The Social Semantic Server: A Flexible Framework to Support Informal Learning at the Workplace

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ABSTRACT

Informal learning at the workplace includes a multitude of processes. Respective activities can be categorized into multiple perspectives on informal learning, such as reflection, sensemaking, help seeking and maturing of collective knowledge. Each perspective raises requirements with respect to the technical support, this is why an integrated solution relying on social, adaptive and semantic technologies is needed. In this paper, we present the Social Semantic Server, an extensible, open-source application server that equips client-side tools with services to support and scale informal learning at the workplace. More specifically, the Social Semantic Server semantically enriches social data that is created at the workplace in the context of user-to-user or user-artifact interactions. This enriched data can then in turn be exploited in informal learning scenarios to, e.g., foster help seeking by recommending collaborators, resources, or experts. Following the design-based research paradigm, the Social Semantic Server has been implemented based on design principles, which were derived from theories such as Distributed Cognition and Meaning Making. We illustrate the applicability and efficacy of the Social Semantic Server in the light of three real-world applications that have been developed using its social semantic services. Furthermore, we report preliminary results of two user studies that have been carried out recently.

Categories and Subject Descriptors

H.2.8 [**Database Management**]: Database Applications—*Data mining*

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Keywords

social semantic server; informal learning; workplace learning; technology enhanced learning; distributed cognition; meaning making; service-oriented architecture

1. INTRODUCTION

Informal learning at the workplace typically accompanies everyday's work processes and tasks [14]. This kind of learning is highly individualized and related to the current problem or challenge the worker is faced with and deeply bound to the respective work context. Hence, informal learning happens on demand, in a specific context and has an episodic and informal character [19, 11].

Ley et al. [24] argue that informal workplace learning processes can be categorized into various perspectives, such as task performance, reflection and sense making, help seeking, guidance and support, and emergence and maturing of collective knowledge. For example, help seeking may take place through discussions with the aim to reach a collaborative solution or by means of learning from a colleague's prior experience who has a certain level of expertise [31] during one-to-one trainings. Hence, informal learning potentially requires a great deal of communication and the transfer of skills and experiences from more experienced workers to less experienced ones [14]. Since it often involves other persons, it leads to a social context [25].

While its individual, context-bound nature makes it highly effective and motivating [15], on the contrary, informal learning at the workplace and its usual one-to-one training brings benefit to only a handful of workers. This hinders scaling of informal learning at the workplace, and that is why suitable tools are needed to fill this gap.

Available learning technologies yet often follow formal training models that are based on teacher-centered teaching in classrooms or courses. Simply transferring these approaches to the screen does not lead to the desired outcome as it is based on a fixed curriculum and not adaptable to the current situation and context, which is needed to support informal workplace learning [24].

We propose the Social Semantic Server (SSS) [20] and its service orchestration as a technical mean to combine social, adaptive and semantic technologies to support informal workplace learning. Our aim is to enable individual and collaborative informal learning processes in distributed systems. By storing and exploiting learning traces and interactions between users and tools in the SSS, it is possible to create a large-scale social semantic knowledge repository that can easily be extended and used to scaffold informal learning. The SSS has been applied and extended in the course of the FP7 European project Learning Layers[1] using extensive design studies in informal workplace learning scenarios [24].

The remainder of this paper is organized as follows: in Section 2, we shortly describe the theory behind the main concepts of the Social Semantic Server and we list the design principles the Social Semantic Server is based on (see 2.2). In Section 3, we describe the technical implementation of the Social Semantic Server, its software architecture and we report on the services that are currently implemented. Section 4 describes three real-world applications that have been built based on the Social Semantic Server. Finally, Section 5 reports on related work and Section 6 concludes this paper and outlines future work.

2. SYSTEM DESIGN

In this section we describe the theoretical considerations and design principles that build the basis for the development of the architecture and the services of the SSS.

2.1 Theory

Several theories from the field of computer-supported collaborative learning assume that individual knowledge is constructed through collaborative knowledge building (e.g., [8, 7, 28, 29]). Vice versa, that means a knowledge base is coconstructed by a community of learners as a result of their activities mediated by shared artefacts.

For example, a worker uploads an annotated video explaining the use of a certain tool to a repository and shares it with colleagues. Later on, others may watch the video to learn about the tool's right usage, enrich or correct the annotations to help in their own tasks and forward it to support colleagues with the same need. The annotated video becomes a shared artefact, which helps scaling informal workplace learning as it makes informally acquired experiences available for others.

