Conceptual Foundations for a Service-Oriented Knowledge & Learning Architecture: Supporting Content, Process, and Ontology Maturing

Andreas Schmidt
(FZI Research Center for Information Technologies, andreas.schmidt@fzi.de)

Knut Hinkelmann
(University of Applied Sciences Northwestern Switzerland, knut.hinkelmann@fhnw.ch)

Stefanie Lindstaedt
(Graz University of Technology and Know-Center, slind@know-center.at)

Tobias Ley
(Graz University of Technology and Know-Center, tley@know-center.at)

Ronald Maier
(University of Innsbruck, Information Systems, ronald.maier@uibk.ac.at)

Uwe Riss
(SAP AG, uwe.riss@sap.com)

Abstract: The knowledge maturing model views learning activities as embedded into, interwoven with, and even indistinguishable from everyday work processes. Learning is understood as an inherently social and collaborative activity. The Knowledge Maturing Process Model structures this process into five phases: expressing ideas, distributing in communities, formalizing, ad-hoc learning and standardization. It is applicable not only for content but also to process knowledge and semantics. In the MATURE IP two toolsets will be develop that support the maturing process: a personal learning environment and an organisation learning environment integrating the levels of individuals, communities and organisation. The development is guided by the SER theory of seeding, evolutionary growth and reseeding and is based on generally applicable maturing services.

Keywords: content, e-Learning, knowledge management, maturity, ontology, process, service, service-oriented architecture

Categories: L.3.4 - Learning Processes; L.3.6 - Technology Enhanced Learning; L.1.0 - Knowledge Construction/Representation

1 Introduction

In a world of constant change, enterprises need to become increasingly agile in order to successfully compete. They need to adapt to changes, deliver new or improved product and service offers. To do so, they need to leverage their employees' creativity and hands-on experience, improve the sharing of knowledge within the enterprise (and often also across its borders), and combine all this with a new form of organizational guidance. To support these activities, we need to move away from

systems conceived and operated in a top-down way (like traditional learning or knowledge management systems). Rather, we need a balance of bottom-up and top-down development of systems supporting learning, knowledge handling and innovation in businesses and organisations. The aim is to bring together Web 2.0-style engagement and user empowerment with the efficiency of organizations in exploiting knowledge on a larger scale. Within the MATURE IP (http://mature-ip.eu), the goal is to develop two toolsets:

- *a personal learning environment* (Attwell, 2007), consisting of work-integrated, personalized tools for communicating, collaborating, structuring, reflecting, and awareness building. The individual learner should be able to easily combine these tools and readily interoperate with others' personal learning environments;
- *an organizational learning environment*, giving the organization (or better its representatives) the opportunity to analyze bottom-up activities within the sum of individual PLEs. The results of these analyses should promote the consolidation of such activities towards organizational gals, enable the breeding of strategically important communities, and help enriching existing knowledge resources so that they can be readily reused as learning objects.

Such toolsets must be flexible and easily extensible, which calls for an infrastructure providing reusable knowledge services. But how should such a service infrastructure look like? What are conceptual foundations for a service-oriented knowledge architecture that could help to reach the goals outlined above?

In this paper, we present an approach to conceptualizing knowledge services based on the knowledge maturing model (Maier & Schmidt, 2007). This model helps to understand the 'flow' of knowledge and its barriers. We extend this by differentiating between knowledge assets of varying degrees of maturity (section 2). We then derive intervention strategies from the SER model (section 3) that form the basis for maturing (support) services (section 4).

2 Knowledge Maturing

The knowledge maturing model views learning activities as embedded into, interwoven with, and even indistinguishable from everyday work processes. Learning is understood as a social and collaborative activity, in which individual learning processes are interdependent and dynamically interlinked with each other: the output of one learning process is input to the next. If we have a look at this phenomenon from a macroscopic perspective, we can observe that knowledge is continuously repackaged, enriched, shared, reconstructed, translated and integrated etc. across different interlinked individual learning processes. During this process knowledge becomes less contextualized, more explicitly linked, easier to communicate, in short: it matures. The **knowledge maturing process** model structures this process into five phases (based on experiences from several practical cases as well as a comprehensive empirical study, [Schmidt 2005, Maier 2007, Maier and Schmidt 2007]):

- **Expressing ideas**. New ideas are developed by individuals from personal experiences or in highly informal discussions. The knowledge is subjective and deeply embedded within the context of the originator. The vocabulary is vague and often restricted to the person expressing the idea.

