

## A Learning Content Authoring Approach based on Semantic Technologies and Social Networking: an Empirical Study

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### ABSTRACT

Semantic web technologies have been applied to many aspects of learning content authoring including semantic annotation, semantic search, dynamic assembly, and personalization of learning content. At the same time, social networking services have started to play an important role in the authoring process by supporting authors' collaborative activities. Whether semantic web technologies and social networking improved the authoring process and to what extent they make authors' life easier, however, remains an open question that we try to address in this paper. We report on the results of an empirical study based on the experiments that we conducted with the prototype of a novel document architecture called SDArch. Semantic web technologies and social networking are two pillars of SDArch, thus potential benefits of SDArch naturally extend to them. Results of the study show that the utilization of SDArch in authoring improves user' performances compared to the authoring with conventional tools. In addition, the users' satisfaction collected from their subjective feedback was also highly positive.

### Keywords

Empirical study, Learning content authoring, Semantic web technologies, Social networking

### Introduction

Authoring of learning content completely from scratch has always been a difficult and time-consuming task. Current research has shown that most authors reuse and modify existing learning content, available in their own archives or on the Web (Betty & Allard, 2004) rather than authoring new content from scratch. Therefore, if the main goal of learning content is for teaching and learning, the second goal should be its reuse. The reuse process requires a meaningful way to search and retrieve the appropriate content. Extensive research has been carried out lately to enhance the reusability of learning content by leveraging the semantic web technologies for standardization and semantic annotation of learning content components (Duval et al., 2001; Jovanović et al., 2006). While these efforts have demonstrated some significant potential to improve the current state of the authoring of learning content, there are still some important issues to be addressed. Firstly, ontology-based semantic annotation approaches (Uren et al., 2006) represent a step ahead comparing to the standardized metadata annotation, but the full potential of the semantic search will be achieved when learning content components can be efficiently searched by means of semantic annotations as well as structural and semantic relationships between them. Thus, not only the semantic annotation, but also the framework for linking learning content components and adding logical assertions over linked components is necessary. Secondly, most of the existing learning content is isolated in huge, centralized repositories with restricted access, which is opposite of trends of the emerging Web 2.0 (Berners-Lee et al., 2006). Thirdly, in spite of a number of different learning object (LO) models and LO repositories (e.g., MERLOT) built on top of them as well as federated protocols (e.g., ECL and SQI) for networks of LO repositories (e.g., GLOBE), most authors still consider conventional documents (e.g., PDFs, Word and PowerPoint) as a primary source of learning content. The main issue with conventional documents with respect to the learning content authoring is that only entire documents can be considered as resources that can be uniquely identified, searched and retrieved. In practice, however, authors usually need only document parts that are related to a certain concept and play a certain pedagogical role (e.g., illustration, definition and example) (Jovanović et al., 2006). Common selective reuse of document content is a cumbersome task requiring copy-and-paste, which is a laborious and error prone process. Finally, despite the fact that some authoring tools can provide some collaborative activities, most of conventional authoring tools are designed primarily for individual users and pay little attention to the users' social activities. Social relations between content authors and the way different authors use and interpret the same learning content could be useful information in the content authoring.

The novel semantic document architecture (such as SDArch as explained in the section "Semantic Documents") along with the underlying document representation model called a semantic document model represents our solution

to the above-discussed issues of the learning content authoring. In this paper, our main focus is on the empirical evaluation of the proposed architecture that we conducted by using the architecture prototype that we developed. Having in mind that semantic web technologies and social networking are two pillars of the new architecture, we can consider the conducted evaluation as the evaluation of the use of these two types of technologies in the learning content authoring. So far, the use of semantic web technologies in learning content authoring has been reported in many studies (Duval et al., 2001; Dodero et al., 2005; Jovanović et al., 2006; Henze, 2005), but none of them provided any experimental data that would justify the benefits of using these technologies. In other words, it is still unclear up to what extent the use of these technologies can improve the authors' effectiveness, efficiency and satisfaction compared to conventional learning content authoring approaches. The evaluation that we conducted was designed to compare the authors' *effectiveness*, *efficiency* and *satisfaction* in using the SDArch prototype for authoring of course material compared to conventional authoring tools. Results of quantitative and qualitative measures that we applied in the evaluation showed promising improvements that the use of semantic technologies and social networking brings to the learning content authoring.

The paper is organized as follows. In Section 2, we first describe a motivational authoring scenario that relies on the use of services that are enabled by semantic web and social networking technologies. Subsequently, in Section 3, we introduce the notion of semantic documents and discuss both the semantic document model and the design of the proposed semantic document architecture. Section 4 provides details of the SDArch tools and services that are essential for the realization of the given motivational authoring scenario. In Section 5, we first discuss the design of our evaluation study, then explain how the evaluation study was conducted, and eventually present and discuss obtained evaluation results. Section 7 outlines relevant related works, and Section 8 concludes the paper.

## **Authoring of Course Material – Motivational Scenario**

Let us suppose that Mark is a university professor who teaches 'Software Architecture and Design' course. For each topic in the course Mark usually prepares presentation slides that he uses during his class. The next topic to be presented in the course is 'Software Design Patterns'. Mark has the presentation on this topic from previous year, but he does not want to reuse it as it is. In order to prepare as good presentation as possible, with up to date information, Mark plans to consider the existing presentation, then presentations on the same topic used by his colleagues at other universities, and some other articles related to the topic from his archive as well as those of his colleagues. As usual, Mark is going to use PowerPoint to prepare the presentation, as he is most confident and familiar with it. However, this time his PowerPoint is extended with a set of tools that provide him a range of new, novel services, which we could categorize into four groups.

