipitous learning experience. The approach could be exploited also in smaller contexts like, for instance, Small and Medium-sized Enteprises (SMEs), where the concept of Web resource is replaced by the concept of digital resource. Other works in literature deal with the adoption of the Social Semantic Web as a learning platform. In particular, the authors of (Jovanovic et al.,), (Torniai et al., 2008) and (Jeremic et al., 2013) were among the first ones to describe the e-learning scenar-

Gaeta M., Loia V., Rita Mangione G., Miranda S. and Orciuoli F..
Unlocking Serendipitous Learning by Means of Social Semantic Web.
DOI: 10.5220/0004845102850292
In *Proceedings of the 6th International Conference on Computer Supported Education* (CSEDU-2014), pages 285-292
ISBN: 978-989-758-020-8

ios supported and enhanced by the Social Semantic Web technologies and methodologies and to discuss the main issues concerning the realization of these scenarios:

- development and maintenance of domain ontologies;
- exploitation of user-generated contents as learning resources;
- provisioning of new forms of interaction;
- support for interoperability;
- support for adaptation and personalization of e-learning experiences;
- ubiquitous access to learning resources.

Moreover, the authors of (Brooks et al.,) provide three main lessons learned by analysing e-learning applications and tools developed by using Semantic Web and Web 2.0 technologies:

- testing the defined approaches in real world scenarios in order to effectively evaluate systems and validate models and methodologies;
- tracking large amount of data related to learners' interactions in order to extract pedagogical patterns;
- extracting implicit knowledge from contents in order to automatically construct metadata to improve search of learning material.

With respect to the reviewed literature, this paper mostly focuses on the anatomy of the ontology structures (two integrated layers of ontologies have been introduced and modelled) and on the methods for constructing, maintaining and evolving the aforementioned ontologies. More details concerning the discovery of links and related resources have been provided by proposing several approaches. If the Semantic Web technologies provide a great solution for interoperability and integration, discovery is considered one of the main lever to enable serendipity. This paper takes care of principles and suggestions of the existing works and advances by trying to solve some of the main issues related to the adoption of Social Semantic Web in e-learning scenarios. Lastly, it is important to underline that the proposed approach aims at working in contexts (e.g. Knowledge-Intensive Organizations) where the ICTs are already exploited to manage and track (also partially) the work activities.

2 SERENDIPITOUS LEARNING

The idea underlying *serendipitous learning* is based on several pedagogical approaches. Among the others, it is possible to recognize *discovery learning*, *exploratory learning*, *experiential learning*, *constructivist learning* and *connectivism* (Kop, 2012). Numerous works (Heinström, 2007) address *serendipitous learning* by taking care mostly of the concept of surprise and on the accidental nature of information discovery. On the other hand, some authors (André et al., 2009) focus on the importance of prior knowledge and sagacity in the *serendipitous learning* processes. Other scientific results affirm that the hidden connection discovery could not occur instantly but require an incubation period to the learners (McCay-Peet and Toms, 2010) (Lu, 2012). These authors assert also that the conditions able to sustain serendipitous connection discovery are those of *active learning* and *social learning* in *knowledge building and discovery* environments (Scardamalia and Bereiter, 2006) (McCay-Peet and Toms, 2010). Furthermore, the effects of serendipity are analysed by the authors in (Gritton, 2007). They assert that there is not sufficient evidence to affirm that *serendipitous learning* is a consequence of intuitive sagacity of learners but they state that there is no doubt that serendipitous browsing can reveal hidden connections among concepts and stimulate thinking and, consequently, learning. Now, the question is: *may the new Web technologies increase and improve serendipitous learning?*. Some ideas are proposed by authors of (Ihanainen and Moravec, 2011) and (Boyd, 2010). They enhance search strategies (e.g. the same adopted by Web search engines) by moving the control from search engines to learners and by fostering randomness in the information stream. Authors of (Boyd, 2010) affirm also that people should find methods for integrating Web searching into their thinking and reflection processes. Technologies have to take care of this integration and the personal context of the learner by considering *an unfiltered but manageable store of resources*.

3 A SOCIAL SEMANTIC WEB APPROACH TO IMPROVE SERENDIPITOUS LEARNING

In this Section, an approach that fosters serendipitous learning is proposed. The approach is based on the main Social Semantic Web principles in order to provide Web-based environments to interact (searching, tagging, rating, recommending, etc.) with digital resources.