In this work, we build on a long-standing line of research and take the distributed system of agents interacting through shared artefacts as the unit of analysis (Distributed Cognition - DC, see [17, 16]). This is why the community of learners is considered as a distributed cognitive system [18]. We take the view that the interaction of actors and artefacts span a network of meaning (Actor Network Theory [23]), where both take an active role to reify particular interpretations that in turn influence the interpretation of other actors. This process of socially constructing meaning in a distributed cognitive system is called meaning making [28]. It depicts individual learning within the socially distributed context and leads to the composition of interrelated reifications of meaning [29].

One important variable in this process is shared understanding, because communication and collaboration via or scaffolding of shared artefacts, through e.g., recommendations, can only be effective if it is based on a minimal shared understanding, i.e., a common ground, within the community of learners (see [5, 26, 9]). That is, a shared mental representation of tasks, equipment, work relationships, situations and concepts is required. For example, an annotated video can only be an effective learning tool if it has grown to include a minimum level of shared understanding among the colleagues using it. This shared understanding can be deepened during artefact-mediated communication [2, 6].

In this sense, actors, artefacts, interpretations and their reifications co-evolve in a constant dynamic process of meaning making. We deal with these meaning making processes that result from artefact-mediated activity by developing a framework and services that make available a network composed of learners and their shared artefacts. The network is built by capturing how these artefacts are used in workplace activity. Services, which create and build upon this network, then expose particular structural aspects of that network in the learning context.

2.2 Design Principles

From the theoretical considerations described in the last section on Distributed Cognition and Meaning Making (see [17, 16]), we derive theoretical claims and, based on them, propose Design Principles (DP) for the SSS. Hence, each theoretical claim is translated into one or more DP, which is then the basis for the framework and services of the SSS (see Section 3).

According to Wang and Hannafin [30], DP represent generalized knowledge in the format of heuristic statements. Following Bell et al. [3], DP can be based on findings of multiple research results and more specific to supporting direct action. Our DP guide direct action in terms of implementation and take the role as intermediary objects between conceptual and technical researchers. Hence, the following DP that have been inferred from the theoretical claims should be fulfilled via the SSS in order to support informal learning at the workplace:

Claim 1: Persons interact in a small group or the whole community of learners via shared artefacts.

DP01 The SSS should establish a hybrid network of persons and artefacts built up by the interactions of persons and artefacts.

DP02 The SSS should create and infer groups of users to let learners interact in trusted learning settings.

DP03 The SSS should remove possible inherent boundaries from existing tools.

Claim 2: The situational context in which knowledge construction and application takes place is important both for individual learning as well as for establishing shared understanding.

DP04 The SSS should track the physical, time, social and semantic context in which interactions have taken place.

DP05 The SSS should provide cues/recommendations (e.g., tags, artefacts, etc.) to remind users of the context in which an interaction has taken place.

Claim 3: People (interpretation) and artefacts influence each other in a dynamic process of coordination of representational states.

DP06 The SSS should make persons aware of collaborators' interpretations via services.

[1]http://learning-layers.eu

DP07 The SSS should allow persons to express their interpretations that lead to manifestations in artefacts via services (e.g., discussion, tagging).

Claim 4: Cognition represents a "cultural process" that allows access to the history of the translations between artefactual, internal and physical structure.

DP08 The SSS should track the history of network interactions and can store different states of that network.

Claim 5: Internal, digital and physical environment is connected so that there is a constant exchange between internal and external structures.

DP09 The SSS should represent different knowledge structures in different levels of maturity.

DP10 The SSS should support different formality levels of metadata.

3. SYSTEM IMPLEMENTATION

In this section, we give a technical overview of the SSS including its software architecture and services. The SSS is open-source software and is freely-available for scientific purposes from our GitHub repository[2].

Currently, the SSS is applied and extended in the context of FP7 European project Learning Layers as backend solution for all tools that have been developed in the frame of the project. While our aim is to support informal learning at the workplace in general, in Learning Layers the specific focus is on supporting workers from healthcare as well as construction in their daily informal learning tasks. In the following, we therefore relate to exactly these two application domains.