The first group contains the social networking services that allow Mark and his colleagues who teach the same topic to organize themselves into an online social networking group dedicated to that topic. For all the member the group manages their subjective, self-assessed expertise on the topic as well as objective, quantitative data that shows the members' expertise such as a number of their citations in the topic's related literature and their ratings within the group formed based on the votes of the other members. Moreover, these services provide functionalities for managing Mark's profile and allow him to specify his preferences regarding the automatic selection of document content for reuse. The examples of these preferences include an ordered list of preferred network members, an ordered list of preferred document formats, and information if the user prefers content that is often reused, recently modified content or content with many versions.

The second group contains services that enable Mark to transform his office documents (i.e., Word and PowerPoint) into a novel document representation form that is completely open and queryable and that encapsulates document content into reusable, uniquely identified and semantically annotated data units. Moreover, these services enable Mark to store transformed documents either on his laptop or to publish them onto a shared document repository of the social networking group.

The third group contains services that enable Mark to search local and shared documents for document units not only based on their content but also their semantics (i.e., semantic search). Moreover, these services take into account Mark's preferences stored in his user profile and recommend to him those search results that correspond well with the preferences. Before reusing some document units, Mark can preview their content and browse available annotations. Once he decides which document unit to reuse, he can fetch the document unit automatically into a new

document without a need to obtain a whole document that the document unit originates from. In addition, these services observe Mark's behavior and track the data of his interaction with document units (e.g., times when he browses and reuses document units) and the way he modifies reused document units to fit to a new context.

The fourth and the last group of services provide Mark the ability to navigate across collections of documents stored on his laptop as well as those documents from the social network repository by following explicit semantic links between semantically related document units. The explicit semantic links are enabled by the new document representation form and are established based on the conceptualized semantics of document units.

To summarize, the novel document representation and the envisioned services that will run on top of it will enable Mark and his colleagues:

- to form a social network around a given topic of interest;
- to transform their local documents in a new form that will enable semantic integration (i.e., semantic annotation and linking) of related data kept in different documents;
- to share such transformed documents within the social network, and thus, semantically integrate related document data that originate from different users;
- to semantically search local and shared collections of the semantically integrated documents for desired data; and
- to navigate across local and shared document collections by following semantic links between document units and thus discover more data units of their interest.

## **Semantic Documents**

In order to bring desktop documents closer to the motivational authoring scenario, we introduced a new form of documents, namely semantic documents, described by a *semantic document model (SDM)*, and designed a supporting software architecture called *Semantic Document Architecture (SDArch)*. Semantic documents enable unique identification, semantic annotation, and semantic linking of fine-grained data units regardless of whether they belong to the same or different documents. Moreover, semantic documents enable semantic links to be established between semantically related data units stored on personal desktops and published on the Web into shared repositories of online social network communities. Therefore, semantic documents have potential to integrate data from desktop documents into a unified desktop information space. At the same, semantic documents can fill the gap between the desktop information space and the information space of the online social network communities. Novice processes such as semantic document search and navigation, which will run on such integrated information space, will improve the effectiveness and efficiency of desktop users in carrying out their daily tasks.

In the rest of this section, we first outline the main features of SDM, and then, describe the SDArch design. In the next section, we take a closer look at SDArch tools and underlying services that are essential for the given motivational authoring scenario.

### **Semantic Document Model – SDM**

SDM defines semantic documents as composite information resources composed of uniquely identified, semantically annotated, and semantically interlinked document units (DUs) of different granularity (Nešić, 2009). Each semantic document is characterized by unique, permanent machine-processable (MP) representation and a number of temporal human-readable (HR) representations rendered from the MP representation. The formal specification of SDM is done by the SDM ontology, which consists of four parts: the core part, the annotation part, the semantic-linking part and the change-tracking part.

The core part of the SDM ontology provides a vocabulary (classes and properties), which defines possible types of DUs and structural relationships among them. The two main DU types are atomic DUs and composite DUs. An atomic DU contains a single unit of raw digital content that exists as a physical entity independently of the document unit it belongs to and cannot be disaggregated into smaller units. A composite DU aggregates a number of atomic or other composite DUs and organizes them in a given order.

The annotation part of the SDM ontology provides the annotation vocabulary that describes possible types of the DUs' annotations as well as provides the annotation interface (i.e., properties) for linking annotations to DUs. The annotation interface is designed, so that all DUs' annotations, regardless of the annotation type, are linked to DUs in the same way. The current version of the annotation vocabulary contains concepts and properties that specify the three types of DU annotations: *semantic annotation*, *social-context annotation* and *pedagogical annotation*. The semantic annotations refer to concepts from domain ontologies that represent the conceptualization of the information/knowledge held by DUs. The social-context annotations (Nešić et al., *SoSEA* 2009) capture relevant information about the user actions such as browsing, reusing and modification that are performed to DUs in a given social context. Finally, if semantic documents hold some learning content, then their DUs can be annotated by the pedagogical annotations that we introduced to model potential pedagogical roles (e.g., *abstract*, *introduction*, *conclusion*, *definition*, *explanation*, *description*, *illustration*, *example* and *exercise*) of the DUs.

The semantic-linking part of the SDM ontology defines the interface for linking semantically related DUs. Semantic links are determined by the ontological concepts that conceptualize shared semantics between the linked DUs. The semantic links enable the semantic navigation across integrated collections of semantic documents and thus help in the discovery of semantically related DUs. Together with the semantic annotations, the semantic links constitute the semantic layer of semantic documents.

The change-tracking part of the SDM ontology provides a vocabulary that defines possible changes of DUs as well as changes of the whole semantic document.

Semantic documents, that is, instances of SDM, employ HTTP-dereferenceable URIs to identify DUs and the Resource Description Framework (RDF) data model to represent structural and semantic links between them. The use of the HTTP-dereferenceable URIs and the RDF data model is inline with the Linked Data principles, so that semantic documents can be seamlessly integrated to the Linked Open Data cloud (Berners-Lee et al., 2006) and further to the envisioned Semantic Web. Moreover, the conceptualization of the document semantics by ontological concepts and the establishment of explicit semantic links between related DUs, can lead to the creation of a sufficient amount of semantically integrated data. This creation is necessary for the Semantic Web to succeed.