3.1 The Social Semantic Web

The W3C[1] provides the following brief definition for Semantic Web: *[..] The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries [..]*. The Semantic Web vision concerns the provisioning of metadata associated with Web resources to assign *machine-interpretable meaning* to them. In order to make this metadata really sharable and understandable, it requires vocabularies and ontologies expressing semantics for terms and values used in the above-mentioned metadata. Being these metadata set represented in uniform way, better linking and decentralization of resources are supported. Among the other issues, the Semantic Web infrastructure provides concrete answers to the requests for *entity identity* and *explicit relationships*. More in details, with Semantic Web, the entities on the Web, previously embedded and hidden in HTML pages, become uniquely identifiable and, thus, understandable and manageable by machines (computers). Moreover, representing entities is not sufficient, thus identifying relationships among entities is also needed (Breslin et al., 2009). In other words, Semantic Web allows the development of software agents that aim at improving search and navigation of Web resources, making new user experiences available. From the technological viewpoint, the core of the Semantic Web architecture[2] is represented by: i) RDF (Resource Description Framework), i.e., a data model natively enabling distribution of data, ii) RDFS (Resource Description Framework Schema) and OWL/OWL2 (Web Ontology Language), i.e., languages for formal description of data and its semantics. These two main layers, supported by URIs and XML, allow querying (by using, for instance, SPARQL) and inference (by using ontology-based inference enabled by OWL reasoners or rule-based inference enabled by specific rule engines). On the top of the core layers, a great number of vocabularies and ontologies, covering different domains (some more specific, others more general), have been developed and deployed. FOAF (Friend of a Friend)[3] for representing knowledge on people and social relationships, SIOC (Semantically-Interlinked Online Communities)[4] for representing knowledge on activities of on-line communities, Dublin Core for describing metadata for (digital) resources, SKOS (Simple Knowledge Organization System)[5] for modelling thesauri, concept maps and controlled vocabularies, SCOT (Social Semantic Cloud of Tags)[6] & MOAT (Meaning of a Tag Ontology) (Passant and Laublet, 2008) for modelling all the entities related to the tagging process, and so on.

[1]http://www.w3.org/2001/sw/
[2]http://www.w3.org/standards/semanticweb/
[3]http://www.foaf-project.org
[4]http://sioc-project.org
[5]http://www.w3.org/2004/02/skos/

In this context, the concept of *Social Semantic Web* emerges. Social Semantic Web represents the ecosystem in which social interactions on the Web applications lead to the creation of explicit and semantically rich knowledge representations. The Social Semantic Web combines technologies, strategies and methodologies from Semantic Web, social software and the Web 2.0 (Weller, 2010). In other words, the Semantic Web provides new and better searching (for people, content, tag, etc.) scenarios for Social Web applications and, vice-versa, users' interactions with Social Web applications extend, update and populate the Semantic Web structures.

SIOC (Bojārs et al., 2008) is one of the most important and known ontologies for the Social Semantic Web. It aims at interlinking on-line user-generated content from applications such as blogs, instant messaging tools, wikis and other Social Web sites, by providing an ontology to model structures (e.g. posts, threads, etc.) and activities (e.g. tagging, replying, etc.) in online communities. Typically, SIOC is used in combination with the FOAF vocabulary for describing people and their friends and the SKOS model for organising knowledge. SIOC lets developers link discussion posts and content items to other related discussions, items, people and topics. Authors of (Bojārs et al., 2008) introduce also the concept of *food chain* (see Fig. 1).

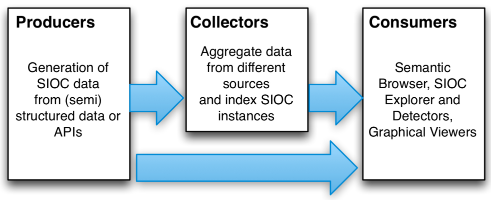

Figure 1: SIOC food chain.

The idea is that semi-structured data is gathered and transformed in SIOC data from different sources. Subsequently, SIOC data coming from different sources is aggregated (by using the native capabilities of RDF data model) and indexed (e.g. with SKOS taxonomies). At the end of the chain, users can search and navigate integrated SIOC structures also by surfing the defined indexes.