- **Distributing in communities**. This phase accomplishes the development of common terminology shared among community members, e.g. in discussion forum entries, blog postings or wikis.
- **Formalizing.** Artefacts created in the preceding two phases are inherently unstructured and still highly subjective and embedded in the context of the community. In this phase, purpose-driven structured documents are created, e.g. project reports or design documents or process models in which knowledge is 'desubjectified' and the context is made explicit.
- **Ad-hoc learning**. Documents produced in the preceding phase are not well suited as learning material because no didactical considerations were taken into account. Now the topic is refined to improve comprehensibility in order to ease its consumption or re-use. The material is ideally prepared in a pedagogically sound way, enabling broader dissemination, e.g. service instructions or manuals.
- **Standardization.** The ultimate maturity phase puts together individual learning objects to cover a broader subject area. Thus, the subject area becomes teachable to novices. Tests and certificates confirm that participants of formal training achieved a certain degree of proficiency.

This maturing process is most intuitively recognized in the case of 'content objects' (knowledge represented in the form of documents, drawings, etc.). However, it also applies to other types of knowledge representations vital for operating and developing any kind of organisation: namely processes and semantics [Riss 2005]:

- **Contents** provide a static picture of the world and are probably the best managed type of knowledge asset. The term knowledge asset points towards a value-oriented perspective on knowledge elements (business value) suggesting the importance of knowledge for the functioning of an organisation's business processes. It can take the form of notes, contributions and threads, protocols, lessons learnt, learning objects, courses, etc.
- **Processes.** This type of knowledge asset is more related to the dynamic aspect of the organisation. Large organisations already support this by developing business process models and workflows. Taking into account that organisational learning processes are much more agile and the costs of modelling approaches are considerable, a more suitable approach is to enable recording and sharing of individual work practices. Processes can take the form of e.g. individual task lists and routines, task patterns, good practices, best practices, work flows or standard operating procedures.
- **Semantics.** This type of knowledge asset is probably the least visible within organizations. Semantics connects the different assets and supports the individual learning processes by providing the basis for mutual understanding. Without semantic integration, grassroot approaches encouraging people to contribute their individual views, experiences and insights would get stuck in misinterpretations and lengthy negotiation processes. These knowledge assets can take the form of tag clouds and emerging folksonomies, folder structures, competence models, local or global enterprise ontologies.

These three knowledge asset types – and thus the three strands of maturing – are closely interwoven and they depend on each other in various respects. Contents and

processes require semantics to become communicable. Therefore, semantics is the fundament for every community-based approach and fosters collaboration between individual knowledge workers. Without process integration, semantics and contents are not directly applicable to work procedures so that additional transformation efforts by the knowledge workers are required. More mature content allows a worker to deal with the high complexity and variability of knowledge-intensive processes and adapt to unpredictable situations [Feldkamp, Hinkelmann & Thönssen 2007]. Finally, contents are required to explicate semantics and processes so that these are comprehensible to knowledge workers with different backgrounds. While semantics and processes focus on the actual doing, contents aim at understanding and reflection.

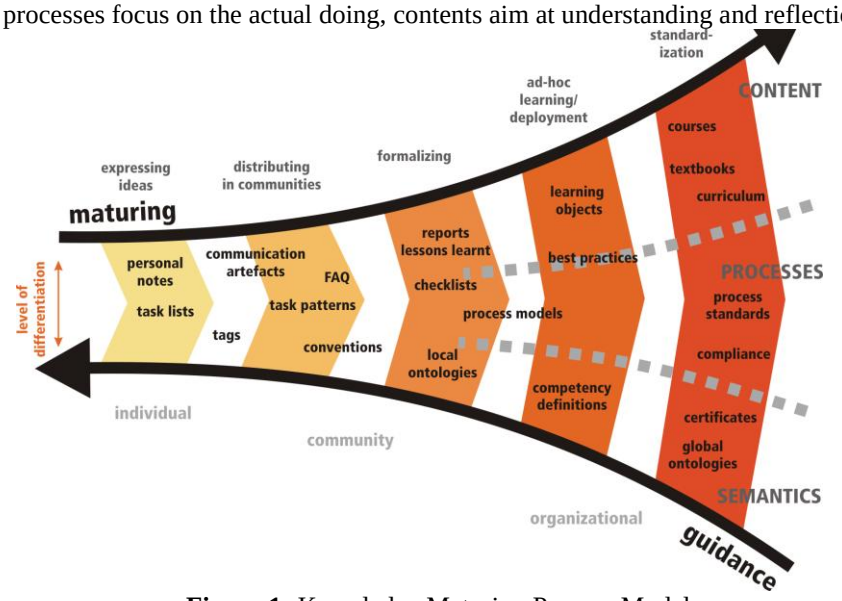


Figure 1: Knowledge Maturing Process Model.

[Figure 1] depicts the described situation schematically. Knowledge asset types are not well differentiated in the early maturing phases; notes can contain content, process, and semantic aspects, sometimes all at the same time. Only with a deepened understanding, this differentiation can take place. This corresponds with a decrease in abundance: while there are many notes and communication artefacts at the beginning of the maturing process, formal training materials are rather scarce at its end. It also shows that the maturing process is accompanied by a process of organisational guidance that supports the identification of significant emerging topics and their transformation to more mature forms of knowledge.