### **Semantic Document Architecture - SDArch**

In order to support semantic document management and to enable users to take advantage of semantic documents, we designed the supporting software architecture called the semantic document architecture or SDArch. SDArch is a three-tier, service-oriented architecture (see Figure 1) composed of the data layer, the service-oriented middleware, and the user interface layer.

The data layer contains the semantic document repository that is composed of the RDF and the binary data repositories, and equipped with the concept and text indexes. The RDF repository stores RDF instances of semantic documents. A binary content of semantic document units is kept separately from RDF document representations and stored in the binary data repository. SDArch maintains the single concept index that enables the semantic document search over RDF data and the single text index that enables the full-text search over document binary data. Both indexes are updated every time a new document is added to or removed from the repository. In addition, the repository exposes remotely accessible SPARQL endpoint, so that SPARQL queries can also be sent from remote machines over HTTP.

The service-oriented middleware provides the service registry and establishes the communication protocol among the SDArch services and between the SDArch services and the user interface. In the actual design, the SDArch (Nešić et al., *SEKE* 2010) functionalities are encapsulated into five services: 1) the semantic document authoring, 2) the semantic document search and navigation, 3) the user profile management, 4) the social network management, and 5) the ontology management services. Among other functionalities, the SDArch services provide most of the functionalities intended for the realization of the motivational authoring scenario. Potential new functionalities can be added to SDArch by registering new services into the SDArch middleware.

The presentation layer is the top layer of SDArch, which provides the user interface for the SDArch services. According to the service-oriented nature of SDArch, the presentation layer is technology- and platform-independent.

It can contain web-based applications, desktop-based applications and mobile phone applications. In the prototype that we have developed, we focused on extending the existing document-authoring suites, instead of creating completely new tools. In this way, we enable users to take advantage of the SDArch services, while still working within familiar environments. As an example, we extended MS Office with a set of tools that we named 'SemanticDoc' tools. We chose MS Office, mostly because of its wide usage and popularity.

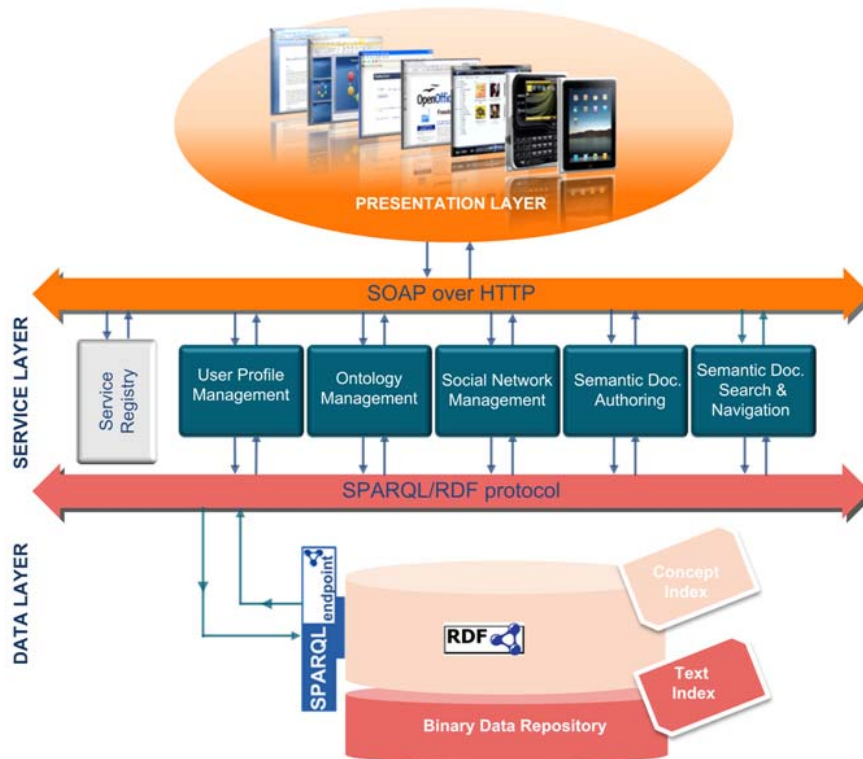


Figure 1. Illustration of the SDArch architecture

## SemanticDoc Tools

SemanticDoc tools enable Microsoft (MS) Office users to take benefits of the SDArch services directly from MS Office (i.e., MS Word and MS PowerPoint). In other words, they provide access to the SDArch services from within MS Office. Since SDArch enables users to share their semantic documents and to form a social network around shared documents, the SemanticDoc tools actually turn MS Office into a social environment.

The tools are grouped and accessible through several toolboxes. Each toolbox contains a set of tools that provide the interface for interacting with a certain group of SDArch services. In this paper, our focus is on the social network manager, the document recommender and the semantic document browser tools, as they are essential for the motivational authoring scenario that we want to evaluate. More information, snapshots and demos of all SemanticDoc tools can be found at our project Web page ([www.semanticdoc.org](http://www.semanticdoc.org)).

## Social Network Manager

The SDArch social network management service provides functionalities for organizing SDArch users into a social network and sharing their semantic documents by publishing the RDF representations of the documents into the network's shared RDF repository. Moreover, the service provides functionalities for capturing interaction between the network members and the shared semantic documents and generating corresponding social-context annotation for the shared semantic documents. SemanticDoc social network manager extends the MS Office with a user interface

that enables the office users to access the SDArch social network management service. By using this tool, the office users can join the SDArch social network, and then, organize themselves within the network into groups dedicated to particular topics of interest. Every member of the SDArch social network can initiate a new group as well as join or leave an existing group. To initiate a new group, the network member needs to specify the group's topic of interest and to provide some topic-related information (e.g., the topic's short description and the list of the topic's Web references). Figure 2 shows a snapshot of the tool displaying: a) a list of all existing groups, and b) group details of a selected group. In the current prototype implementation, there is no restriction for joining existing groups, that is, all groups are available to all members of the SDArch social network.