[6]http://scot-project.net/scot/spec/scot.html

3.2 Generalizing the SIOC Approach

It is possible to generalize the SIOC (Breslin et al., 2006) approach by considering different types of data source and not only Social Web applications. The idea is to provide additional ontologies, to integrate with SIOC, to cover different domains. For instance it is possible to use Dublin Core to describe documents in Document Management Systems (DMSs), IEEE LOM (a binding in RDF[7]) to describe learning objects in Learning Object Repositories (LORs) and so on. Fig. 2 shows a generalization of the SIOC food chain and proposes SKOS as a mechanism to integrate and index different types of individuals.

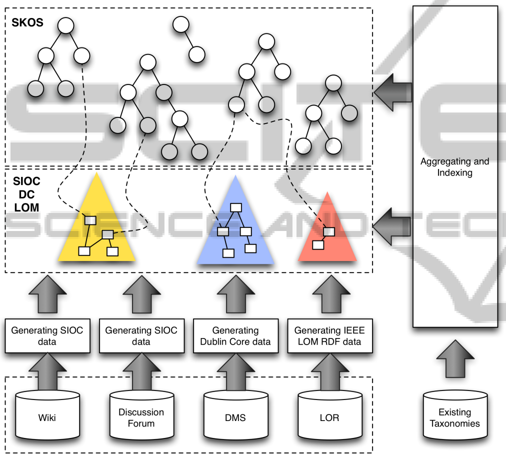

Figure 2: Generalizing the SIOC food chain.

Fig. 2 clearly shows two ontology layers, the upper layer (in Fig. 2), realized by means of SKOS, provides *classification ontologies*, i.e., lightweight semantic structures used to annotate and classify individuals belonging to the ontologies at the lower layer. The lower layer provides *descriptive ontologies* which model key concepts of the domain of interest. For instance, in a Knowledge-Intensive Organization (KIO), the key concepts like Project, Task, Activity, Document, UGC (User-Generated Content) should be considered and modelled by using the ontologies at the lower level (Mangione et al., 2012) (Gaeta et al., 2013). These ontologies are, relatively, static in the sense that they do not rapidly evolve and have to be built and managed by human experts following methodologies like NeON (Suárez-Figueroa, 2010) also by adopting (as suggested in this work) existing vocabularies. Ontologies at the upper layer are dynamic, in the sense that they evolve as soon as new activities (dealing with new topics) start in the KIO. These ontologies model and structure, for instance, the topics of the projects in the KIO. The *classification ontologies* can be constructed by means of automatic, semi-automatic or non-automatic processes. More in details, the automatic process can be realized by means of *Fuzzy Formal Concept Analysis (FFCA)* (Maio et al., 2011) that is used to extract concepts from a set of full-text documents and construct a *Fuzzy Concept Lattice*, i.e., a structure that represents the conceptualization of the document set taken as input. The same authors define a methodology to build SKOS ontologies starting from a *Fuzzy Concept Lattice*. If the considered documents are packaged as structured learning contents it is possible to adopt approaches like, for instance, those provided in (Capuano et al., 2009) and (Gaeta et al., 2011), where the content structure is exploited to construct lightweight ontologies from the source learning material. Definitely, the combination of the two ontology layers allows interoperability, integration (in particular *descriptive ontologies*) and serendipity (in particular *classification ontologies)* as we will show in the next Sections.

3.3 Using SKOS to Link Heterogeneous Contents

In the Semantic Web, SKOS provides a vocabulary to define thesauri, taxonomies, controlled vocabularies, concept maps and so on. SKOS provides the `skos:Concept` class that can be instantiated in order to define individual concepts (or subjects, topics, tags, etc.) which can be hierarchically related by means of `skos:narrower` and `skos:broader` (Baker et al., 2013). Other relations among individual concepts can be expressed by means of `skos:related` (for weak semantic relations) or by defining subproperties of the above mentioned properties, including `skos:semanticRelation`. Moreover, two concepts belonging to two different SKOS taxonomies can be related by using `skos:relatedMatch`, `narrowMatch` and `broadMatch`.

According to the need of indexing and integrating individuals coming from different classes (of different vocabularies), it is important to introduce two properties: `sl:isSubjectOf` and `sl:subject`. The first one is the inverse of the second one that is defined as a subproperty of `dct:subject`[8] (coming from Dublin Core vocabulary).