3.1 Software Architecture

The SSS is implemented in Java and follows a service-based approach to gain benefits from service-oriented architecture (SOA) design, i.e.: loose coupling, abstraction, reusability, autonomy, statelessness, and composability [12]. This is achieved by dividing the functionalities of the SSS into fine granular services that can be easily maintained, tested, reused and combined to new and more complex functionalities. As such, providing new functionalities or extending existing implementations is fostered by the light-weight service layout shown in Figure 1.

The Service Registry keeps references to self-registering Service Containers, which represent access points to concrete Service Implementations. Thus, the Service Registry provokes Service Containers to instantiate corresponding Service Implementations either upon incoming client-side requests from the REST API or upon server-side invocations of particular functionality needed in other Service Implementations. The Service Registry decides whether a service request can be handled by one of the services up running. As each Service Implementation has to consider client-side oriented functionalities as well as server-side duties hidden from client access, the Service Interfaces are split in corresponding client- and server-side parts. Additionally, Service Implementations foster overarching execution of functionality (possibly involving many different services) by implementing from common interfaces available in the service infrastructure.

For convenience, the SSS service architecture set up, provides interfaces and abstract classes respectively to ease the implementation of Service Containers, Implementations, Input and Output parameters (i.e., Datatypes) and Configurations. As shown in Figure 1, the SSS uses a hybrid approach to persist its entities and relations, namely uses both a SQL engine (i.e., MySQL) and a key-value store (i.e., Apache Solr) for querying and updating respective networks created from instances of users, artefacts and their relations. Therefore, each Service Implementation is equipped with references to both Service Implementations representing storage engines and Data Access Functions to reuse common database access utilities for convenient querying and updating of information from within the network. Additionally, External Datasources (e.g., Evernote[3]) can be plugged in, to incorporate external data in the corpus of information available via services.

3.2 Services

The services that are currently implemented in the SSS can be organized into eight main categories. A mapping of this service categories to the Design Principles introduced in Section 2.2 can be found in Table 3.2.

Metadata. The SSS provides a set of contextual metadata services. More specifically, we distinguish between three different degrees of formality of metadata: (i) formal metadata (e.g., location, time, domains of interest, etc.) defined by system designers, (ii) domain specific metadata (e.g., coming from a domain ontology) defined by domain experts, and (iii) user provided metadata (e.g., tags) from which emergent metadata can be extracted (e.g., by topic modeling). As such, it is possible to use, e.g., certain flags, categories or ratings to characterize entities within the network with social features and e.g., capture the context of their generation of a certain video or the situation a worker is in. Moreover, the categorization of entities with predefined vocabularies was made possible besides manipulating certain kind of metadata to respect and reflect the socially constructed and accepted meaning of a community in the applications based on the SSS.

Activity. The SSS provides functionality to trace users' interactions (with digital artefacts) as well as to explicitly generate user activities. The availability of such activity functionality enables to retrieve more detailed information about meaning making processes and respective events in the learning system and thus, provides means to reveal hidden relations / knowledge from usage, which can be reflected in an activity stream. Based on this, increased awareness of changes in the system is achieved and users can easily keep up to date on recent topics, history and advances of making generation of collaborators and possibly interesting learning resources.

Search. Search is an important instrument to support contextualized learning since respective services are typically used in situations where the user exactly knows what she is looking for. The SSS gives users the possibility to perform full-text searches based on metadata (i.e., tags, title, description, flags, ratings, etc.) or the content of the entities (e.g., learning resources). Content-based search is implemented using Apache Solr[4].

Recommendations. The SSS provides several recommender services to suggest contextual metadata and entities based on user-resource interactions and semantic-, so-