As the process of guidance already indicates, the development should not be misunderstood as a continuous linear process. On the contrary, **maturing is made up of a complex pattern of individual steps**. Not all knowledge assets are developed up to the ultimate maturity phase, some of them end up in a stalemate or are discarded; others are combined with other assets at various maturity levels, or split up into more differentiated assets. What we observe is an **evolution** of knowledge assets.

3 Seeding –Evolutionary Growth – Reseeding

A closer look at how individual maturing phases actually take place reveals that the theory of **Seeding, Evolutionary Growth and Reseeding**, (SER) [Fischer et al. 2001] is applicable here. The SER model describes how complex systems evolve out of an initial seed (units, structure, and capabilities) and through the use of combination, analysis and change tools by many diverse users. Community activity leads to evolutionary, undirected (and often confusing) growth of the original units, structures and capabilities. At some point in time, the evolved system needs to be reseeded in order to be kept manageable. This reseeding can happen in a form of consolidation and negotiation processes in which the variety of units, structures, and capabilities are pruned and consolidated.

[Figure 2] illustrates the application of the SER model to the maturing model. The main hypothesis is that seeding, evolutionary growth and reseeding can be applied to each maturing phase. Seeding initiates the maturing process and leads into the evolutionary growth phase. At the end of each maturity process phase, a decision has to be made. One alternative is to reseed the current maturity step. This would involve cleaning out the current knowledge base (the collection of relevant knowledge assets), selecting a portion of the knowledge elements and re-starting the maturing process on the same maturity level. This reseeding implements the guidance direction (see [Figure 1]) by aligning knowledge assets with objectives and process requirements. If a portion of the knowledge base is considered sufficiently mature, it is selected and used to seed a maturity process at a higher level of maturity.

For an example consider the maturity phase ‘distributing in communities’. First a community ‘space’ is seeded with the initial idea or topic. This involves creating an initial knowledge structure together with its knowledge units and their capabilities and characteristics. In order to enable evolutionary growth this community environment needs to be equipped with means (tools) for combination, analysis, and change of the structures and the units themselves. Such tools allow the diverse users to combine knowledge units to build (increasingly complex) knowledge structures and to change the knowledge units themselves according to their needs. Analysis tools enable the community to monitor and guide its activities. If the development of the topic reaches a certain level, the decision whether to take the topic to the level of formalizing has to be made. If the development of the topic stagnates, reseeding might be an option. This includes pruning the current knowledge base, introducing new ideas, knowledge elements or people into the community or changing the topic.

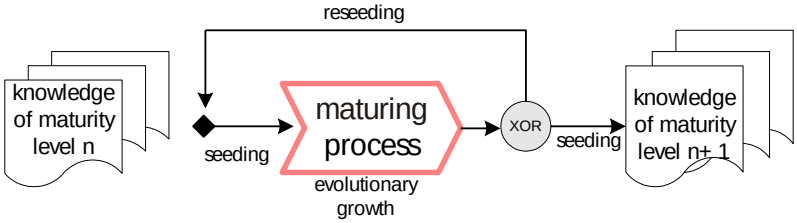
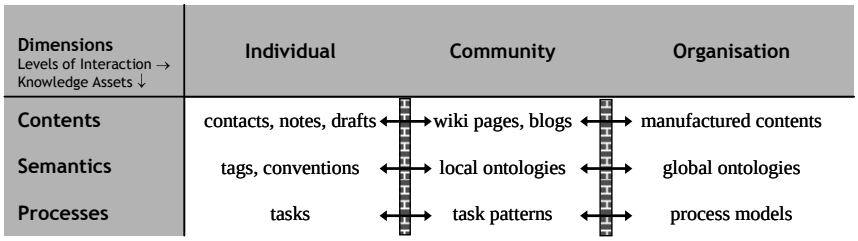


Figure 2. *The SER model guides maturity processes.*

4 Maturing Services

If we consider the knowledge asset types that appear in [Figure 1] we find that they are supported by a variety of mainly independent tools divided both along the levels of interaction and along the types of knowledge asset. The independence of these tools reflects the existing gaps in the support for maturing processes as it exists so far.

Table 1: Separation of knowledge asset types within different tools.



To overcome the described separations, we need to interconnect tools which manage the different knowledge assets and provide services that support the knowledge flow between the different levels [Table 1]. We refer to such tool connections and services as **maturing services**, since they support the maturing process.