Moreover, `sl:subject` has range `skos:Concept` whilst `sl:isSubjectOf` has domain `skos:Concept`. More in details, as shown in Fig. 3, by means of the `sl:isSubjectOf` property it is possible to assert that

[7]http://ltsc.ieee.org/wg12/

[8]http://dublincore.org/documents/2012/06/14/dcmi-terms/?v=terms#terms-subject

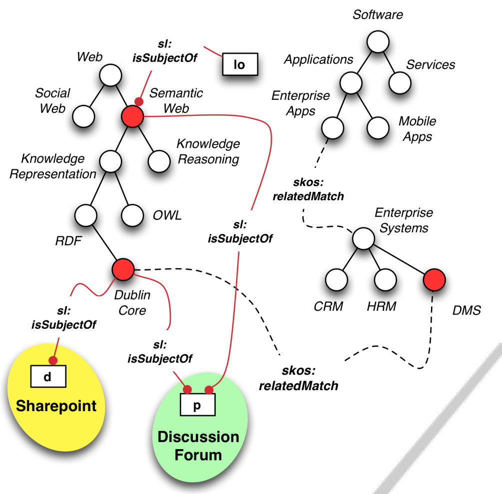

Figure 3: SKOS to link heterogeneous contents.

both the document `d` and the (forum) post `p` deal with the topic `Dublin Core`. The post `p` also deals with the topic `Semantic Web`. The concept `Dublin Core` is related to the concept `DMS` of a different concept schema, as well as the concept `Enterprise Apps` is related to the same concept `DMS`.

Definitely, as we will see also in the next Section, the *classification ontologies* represent the core structure enabling the serendipitous discovery.

3.4 Serendipitous Learning in the Social Semantic Web

According to the example provided in Fig. 3, assume that user `A` is interested in the concept `DMS` because she has to introduce a Document Management System in the SME (Small and Medium-sized Enterprise) she works for. While addressing the `DMS` concept, `Dublin Core` concept is signalled to `A` because it is related to `DMS`. Once the attention of `A` is focused on `Dublin Core`, she learns that `Dublin Core` is related to `DMS` (we assume that a standard viewer, for a SKOS ontology, shows and emphasizes at least all the concepts directly linked to the concept the user is currently addressing) and she can see two resources (coming from two different systems) dealing with the aforementioned concept. By reading the text document `d`, `A` goes deep into her knowledge on the connection among `Dublin Core` and `DMS`. `A` learns that some existing Document Management Systems represent document metadata by means of Dublin Core schema.

Moreover, `A`, by reading the forum post `p` understands that the use Dublin Core follows the principle of the Semantic Web, a concept that is unknown for `A` until this moment. `A` acquires knowledge about the `Semantic Web` concept by enjoying the learning object `lo`.

This sample flow emphasizes the main principles of *Serendipitous Learning*:

- Fostering autonomous interaction of users-learners with content space;
- Valorizing the users-learners' prior knowledge (in the out-of-the-box thinking) by means of SKOS concept schemas which recall the human mind model;
- Stimulating *surprise* (by showing hidden connections) during exploratory processes;
- Providing active and social learning space aiming at knowledge building processes.

The relations among concepts (`skos:Concept`) and Web resources (i.e. the *Aggregating and Indexing* process of Fig. 2), in the Social Semantic Web platform could be generated with non-automatic, automatic and semi-automatic mechanisms. In the first case, it is possible to exploit the tagging features of Social Web applications and integrate tagging ontologies like, for instance, SCOT and MOAT with SKOS. In the second case, it is possible to exploit *knowledge extraction & discovery* methods like, for instance, *FFCA* (see Section 3.2) that is able to conceptualize a set of full-text contents and automatically classify them with respect to the extracted concepts. It is also possible to recommend some of the connected resources to the learner, on the basis of his/her profile (Gianforme et al., 2009) in order to foster his/her discovery process.

A sample result of this process is depicted in Fig. 3 where the *FFCA* algorithm extracts the concept `Dublin Core` from two contents, i.e., document `d` and post `p`. The relation among the two contents and the extracted concept is explicitly asserted (in the RDF/RDFS/OWL sense) by means of the `sl:isSubjectOf` property. The third case foresees the application of the aforementioned methods, whose results are supervised and revised by means of human interventions.