[2]https://github.com/learning-layers/SocialSemanticServer

[3]http://www.evernote.com

[4]http://lucene.apache.org/solr/

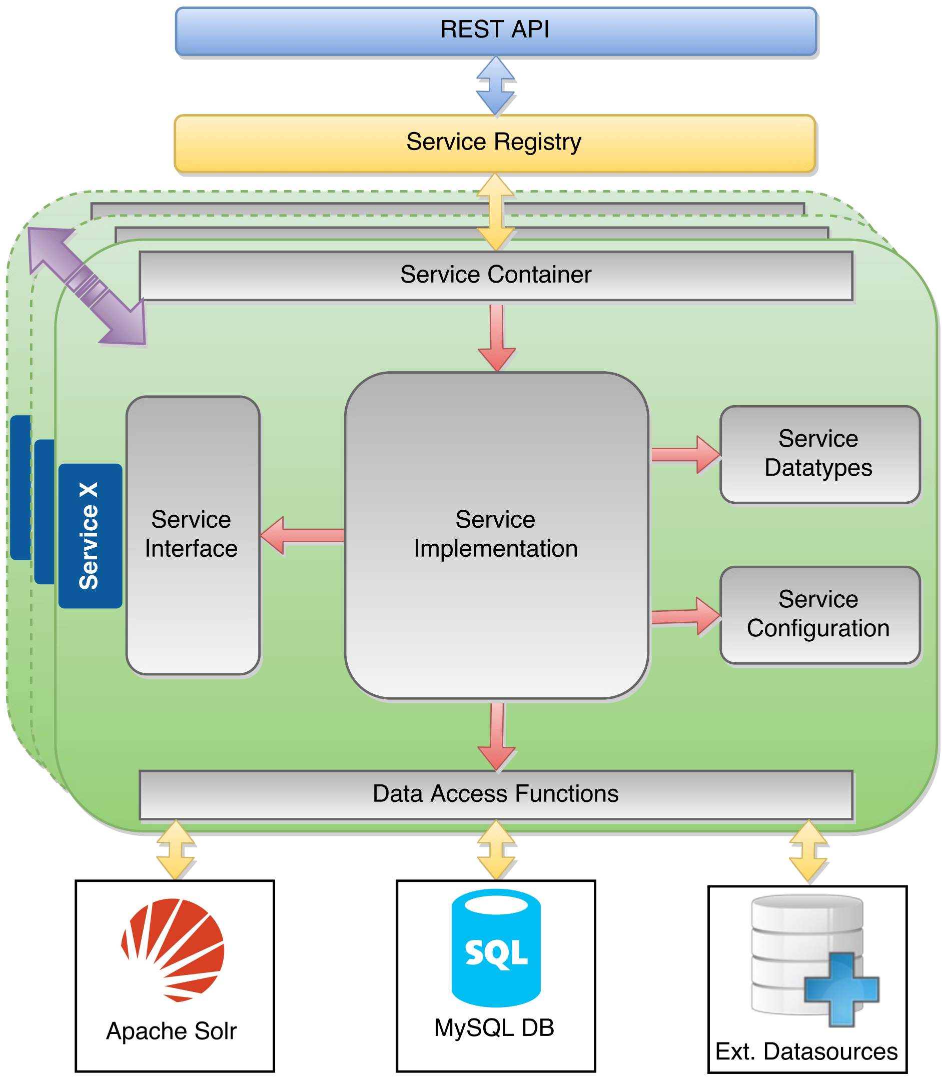

Figure 1: The software architecture of the SSS with services as the main component.

cial network- and location-based data. In contrast to search services, recommendation services directly bring resources to the users based on their previous interactions in the system. Recommendation services are typically used to help discover resources users might not have found by themselves and therefore, they are also important to support contextualized learning. The SSS makes use of our Java-based open-source framework TagRec[5] [21] for calculating these recommendations (e.g., based on our time-dependent and cognitive-inspired tag recommender algorithm presented in [22]).

Gardening Knowledge Structures. In terms of services for the gardening of knowledge structures, the SSS includes tag recommendations and topic modeling services based on Latent Dirichlet Allocation (LDA). LDA is a generative probabilistic model in which documents are represented as random mixtures over latent topics, and each topic is characterized by a distribution over words, in our case tags [4]. This way, a group of collaborators or the whole community can be supported in arriving at a shared vocabulary, reflecting the shared understanding necessary for fruitful further collaboration.

Discussion / Q&A. The SSS contains discussion functionalities including a sophisticated Question and Answer (Q&A) paradigm to enable interacting users to find help in a multimedia Q&A forum. In this forum, (multimedia) artefacts, community features such as groups or commenting possibilities enable and improve the negotiation of meaning via text and multimedia artifacts and their ranking to arrive at a shared understanding.