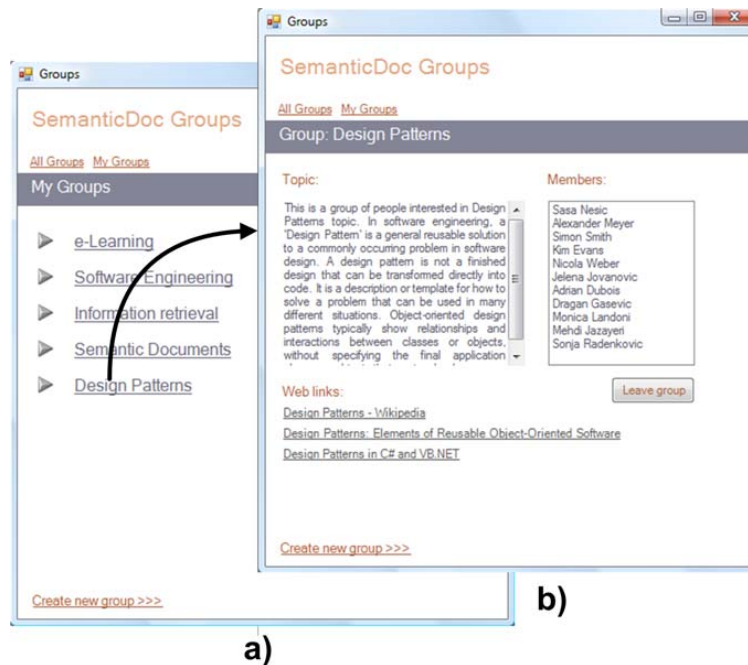


Figure 2. Social network manager: a) a list of existing groups within the SDArch social network, b) a detailed view of a selected group

## Document Recommender

Document recommender tool is a starting point from where the office users start to explore semantic documents whether they are stored in a local desktop repository or in a shared repository of the SDArch social network. This tool actually provides the user interface for the personalized semantic document search (Nešić et al., *SEMAPRO* 2010) that is realized by the SDArch semantic document search and navigation service. The personalized semantic document search is founded on the utilization of the conceptualized DU semantics (i.e., DU semantic annotations), DU social-context annotations, and user preferences held in the SDArch user profile (Nešić et al., *SoSEA* 2009).

The user interface of the document recommender (see Figure 3) enables the office user to specify the following search parameters. Firstly, the user specifies which semantic document repository will be searched (i.e., local or shared). Secondly, the user specifies the user query in a form of the free-text keyword query. The tool offers the auto-completion keyword suggestion support, which helps the user while specifying the query. Suggested terms are concept labels from domain ontologies that have been used for the semantic annotation and indexing of the semantic documents from the specified repository. Thirdly, the user selects the content type of the desired document units (i.e., text, image, audio or video). Fourthly, if searching for learning content, the user specifies a pedagogical role (Jovanovic et al., 2006) of the document units (e.g., definition, example and illustration). Finally, the user specifies the search type: the semantic document search or the full-text search. If the user selects the semantic document search, the keyword query will be transformed into a semantic query and then executed by the service against the concept index of the selected repository. Otherwise, the service executes the initial keyword query against the text index of the repository. When the search is done, the document recommender displays previews of the retrieved document units to the user. Figure 3 gives snapshots of the document recommender displaying: a) the search form

and previews of the top ranked textual document units, and b) the search form and previews of top-ranked document units of image content type. For each of the retrieved document units, the user can see the detailed view including document unit content and document unit annotation data. The detailed view is shown in the semantic document browser, which is another SemanticDoc tool that we explain next.

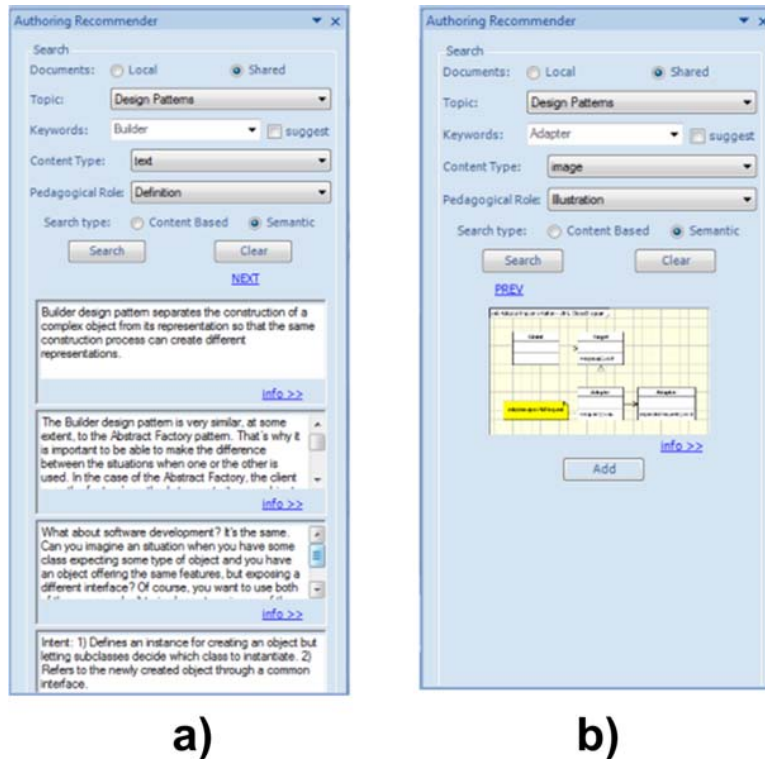


Figure 3. Document Recommender: a) an example search for textual document units, and b) an example search for document units of the image content type

### Semantic Document Browser

The semantic document browser enables the user to browse details of semantic document units and to navigate across semantic documents following semantic links between the document units. In the current implementation, the browser is launched from the document recommender by clicking on previews of DUs retrieved as search results. For the next generation of the tool, we plan to enable its individual launching and the possibility to start the semantic navigation not only from the search results, but also by entering the URI of an initial document unit.