An important aspect of the proposed approach is its capability to link concepts belonging to different *classification ontologies* (*cross-ontologies* links). Several methods can be exploited to discover *cross-ontologies links*. One of the simplest ones is to calculate the *document-oriented word similarity measure* (Terra and Clarke, 2003) among the labels which describe two different concepts:

$$rel(c_1, c_2) = \frac{df_{c_1,c_2}}{N_{max}}. \quad (1)$$

In the equation 1, df_{c_1,c_2} is the number of contents annotated with both concept c_1 and concept c_2

(coming from two different SKOS ontologies, i.e., individuals of `skos:Concept`). Whilst N_{max} is the total number of considered contents. An instance of the property `skos:relatedMatch` is asserted among c_1 and c_2 if $rel(c_1, c_2)$ is bigger than a given threshold.

3.5 Using SPARQL to Access Contents and Concepts

The proposed approach enables high interoperability and integration by laying upon the Semantic Web stack. This capability allows to navigate on the ontology graphs by using the SPARQL language and obtain useful results (able to concretely realize the scenario depicted in Section 3.4) by means of simple queries, like the following one.

```
...
SELECT ?s ?obj
WHERE
{
  ?s1 skos:relatedMatch unisa:DMS .
  ?s1 sl:isSubjectOf ?obj .
  ?s sl:isSubjectOf ?obj
}
...
```

The previous query (it is only a sample code) allows to retrieve all concepts related (in the example we consider only the cross-ontology links) with `DMS` and all contents (the result parameter is `?obj`) annotated with these concepts. The retrieved contents are further analysed in order to found other relevant concepts (the result parameter is `?s`). This is the way to discover that `Dublin Core` follows the principles of the `Semantic Web` (see the scenario described in Section 3.4).

Lastly, the inference capabilities provided by the ontology-based reasoners (supporting RDFS, OWL and OWL2) generate new facts (from existing ones) which increase the knowledge base and, consequently, enrich learners' exploration experience.

3.6 Identifying Relevant Paths: A Data Mining Approach

Suggesting hidden connections (among concepts and, conseuently, resources) is one of the main chances to provide surprise to learners during the exploratory process. The method we propose is based on the *Context-Dependent Sequential Pattern Mining* algorithm. The idea of traditional *Sequential Pattern Mining* (Pei et al., 2004) applied to the domain of this paper is that the exploratory paths of learners, in terms of visited concepts (on the *classification ontologies*), can be analysed in order to find frequent sequences of visited concepts. For instance, the algorithm can assert something like this: *learners who visit concepts c_x, c_y and c_z also visit concept c_k*. This rule can be used to recommend c_k to those learners who have visited c_x, c_y and c_z. Moreover, the authors of (Rabatel et al., 2013) add *context awareness* to the extraction of frequent sequences. In brief, they suggest finding frequent sequences in specific contexts. For the aim of this paper, we can define the context as the prior knowledge (or/and competencies) of learners. For instance, it is possible to locate frequent sequences for *expert java developers*, *novice project managers* and so on. This approach requires the definition of rules able to assign individual learners to one or more contexts. During exploration, learners could receive suggestions like, for instance, *resource annotated with concept c_k could be useful for you* on the basis of: i) known contextualized frequent sequences, ii) contexts associated to them, and iii) concepts visited in the current session.

4 LEARNING DOMAINS AND SCALABILITY

One of the main advantages of the Social Semantic Web platform is that we may contextualise them for different types of communities acting in different environments and having different sizes. This characteristic is enabled by the numerous existing vocabularies covering different domains. For instance, if the community we would like to consider is composed by the employees of a Knowledge-Intensive Organization, we need to integrate vocabularies and ontologies for describing projects, competencies, roles, strategies, tasks, documents, training material and so on. Otherwise, if the community we would like to consider is composed by consumers related to the world of cultural heritage, we need to consider ontologies like CIDOC-CRM[9], Geonames[10], etc. Thus, if we change the domain, Semantic Web mechanisms allow us to change the vocabularies and ontologies but not the approach (SKOS-based) presented in Section 3.4.

Furthermore, the Social Semantic Web platform is highly and natively scalable. Both horizontal and vertical scalability can be considered. More in details, horizontal scalability occurs when more than one communities are considered. This case is illustrated in Fig. 4. A community can be repre-

[9]http://www.cidoc-crm.org
[10]http://www.geonames.org

sented by a set of SKOS concepts schemas, a set of persons and a set of vocabularies and ontologies modelling data (coming from software applications used in that community) which are relevant in a specific domain. The proposed approach and, in particular, `skos:relatedMatch`, `skos:broadMatch`, `skos:narrowMatch` properties can link SKOS concept schemas belonging to different communities and enable serendipitous learning process among different communities. Adding a new community is allowed also at run-time.