Group / Access Restriction. Sharing functionalities on top of group functionalities are implemented in the SSS in order to support fine-grained access restriction for learners requesting and sharing information. Hence, users are able to share artefacts with individual users directly or post them to groups of two or more persons. The group / access restriction services enable users to join communities of interest as well as to collaboratively work on shared artefacts and en-

[5]https://github.com/learning-layers/TagRec/

Services	Design Principles
Metadata	DP07, DP10
Activity	DP03, DP04, DP08
Search	DP03, DP05, DP06
Recommendations	DP04, DP05, DP06
Gardening Knowledge Structures	DP07, DP08, DP09, DP10
Discussion / Q&A	DP01, DP06, DP07
Group / Access Restriction	DP02, DP03
Learning Episode / Collections / Aggregation	DP04, DP06, DP07, DP09

Table 1: Mapping of SSS service categories to Design Principles derived from theoretical claims coming from Distributed Cognition and Meaning Making theory.

gage in meaning making processes. Since the SSS is agnostic to the type of artefact or entity, various types of learning resources, such as multimedia documents, discussions, Q/As, folders, learning episodes, etc., can be shared. To restrict access to artefacts, the group feature enables users and groups to keep their entities private and thus, only visible to their respective audience. As such, services considering group features help to create and maintain (trusted) social networks, build a shared understanding for effective collaboration and therefore, they provide ground laying community support.

Learning Episode / Collections / Aggregation. The SSS realizes (collaborative) organizing of data in form of collections and learning episodes. While collections offer individual and collaborative structuring in folders, learning episodes provide a visual approach to structuring data via the relation of entities to each other, i.e., sensemaking, in Venn diagram style. Thereby, both kinds of organization are supported by sophisticated recommendation and aggregation mechanisms such as tag recommendations and clouds. The SSS provides extended support for scaffolding, generating shared understanding, aggregating of information and structuring and making sense out of various learning experiences in this way. Specifically, we improved how to better support the process of retrospective handling of work-based information, and how to better support sensemaking out of collected information parts.

In summary, the SSS provides extended support for scaffolding, generating shared understanding, structuring data and making sense out of various learning experiences by means of aforementioned service categories.

4. APPLICATIONS

In this section we illustrate the flexibility of the SSS and its applicability in the light of three real applications (see Figures 2, 3, and 4). Parts of them are currently used in real life context in a health care setting, e.g. Bits & Pieces (B&P) by healthcare professionals in the context of an as-part-of-work study. All three tools have been built upon its services and that support different informal learning settings. Additionally, we report preliminary results of two user studies that have been carried out recently. In this respect, another key feature of the SSS is that it can be adapted to different contexts since new services can be created or existing services can be extended with a reasonable effort, since behind the SSS, there is a growing open-source community. Currently, the Learning Layers GitHub repository has 31 members and the SSS project in GitHub has close to 700 commits over a time period of 2 years.

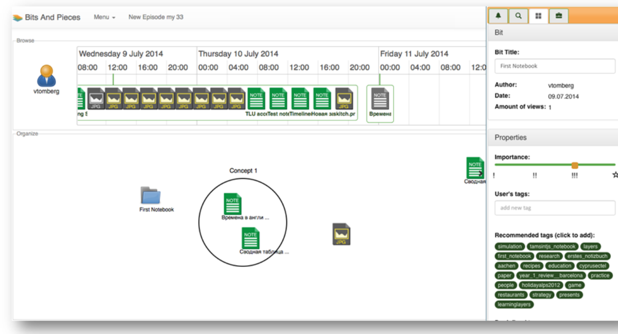

Figure 2: The Bits & Pieces tool as one application that has been developed using the services of the Social Semantic Server.

4.1 Bits & Pieces

Bits & Pieces (B&P) is a Web-based tool for healthcare professionals that helps to remember gathered traces of informal learning experiences based on contextual cues and enables their iterative visual categorization to make sense out of them. As indicated in Figure 2, the tool supports remembering collected pieces of information (e.g., gathered from Evernote) in the upper part of the screen ("Browse") as well as making sense of this information in the lower part of it ("Organize"). Furthermore, the right panel shows additional information for the selected pieces, such as metadata or recommendations. Thereby, B&P makes use of the Recommendations, Search, Learning Episode, Metadata, Activity and Group / Access Restriction SSS services, why it addressed DP 02, 03, 04, 05, 06, 07, 08 and 10.

User study. B&P has already been evaluated in a pilot experiment for two months where eight healthcare professionals of a English GP practice , i.e. one general practitioners, two nurses and five workers of admin and management staff, used the tool as part of their daily work to gain a deeper understanding of topics such as 'NHS Pensions System' and 'risks in treating elderly diabetic patients'. They used B&P to organize notes collected with Evernote beforehand. These organizations then could be shared to engage in meaning making. Thus, B&P supported them to reflect individually and collaboratively. In total, the practitioners collected 257 learning experiences in notes, organized 98 of them during individual sensemaking and shared 25 of them for collaborative sensemaking.