The main window of the semantic document browser (see Figure 4) is composed of two panels. The right panel displays the document unit's content, metadata (e.g., creator and creation date), and social-context annotations (e.g., the number of the document unit's reuses and the list of SDArch users who have reused the document unit). The left panel displays the document unit's semantic annotations in a form of an ordered list of ontological concepts that annotate the document unit. For each annotation concept, the user can see the concept's rank, the concept's relevance weight for the document unit, and the ontology in which the concept is defined. Moreover, for each annotation concept if there exist some document units that are linked to the document unit via semantic links determined by that concept, the browser displays the link labeled as 'browse annotated document units'. By clicking on this link, the browser invokes the SDArch semantic document search and navigation service and initiates the semantic document navigation process. The discovered document units are ordered by the strength of the semantic links between them and the initial document unit and displayed on the right panel of the browser's window.



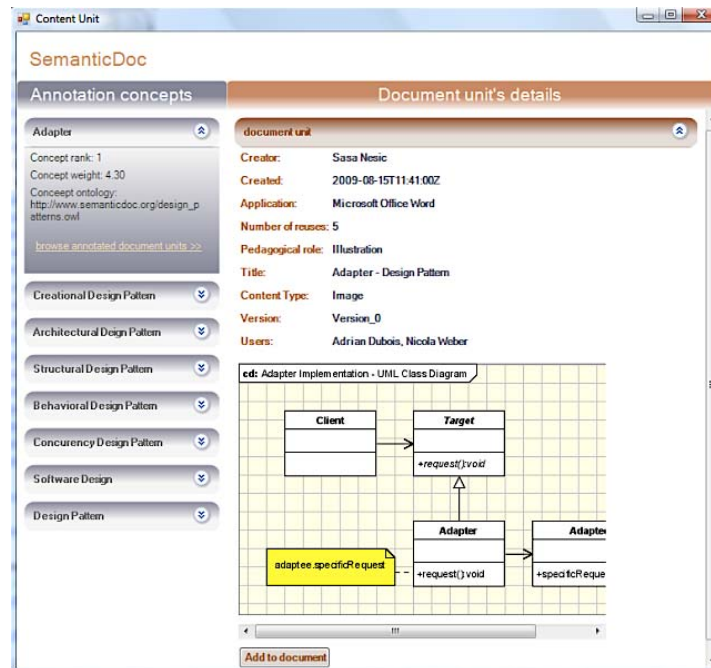


Figure 4. Semantic document browser

## Empirical Evaluation of the Proposed Authoring Scenario

The goal of the empirical evaluation of the proposed authoring scenario was to investigate to which extent the authoring of course material can benefit from the proposed semantic document architecture and the underlying semantic document model. Since semantic web technologies and social networking represent two pillars of the architecture, potential benefits naturally extend to them. We formulated the evaluation hypothesis as follows:

“Using semantic web technologies and social networking results in a more **effective**, **efficient**, and **satisfactory** experience, when authoring course material compared to the conventional authoring approach.”

- With respect to user **effectiveness**, we intended to measure the accuracy and completeness with which SDArch users complete authoring tasks. In other words, how many and what tasks the users can complete successfully using the SDArch services and tools.
- With respect to user **efficiency**, we intended to measure the resources expended in relation to the accuracy and completeness with which SDArch users complete the authoring tasks. In other words, how much effort the users spend for completing these tasks using the SDArch services and tools.
- With respect to user **satisfaction**, we intended to measure the freedom from discomfort, and positive attitudes towards the use of the SDArch services and tools in authoring of course material.

## Designing the Evaluation

In order to validate the evaluation hypothesis, we chose a task-based comparative evaluation (Whittaker et al., 2000) complemented with the goal-question-metrics (GQM) measurement model (Bastili et al., 1994). This implies asking test persons to perform a set of tasks in order to properly engage with two systems to be compared. In our case, one system was a conventional Windows system equipped by regular MS Office, while the other one was a Windows system featured by SDArch services and MS Office extended by the SemanticDoc tools. In the rest of the paper, we refer to these two systems as the conventional system and the SDArch system, respectively.



The set of tasks that we considered in the evaluation was composed of tasks that realize the motivational authoring scenario. It actually meant that a successful completion of the tasks should have resulted in a short PowerPoint presentation on the ‘Software Design Patterns’ topic that is composed exclusively of reused content from shared semantic documents. By considering the authors’ experience in preparing course material and in order to obtain both meaningful and feasible proof of concept we decided to keep the outcome presentation to a minimum of seven slides covering: 1) *Introduction*, 2) *Role of Design Patterns*, 3) *Design Patterns Definition*, 4) *Design Patterns Classification*, 5) *Pattern Example 1*, 6) *Pattern Example 2*, and 7) *Topic’s Conclusions*. This limited the amount of efforts required from the participants while at the same time producing an overall presentation of an appropriate quality level. All slides had to contain certain numbers of textual items and slides 5 and 6 should have also contained graphical illustrations of the chosen example patterns. Even if this sounds pretty restrictive, the aim was to set up a controlled environment where comparing effectively experiences across the new and conventional system for producing presentations, while still encouraging participants to use their creativity and expressivity.