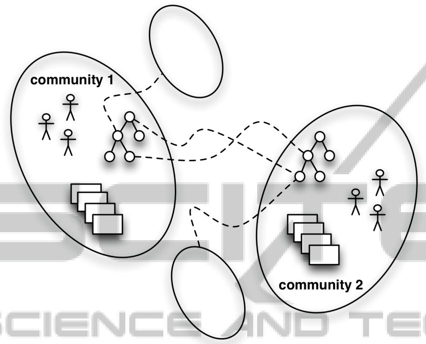

Figure 4: Horizontal scalability.

Vertical scalability is allowed by the capability of Semantic Web to add new information systems and, thus, new data at run-time.

Lastly, a third type of scalability may be considered: infrastructure scalability. This means the capability to handle different and distributed storage systems for ontologies and, in general, semantic data is guaranteed by the distributed nature of RDF.

5 EARLY EVALUATION, FUTURE WORKS AND FINAL REMARKS

The work proposes an approach to exploit the Social Semantic Web platform to support Serendipitous Learning. The SIOC framework and its *food chain* have been generalized in order to support multiple domains. Two interconnected ontology types have been introduced. The first one is used to describe relevant resources. The second one is used to classify and connect heterogeneous resources and it is mainly based on SKOS. Moreover, suitable methods for link and path discovery, leveraging on *classification ontologies*, have been proposed. The scalability of the proposed approach has been shown. An early partial evaluation has already been executed in the context of the experimentation of an integrated workplace learning system (developed in the context of another R&D Project by the same authors). More in details, we deployed *SMW+ (Semantic Media Wiki Plus)*[11] to allow users to interact with the ontology layers for a fixed time interval in order to experience and answer to a Likert-based questionnaire. In particular, 20 workers of CRMPA (Centre of Research in Pure and Applied Mathematics)[12], involved in four R&D Projects, were asked to use the deployed system for two months in order to support their project tasks. At the end of this period, the 20 workers are asked to answer the questionnaire consisting in 12 questions. Among these questions, the item Q10 asked workers to evaluate their serendipitous learning experience with the deployed system. In a scale from 1 (worst) to 5 (best), the *median* was 4, the *mode* was 5, the *variability* was 1.2 (for *range*) and 3 (for *iq range*). All these values refer to the item Q10. Of course, the executed experimentation is largely insufficient to evaluate the proposed approach but it has been performed in order to understand its potential usefulness. Thus, we have already planned to execute a complete experimentation in a larger community of users in the context of the SIRET Project (see Section 5), where we will set two groups (an experimental group and a control group) of learners (with the same objectives) and we will try to analyse the differences in the knowledge acquired in a group rather than in the other one. Discriminate the knowledge acquired by means of serendipitous processes will be one of the main challenges of the experimentation methodology. Additional experimentation phases will be executed to evaluate the algorithms proposed to construct and manage ontologies and to perform link discovery and context-dependent sequential pattern mining.

ACKNOWLEDGEMENTS

Partially supported by the Italian Ministry of University and Research under the PON 01_03024 SIRET, Recruiting and Training Integrated System, project approved by D.D. 721/Ric 2011, October 14 and started in 2011, November 1. Special thanks to the other partners involved in these activities: CRMPA, Centro di Ricerca in Matematica Pura e Applicata, Fisciano (SA), Italy and MOMA S.p.A., Baronissi (SA), Italy.

REFERENCES

André, P., Teevan, J., Dumais, S. T., et al. (2009). Discovery is never by chance: designing for (un) serendipity. In

[11] http://www.smwplus.net/
[12] http://www.crmpa.it/

Proceedings of the seventh ACM conference on Creativity and cognition, pages 305–314. ACM.

Baker, T., Bechhofer, S., Isaac, A., Miles, A., Schreiber, G., and Summers, E. (2013). Key choices in the design of simple knowledge organization system (skos). *Web Semantics: Science, Services and Agents on the World Wide Web*.

Bojārs, U., Breslin, J. G., Finn, A., and Decker, S. (2008). Using the semantic web for linking and reusing data across web 2.0 communities. *Web Semantics: Science, Services and Agents on the World Wide Web*, 6(1):21–28.

Boyd, D. (2010). Streams of content, limited attention: The flow of information through social media. *Educause Review*, 45(5):26–28.