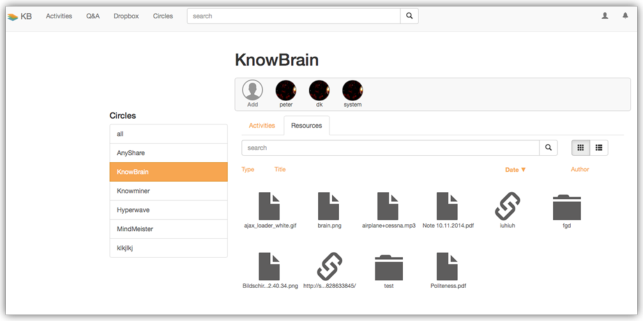

Figure 3: The KnowBrain tool as one application that has been developed using the services of the Social Semantic Server.

4.2 KnowBrain

KnowBrain is a knowledge repository that combines DropBox-like functionalities with social and collaborative features for informal workplace learning [10]. KnowBrain makes use of many of the SSS services such as Recommendations, Gardening Knoweldge Structures, Collections, Q&A, Search, Metadata, Activity and Group / Access Restriction SSS services (i.e., it follows DP 1, 2, 3, 4, 5, 6, 7, 8, 9 & 10) and provides intuitive user interfaces to enable users to share and structure knowledge, to access knowledge via search and recommendation features, and to discuss entities using a multimedia-enriched Q&A forum. Figure 3 shows the DropBox-like functionality where a group of people shares and interacts with a set of entities.

Currently, we are planning to conduct a user study for KnowBrain where a group of researchers in a institute of Graz University of Technology is asked to collect, structure and annotate (i.e., tag) resources for a project (e.g., write a paper together). This will include doing a literature review, i.e. searching and gathering relevant literature, collecting necessary data such as log files and questionnaires and respective results and exchanging the paper documents for mutual iterations and feedback. Thereby, two different groups will use the system receiving suggestions from different recommendation mechanisms to get evaluate and improve the respective recommendation services.

4.3 Attacher

Attacher is a WordPress extension that facilitates the writing process by providing access to bookmarks stored in the SSS and their citation in the blog post. Thus, Attacher utilizes the Metadata (especially tagging) and Search services of the SSS and thus, follows DP 03. 05, 06, 07 and 10. As seen in Figure 4, its interface includes a tag cloud where the user can choose to visualize his own or all the tags in the SSS. When a tag is clicked, the bookmarks categorized by respective tags are listed. By clicking on the bookmarks, their corresponding URLs are accessed.

User study. Attacher has already been evaluated in a master course for training future teachers at Tallinn University with one teacher and 10 students. During the pilot study, the students first used a Chrome plugin that allowed them to collect tagged bookmarks about web resources related to the course topics into the SSS. Subsequently, they wrote a blog post about their reflections on the different topics using WordPress and Attacher to access the bookmarks published in the SSS. A total amount of 52 bookmarks where collected and shared among the students using 116 different tags to describe them.

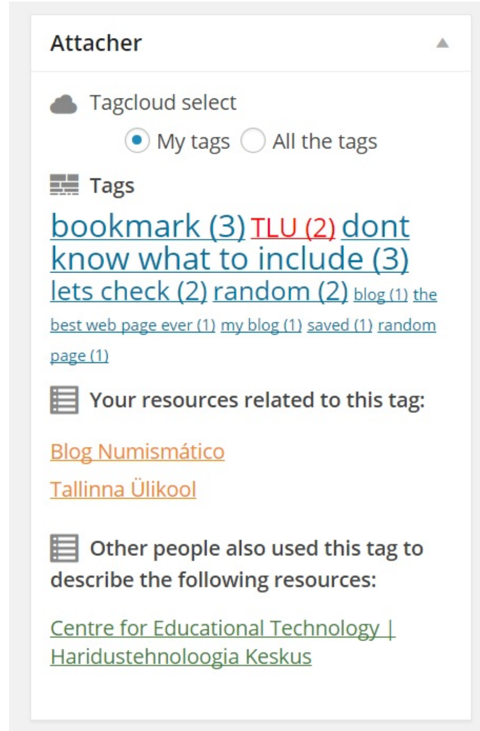

Figure 4: The Attacher tool as one application that has been developed using the services of the Social Semantic Server.