In accordance with the evaluation hypothesis and by following the GQM model, we considered *user effectiveness*, *efficiency* and *satisfaction* as main evaluation criteria and defined qualitative and quantitative measures for them. With respect to user effectiveness, we planned to measure how effective participants were in completing the evaluation tasks. Thus, we tracked how many and which tasks participants could complete successfully by using the two systems. With respect to user efficiency, we planned to measure how efficiently participants were in completing the evaluation task. Thus, we measured the execution time, the number of mouse clicks and the number of window switches. Finally, with respect to user satisfaction, we planned to evaluate which of the compared two systems the participants liked more and why. For this purpose, we used a follow-up questionnaire that we created by selecting a subset of questions/statements from the Perceived Usefulness and Ease of Use questionnaire (Davis, 1989) that was appropriate for our evaluation. We expected participants to implicitly and naturally refer to their previous experiences in using the conventional system when considering the performance of the SDArch system. Nonetheless, we set up a more formal comparative experiment making all participants engaged with the same documents and tasks via the two systems. This way we could extract a richer set of data to be compared in order to address our hypothesis and related research questions in terms of evaluation criteria. Table 1 summarizes the chosen evaluation methods and metrics for each of the three considered evaluation criteria.

The initial step of an empirical evaluation is the selection and recruitment of participants, whose background and abilities are representative of intended users of the system to be evaluated (Nielsen, 1993). The evaluation results will only be valid if the participants are typical users of the system, or as close to that criterion as possible. Another issue regarding the selection of the participants, which has attracted a lot of attention in the HCI community, is what should be a sufficient number of participants of the usability study. In terms of quality, Nielsen (Nielsen et al., 2003) argues that five expert users are sufficient to discover 85% of the usability problems in a system under evaluation. In our evaluation, we had six participants from three universities: University of Lugano ([www.usi.ch](http://www.usi.ch)), Switzerland; Simon Fraser University ([www.sfu.ca](http://www.sfu.ca)), Canada; and University of Belgrade ([www.bg.ac.rs](http://www.bg.ac.rs)), Serbia. All the participants were volunteers and had genuine motivation in using the new systems. Moreover, each participant had been involved in some courses covering the topic of our evaluation scenario, either as a lecturer or teaching assistant. Thus, they qualified as domain experts and final users of the system.

Table 1. Evaluation criteria and the corresponding evaluation methods and metrics

Evaluation Criterion	Evaluation Method	Evaluation Metric
Effectiveness	Objective – Quantitative Measure	Task Success Rates
Efficiency	Objective – Quantitative Measure “ “	Task Completion Times Number of Mouse Clicks Number of Window Switches
Satisfaction		5-level Likert scale

## Conducting the Evaluation

We started the evaluation by the preparation phase whose main objectives were to create SDArch social network, to collect the evaluation document set, and to familiarize the participants with the SDArch services and tools. First, we initiated the SDArch social network by using the social network manager tool and created a *software design patterns* interest group. Then, we transformed initial 20 documents from our archive into semantic documents and added them

to the group's shared semantic document repository. After that, we invited the participants to register to the SDArch social network and to join the group. Moreover, we asked the participants to check if they had some Office (i.e., Word and PowerPoint) documents related to the software design patterns topic in their archives, and if so to transform and publish some of them to the group's semantic document repository. For the documents transformation (i.e., semantic annotation) process, all the participants were required to apply the same domain ontology, which we added to the group's ontology repository. In addition, we created a simple web-based file upload form application and asked the participants to upload the original office documents that they transformed and published to the shared repository. In that way, we also obtained the original MS Office documents, which we needed for the tasks executions with the conventional system. One week after we initiated the software design patterns group, the total number of the shared semantic documents reached 50 documents. According to our experience in preparing course material, it was a sufficient number of documents that we planned to consider in the evaluation. Therefore, we decided to organize the evaluation session and conduct the evaluation tasks.

The evaluation session consisted of two phases, namely the *observation* and *feedback* phases. In the observation phase, we were observing the participants while they were conducting the evaluation tasks and tracked their behavior by using an appropriate screen-recording software ([www.techsmith.com/camtasia.asp](http://www.techsmith.com/camtasia.asp)). To avoid asking the participants to install the screen recording software and to simplify the manipulation of the recorded materials, we asked the participants to perform the evaluation tasks on our PC with remote access control. For all the participants we created accounts on the PC and enabled them to access and control it remotely. In that way the only software that the participants needed to install/enable on their computers was a remote desktop connection software. This kind of software is supported as an official feature on all new-generation, Windows operating systems (e.g., Windows XP/Vista/7), so that the participants using Windows only needed to enable it, unless they had used it before. Four out of six participants already had the software installed on their laptops and were familiar with it, while the other two did not experience and report any difficulties in using it.

The participants were split into two control groups of three participants. The first group was asked to execute the tasks first by using the conventional system and then using the SDArch system. The second group used the compared systems in the opposite order. Each participant was allowed to do the evaluation tasks within two given days at the time he preferred, but in two separate, continuous time sessions one for the conventional system and the other one for the SDArch system. The sessions started and ended by the participants activating and deactivating the screen recording software.

The observation phase was followed by the feedback phase, where we asked the participants to fill in the follow-up questionnaire. The questionnaire was composed of the following nine statements:

- S1: Using the SDArch services and SemanticDoc tools enables me to accomplish tasks more quickly;
- S2: Using the SDArch services and SemanticDoc tools increases my productivity;
- S3: Using the SDArch services and SemanticDoc tools improves the quality of the work I do;
- S4: Using the SDArch services and SemanticDoc tools makes it easier to do my work;
- S5: Overall, I find the SDArch services and SemanticDoc tools useful in my work;
- S6: Learning to operate the SDArch services and SemanticDoc tools is easy for me;
- S7: I find it easy to get the SDArch services and SemanticDoc tools to do what I want them to do;
- S8: Interaction with the SDArch services and SemanticDoc tools is clear and understandable;
- S9: Overall, I find the SDArch services and SemanticDoc tools easy to use.