Breslin, J. G., Decker, S., Harth, A., and Bojars, U. (2006). Sioc: an approach to connect web-based communities. *International Journal of Web Based Communities*, 2(2):133–142.

Breslin, J. G., Passant, A., and Decker, S. (2009). *Social Semantic Web*. Springer.

Brooks, C., Bateman, S., Greer, J., and McCalla, G. Lessons learned using social and semantic web technologies for e-learning.

Capuano, N., Dell'Angelo, L., Orciuoli, F., Miranda, S., and Zurolo, F. (2009). Ontology extraction from existing educational content to improve personalized e-learning experiences. In *Semantic Computing, 2009. ICSC'09. IEEE International Conference on*, pages 577–582. IEEE.

Gaeta, M., Mangione, G., Miranda, S., and Orciuoli, F. (2013). Adaptive feedback improving learningful conversations at workplace. pages 175–182.

Gaeta, M., Orciuoli, F., Paolozzi, S., and Salerno, S. (2011). Ontology extraction for knowledge reuse: The e-learning perspective. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, 41(4):798–809.

Gianforme, G., Miranda, S., Orciuoli, F., and Paolozzi, S. (2009). From classic user modeling to scrutable user modeling. pages 23–32.

Gritton, J. (2007). Of serendipity, free association and aimless browsing: do they lead to serendipitous learning. *Retrieved March*, 20:2012.

Heinström, J. (2007). Psychological factors behind incidental information acquisition. *Library & Information Science Research*, 28(4):579–594.

Ihanainen, P. and Moravec, J. (2011). Pointillist, cyclical, and overlapping: Multidimensional facets of time in online education. *The International Review of Research in Open and Distance Learning*, 12(7):27–39.

Jeremic, Z., Jovanovic, J., and Gasevic, D. (2013). Personal learning environments on the social semantic web. *Semantic Web*, 4(1):23–51.

Jovanovic, J., Gasevic, D., and Devedzic, V. E-learning and the social semantic web.

Kop, R. (2012). The unexpected connection: Serendipity and human mediation in networked learning. *Educational Technology & Society*, 15(2):2–11.

Lu, C.-J. (2012). *Accidental Discovery of Information on the User-Defined Social Web: A Mixed-Method Study*. PhD thesis, University of Pittsburgh.

Maio, C. D., Fenza, G., Loia, V., and Senatore, S. (2011). Hierarchical web resources retrieval by exploiting fuzzy formal concept analysis. *Information Processing & Management*, (0).

Mangione, G. R., Orciuoli, F., Gaeta, M., and Salerno, S. (2012). Conversation-based learning in the social semantic web. *Journal of e-Learning and Knowledge Society-English Version*, 8(2).

McCay-Peet, L. and Toms, E. G. (2010). The process of serendipity in knowledge work. In *Proceedings of the third symposium on Information interaction in context*, pages 377–382. ACM.

Passant, A. and Laublet, P. (2008). Meaning of a tag: A collaborative approach to bridge the gap between tagging and linked data. In *LDOW*.

Pei, J., Han, J., Mortazavi-Asl, B., Wang, J., Pinto, H., Chen, Q., Dayal, U., and Hsu, M.-C. (2004). Mining sequential patterns by pattern-growth: The prefixspan approach. *Knowledge and Data Engineering, IEEE Transactions on*, 16(11):1424–1440.

Rabatel, J., Bringay, S., and Poncelet, P. (2013). Mining sequential patterns: a context-aware approach. In *Advances in Knowledge Discovery and Management*, pages 23–41. Springer.

Scardamalia, M. and Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. *The Cambridge handbook of the learning sciences*, pages 97–115.

Suárez-Figueroa, M. C. (2010). *NeOn Methodology for building ontology networks: specification, scheduling and reuse*. PhD thesis, Informatica.

Terra, E. and Clarke, C. L. (2003). Frequency estimates for statistical word similarity measures. In *Proceedings of the 2003 Conference of the North American Chapter of the Association for Computational Linguistics on Human Language Technology-Volume 1*, pages 165–172. Association for Computational Linguistics.

Torniai, C., Jovanovic, J., Gasevic, D., Bateman, S., and Hatala, M. (2008). E-learning meets the social semantic web. In *ICALT*, pages 389–393. IEEE.

Weller, K. (2010). *Knowledge representation in the social semantic web*. Walter de Gruyter.