Generally, a service is an abstract resource that represents a capability of performing tasks that form a coherent functionality from the point of view of providers entities and requesters entities [W3C 2004]. It consists of a contract, interfaces as well as implementation and has a distinctive functional meaning typically reflecting some high-level business concept covering data and business logic [Krafzig, Banke and Slama 2005, 57-59]. In our case, the business concepts represented by maturing services are the knowledge asset types identified above, i.e. the contents of varying degrees of maturity, the maturing and guidance processes as well as the various types of semantics. Consequently, maturing services are needed that help knowledge workers to handle these knowledge assets. Whereas the technical definition of services is supported by a set of standards (such as Web services), it is the conceptual part (i.e. defining types of services that are useful) that is currently lacking. But exactly this conceptual part matters most when organisations attempt to profit from the promised benefits of service-oriented architectures. In the following, we introduce three maturing service types which we will consider in the future, and give an example of one intelligent service which we have implemented for a collaborative tagging environment.

4.1 Maturing Service Types

According to the SER model we distinguish between three types of maturing services:

Seeding services enable the user to set up and initialize knowledge units and structures within a community. Such services could include the initialization of an associative network (AN) based on document similarities or the initialization of user models based on social network analysis (SNA). During seeding specific similarity measures and characteristics which the SNA algorithm operates upon will be determined. Seeding services also include functionalities to use the instantiated

structures. In our example these would include services that recommend relevant documents and persons based on the AN or the user model. An example will be presented in the next section.

Growth services allow users to add new knowledge units (e.g. documents or users), to adapt their characteristics (e.g. the users' competencies) to provide comments and to change the system behaviour. Growth services are based on the Web2.0 paradigm in which users can produce their own content and which utilizes collective usage data and user feedback to improve the system's performance. In our example, growth services include mechanisms to change weights within the AN and mechanisms to infer user characteristics based on their activities.

Reseeding services allow the user to analyse and visualize the collective activities of the community, negotiate between conceptualizations of different users and finally (and most importantly) to change the underlying structures and functionalities. These reseeding services will go beyond the Web2.0 paradigm by enabling users to not only add and change content but also to change the underlying structure and functionality of the evolving knowledge system. In our example this could include adapting similarity measures and changing user characteristics.

4.2 Seeding and Growth in a Collaborative Tagging Environment

Tagging resources can be seen as a first step of providing semantic descriptions for these resources. The results of such activity are knowledge assets (tags) which are used on an individual level (see [Table 1]). Collaborative tagging environments (such as http://www.flickr.com or http://www.del.icio.us) make it possible to share these in a community setting. How could services be designed to facilitate the seeding and evolutionary growth in the community setting.

As a basis of our maturing services we use cognitive models that have been extensively used for modelling individual cognitive processes of knowledge encoding, representation and retrieval. An example here is the declarative knowledge module in ACT-R [Anderson et al. 2004] which models knowledge as an associative network. We then seek to transfer these models to a distributed community setting where several actors and shared artefacts are involved. So in fact what we are aiming to do is to describe knowledge maturing in an organisation as a distributed cognitive process which is based on a knowledge representation that describes the knowledge of a whole community .

In the example of the collaborative tagging environment, the folksonomy (shared tags) is modelled as an associative network using tag co-occurrences [e.g. Steels 2006]. Tags are modelled as nodes in a network where co-occurrence with other tags determines the associations, or the weights on the edges. We have modelled a folk-sonomy in this way for a flickr data set [Pammer, Ley and Lindstaedt 2008].

After an appropriate model has been established (and evaluated for its validity) intelligent services can be built upon it by simulating cognitive processes on a community level, such as knowledge retrieval. In the flickr example, the service we implemented was to recommend tags when users uploaded new pictures. This service simulates tag associations in a distributed cognitive structure. In another case, we employ spreading activation mechanisms for these processes (which are also implemented in the ACT-R architecture) [Scheir, Ghidini and Lindstaedt 2007]. First experiments have shown that this service reduces the number of tags people use as

they make use of existing tags. In our view this helps to emerge a shared understanding, as the system grows evolutionary.

5 Conclusions

In this contribution we have introduced our current understanding of the knowledge maturing process. In the MATURE project we will study in detail how this maturing process currently takes place within organizations and communities. Based on the insights we gain we will develop maturing services which will support knowledge maturing along the knowledge asset type dimension (supporting maturing of contents, semantics, and processes tightly interwoven) and providing integrated support for the whole maturing process from individual learning to organizational learning.

These services enable the creation of learning environments as a set of loosely coupled tools which can be integrated based on the emerging mashup paradigm. This brings learning & maturing support to the end user and creates a flexible and dynamic knowledge and learning architecture.

Acknowledgements

This work has been partially funded under grant 216346 in the IST work programme of the European Community. The Know-Center is funded within the Austrian COMET Program - Competence Centers for Excellent Technologies - under the auspices of the Austrian Ministry of Transport, Innovation and Technology, the Austrian Ministry of Economics and Labor and by the State of Styria.

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