The participants were supposed to rate each of the statements using 5-level Likert scale (Gediga et al., 1999), starting from 1 (strongly disagree) to 5 (strongly agree). First 5 statements from (S1-S5) were designed to gather subjective evaluation of the system usefulness. Statement S6 evaluated the system ease-of-learning. Statements S7-S9 were designed to gather subjective evaluation of the ease-of-use of the system.

## Evaluation Results

By analyzing the data recorded during the observation phase, we gather indications about user effectiveness and user efficiency. With respect to user effectiveness, we tracked how many and which tasks participants completed successfully. All participants completed successfully all tasks, using both systems. In our opinion, this result is

mostly due to time-unlimited sessions and the ability of the participants to set the evaluation sessions at preferable time as well as their genuine motivation to participate in the evaluation.

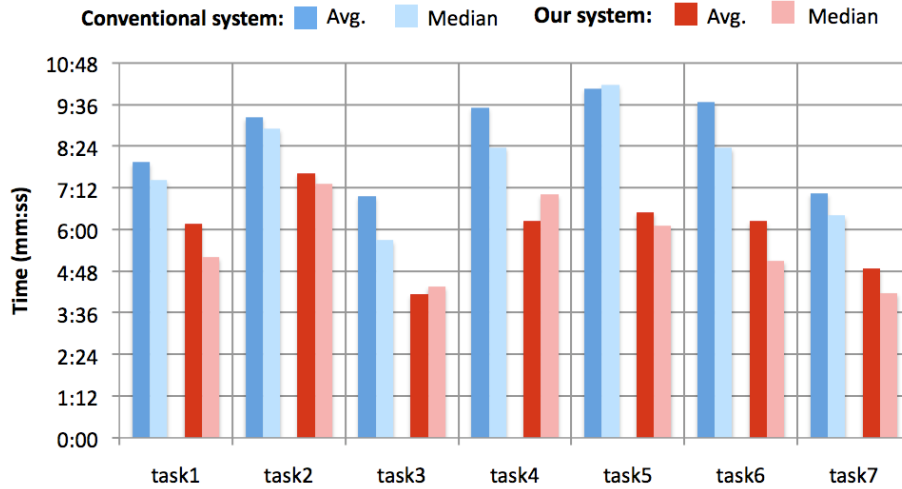


Figure 5. Average and median task completion times

With respect to user efficiency we measured the task completion times, the amount of mouse clicks and the number of window switches during the tasks executions. Table 2 and Figure 5 show the average and median task execution times of all seven considered tasks for the two compared systems. Moreover, Table 2 reports standard deviation of the task completion times for both systems, the relative performance of the participants when using the SDArch system with respect to the conventional system. For example, the relative performance of 70% indicates that the participants using the SDArch system needed 70% of the time that the participants using the conventional system needed. Finally, we performed a *t-test* (Zimmerman, 1997) to investigate on the statistical significance of the difference in the task completion times between two control groups (i.e., the participants using the SDArch system and the participants using conventional system). The results of the *t-test* (i.e., *p-values*) are shown in the last column of the table. In our case, *p-values* represent the probability that the measured task completion times for the two control groups are part of the same distribution. In general, *p-values* below 0.05 are considered statistically significant. In other words, *p-values* of 0.05 or greater indicate that there is no statistically significant difference between the results of two control groups.

Table 2. Tasks completion times' statistics

Task	Conventional System			SDArch System			Relative Performance		t-test p(T<=t)
	Avg.	Median		Avg.	Median		Avg.	Median	
1	7:56	7:25	0:52	6:10	5:12	1:56	77.7%	70.1%	0.0031
2	9:14	8:54	0:32	7:37	7:19	0:48	82.5%	82.2%	0.0022
3	6:58	5:41	1:23	4:08	4:21	1:02	59.3%	76.5%	0.0045
4	9:31	8:22	1:07	6:14	7:00	1:12	65.5%	83.7%	0.0007
5	10:04	10:10	0:34	6:30	6:06	0:32	64.6%	60.0%	0.0027
6	9:41	8:21	1:14	6:15	5:06	0:33	64.5%	61.1%	0.0004
7	7:03	6:24	0:39	4:52	4:10	1:27	69.0%	65.1%	0.0014

The measured times reported in Table 2 show that for each of the considered tasks, the participants needed less time by using the SDArch system than the conventional one. The values of the relative user performance with respect to the average task completion time range from 59.3% to 77.7%. Moreover, calculated *p-values* for all tasks were statistically significant (i.e., < 0.05), which actually means that by using the SDArch system the participants needed significantly less time than by using the conventional system for all tasks.

Tables 3 and 4 show the same descriptive statistics for the number of mouse clicks and the number of window switches, respectively. For both of these metrics, regarding all the tasks, the relative performance of the participants when using the SDArch system with respect to the conventional system was less than 100%. In other words, the

participants performed less mouse clicks and window switches by using the SDArch system than by using the conventional one, regarding all considered tasks. In particular, a number of window switches for each task was significantly (more than two times) less with the SDArch system. Finally, *t-test* revealed that the difference between the results of the two control groups regarding the applied evaluation metrics is also statistically significant (*p-values* of all the tasks for both metrics are less than 0.05).