4.4 Discussion

This initial set of tools and their application in various real life learning contexts show how the SSS infrastructure and its service orchestration can be exploited to support informal learning (at the workplace). B&P, KnowBrain and Attacher are diverse applications, which aim at supporting different informal learning practices: i.e. sensemaking of the own learning experiences, collaborative organization and discussion of project related materials and documents and exploration of certain topics in the web and their formalization into grounded blogs. The fact that all three tools could be developed on top of the SSS service based infrastructure exemplifies the flexibility of the SSS in the sense that it is capable of supporting different informal learning practices that occur at the workplace.

These applications also show that the SSS is able to facilitate the sharing of resources among small group of collaborators or even a communities of learners. While the B&P study shows that learning experiences traced with different Evernote accounts can be collaboratively organized in B&P thanks to the integration of these two application into the SSS, the Attacher study demonstrates how bookmarks collaboratively collected by several persons via a Chrome plugin can be referenced in blogposts via Attacher. Additionally, these applications demonstrate how the SSS supports building awareness of activities of collaborators within the working group or the bigger community.

It is also important to note that all three applications capture the context of resources collected, created or manipulated within them via the SSS. In the case of Attacher, the context of the bookmark is described by its author, the time of collection, as well as by the set of attached tags. A more complex description of context is provided by B&P and Knowbrain, which additionally enable the description of the context via categories, ratings and discussions. This contextual characteristics can be exploited to create networks of actors and artifacts, as well as to make Learning Analytics [27].

5. RELATED WORK

We identified two types of systems, namely workplace collaboration systems and personal learning environments, that are related to the functionalities of the SSS.

5.1 Workplace collaboration systems

When thinking of systems or frameworks that support the collaboration of learners in workplace settings, the dominant software is Microsoft SharePoint[6], since around 50% of all intranets developed use it. SharePoint provides document and file management, social network features, collaborative working tools and powerful search facilities. Furthermore, there exist extensions for including semantic data and recommendation functionalities. Although SharePoint provides a framework for implementing extensions, in contrast to the SSS, it is proprietary software and thus, is often no option for application developers.

With regard to an open-source alternative to SharePoint, Alfresco[7] should be named. It is implemented in Java and is build upon an extensible and configurable service-based architecture that utilizes many enterprise-class components, such as Spring, Lucence and Hibernate. However, in contrast to the simple and straight-forward theory-driven design of the SSS, Alfresco is designed as an Enterprise Content Management System with lots of rich user interfaces and functionalities that go beyond the typical needs of an application developer. Another problem of Alfresco is that its free and open-source community edition has some important limitations in terms of scalability which is an important factor for informal learning at the workplace.

5.2 Personal learning environments

PLEs are systems that allow learners to individually manage their learning and can be seen as a highly personalized approach to use technology for learning [1]. In terms of software frameworks for PLEs, the most promising approach has been proposed in the course of the European collaborative project Responsive Open Learning Environments (ROLE)[8]. The role project aimed at exploring the psycho-pedagogical and technical challenges of such a PLE solution, especially in terms of openness and responsiveness.

From a technical perspective, the ROLE interoperability framework [13] provides an infrastructure to gather services and widgets in PLEs. This infrastructure contains a widget store to search existing widgets, a container for rendering and managing widgets and a tracking service for logging contextualized user interactions in the system. Similarly to the SSS, these user interactions can then be exploited for personalized recommendations, e.g., to recommend learning resources. As the ROLE framework is a very nice solution for developing widgets in PLEs, the SSS aims at providing a more general and flexible framework for all type of informal learning applications.

6. CONCLUSION AND FUTURE WORK

In this paper, we presented the Social Semantic Server (SSS) as a flexible technical infrastructure to develop tools and applications to support informal learning at the workplace. The SSS has been conceptualized and designed based on insights gained from relevant theories such as Distributed Cognition and Meaning Making. Specifically, we translated the requirements we identified to support informal learning at the workplace to a set of Design Principles, and consequently, in a set of service categories which have been implemented in the SSS. The resulting services are exploited in three client-side tools that support different perspectives on informal learning. This demonstrates that the SSS is capable of supporting different informal learning practices that occur at the workplace.

For future work, we will further extend the SSS with services to support informal learning in different workplaces and settings. These services will again be made available to the research community in form of open-source software. Apart from that, we will also try to identify further client-side informal learning tools that could make use of our services and evaluate their usefulness in these tools. This would give us further evidence for the flexibility and potential of the SSS to support informal learning at the workplace.

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