Table 3. Mouse clicks statistics

Task	Conventional System			SDArch System			Relative Performance		t-Test p(T<=t)
	Avg.	Median	$\sigma$	Avg.	Median	$\sigma$	Avg.	Median	
1	124.3	107	14.23	108.3	93	15.32	87.1%	86.9%	0.0003
2	137.2	118	15.31	109.2	102	9.30	79.6%	86.4%	0.0048
3	128.4	122	11.42	96.7	84	8.42	75.3%	68.8%	0.0001
4	141.9	124	19.21	112.0	104	11.52	78.9%	83.8%	0.0023
5	152.0	133	16.73	77.7	71	7.32	51.1%	53.3%	0.0022
6	144.6	136	10.82	82.6	77	6.80	57.1%	56.6%	0.0007
7	122.5	109	18.34	98.5	94	5.32	80.4%	86.2%	0.0026

The measured task completion times (Table 2), numbers of mouse clicks (Table 3) and numbers of window switches (Table 4) indicate that the user efficiency when using the SDArch system outperforms from the user efficiency when using the conventional system, with respect to these three applied evaluation metrics.

Table 4. Window switches statistics

Task	Conventional System			SDArch System			Relative Performance		t-test p(T<=t)
	Avg.	Median	$\sigma$	Avg.	Median	$\sigma$	Median	Avg.	
1	20.4	12	7.04	4.4	4	1.45	33.3%	21.5%	0.0041
2	17.3	15	3.22	6.2	4	1.82	26.6%	35.8%	0.0032
3	21.6	17	4.54	5.2	5	1.37	29.4%	24.0%	0.0009
4	23.2	18	5.21	6.6	5	2.32	27.7%	28.4%	0.0015
5	21.8	19	3.18	5.6	4	2.41	21.0%	25.6%	0.0023
6	22.4	19	3.71	6.3	5	1.62	26.3%	28.1%	0.0042
7	18.5	14	5.57	4.0	4	0.82	28.5%	21.6%	0.0028

The user satisfaction was the third evaluation criterion, besides the user effectiveness and efficiency, which we considered in the SDArch evaluation. The participants provided us their subjective feedback about the following user satisfaction dimensions: the system usefulness (S1-S5), ease-of-learning (S6) and ease-of-use (S7-S9). Table 4 shows average and median rating for all the nine statements. As all statements had been formulated as positive, the same rating value has the same interpretation for each of them. Statements S5 and S9, which express the overall satisfaction regarding the usefulness and ease-of-use respectively, were the two best-rated statements with an average rating of 4.8. The other statements were also rated as highly positive with average ratings ranging from 4.1 to 4.7.

Table 5. Subjective user feedback for the SDArch system

Statement	S1	S2	S3	S4	S5	S6	S7	S8	S9
Average	4.7	4.3	4.1	4.7	4.8	4.7	4.3	4.6	4.8
Median	5	4	4	5	5	4	4	4	5

## Related Work

Extensive research has been carried out lately on the application of semantic web technologies to different aspects of the learning content authoring. There are numerous approaches such as (Duval et al., 2001) that attempt to semantically annotate learning content at different levels of granularity in order to make it easily discoverable and reusable. However, in most of these approaches, the semantic annotations of the leaning contents are stored in huge centralized repositories, which is contrary to the trends of the emerging Web of interlinked data (Berners-Lee et al., 2006). Two major problems with the centralized learning content repositories are the problem of restricted access and the weak integration with most frequently used authoring suites (e.g., MS Word and PowerPoint). There is still a

big lack of tools that would enable content authors to connect and search the existing learning content repositories directly from within the authoring suites. Besides semantic annotation and search, there are approaches (Dodero et al., 2005) that try to make use of ontologies and the semantic web protocols into collaborative authoring of learning content. Finally, there are approaches (Jovanović et al., 2006; Henze, 2005) that apply semantic web technologies to support dynamic assembly and personalization of learning content.

The use of social networking in e-learning has also started to attract a lot of attention recently. Terry Anderson has introduced the concept of 'educational social software', which he defines as networked tools that support and encourage individuals to learn together while retaining individual control over their time, space, presence, activity, identity and relationship (Anderson, 2005). The social networking tools have started to be applied to different aspects of the e-learning process. They are used to support a social constructivist approach to e-learning (Friensen et al., 2004), or more specifically, to support self-governed, problem-based and collaborative activities (Gillet et al., 2008). Moreover, the social networking has found its place in forming "optimal" student groups (Ounnas et al., 2008), thus helping teachers allocate students to groups based on a set of constraints. The use of social networking in e-learning has also initiated discussion about the extent to which social tools should be separated or integrated in learning management systems (LMS) (Gillet et al., 2005). Recent trends have showed moving e-learning beyond centralized and integrated LMS towards a variety of separate tools, which are used and managed by the students in relation to their self-governed work (Klamma et al., 2006).

In spite of the fact that semantic web technologies and social networking have already been applied to many aspects of e-learning, a full synergy of these two initiatives in the context of e-learning still needs to happen. To what extent e-learning and the learning content authoring can benefit from this synergy has to be answered through appropriate empirical studies. We believe that the empirical study that we conducted with SDArch represents a step in the right direction.

## Conclusions

Although the use of semantic web technologies and social networking in the authoring of learning content has been studied extensively over recent years, the real benefit they brought to the authoring process is still unclear. Up to what extent these innovative technologies can improve the effectiveness and efficiency of authors in carrying out authoring tasks is a question that still seeks an answer. In our opinion, the right answer to this question can be obtained through an empirical study conducted with an authoring system that is featured by these technologies. In this paper, we presented the results of one such empirical study that we conducted to investigate the benefits of the novel, semantic document architecture (SDArch) with respect to the authoring of the course material. Since semantic web technologies and social networking are two pillars of SDArch, the benefits of SDArch naturally extend to them. Based on objective, quantitative measures of user effectiveness and efficiency, and the users' subjective feedback, we found that the use of semantic web technologies and social networking results in improvements of the authoring of the course material compared to the conventional authoring approach. In the future work, we plan to perform a new, long-term evaluation study with more participants and a larger document collection. We also plan to consider the application of some other evaluation metrics, in addition to those applied in this study, as well as to provide more comprehensive statistical analysis of collected data.

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