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

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Abstract Effective learning support in organizations requires a flexible and personalized toolset that brings together the individual and the organizational perspective on learning. Such toolsets need a service-oriented infrastructure of reusable knowledge and learning services as an enabler. This contribution focuses on conceptual foundations for such an infrastructure as it is being developed within the MATURE IP and builds on the knowledge maturing process model on the one hand, and the seeding-evolutionary growth-reseeding model on the other hand. These theories are used to derive maturing services, for which initial examples are presented.

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1 Introduction

In a world of constant change, enterprises need to become increasingly agile in order to compete successfully. 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, and improve the sharing of knowledge within the enterprise (and often also across its borders). 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). These systems are slow to adapt to new developments, and hardly adapt to the personal needs of individuals and their situations. As a consequence, they lack user acceptance and don't live up to the initial expectations.

To avoid that, we need a balance of bottom-up and top-down development of systems supporting learning, knowledge handling and innovation in businesses and organisations. Web 2.0-style engagement of individuals in sharing and other social activities shows that we clearly need to take into the motivational aspects of knowledge workers. Motivational theories like the self-determination theory of Deci and Ryan [23] emphasize the important needs of experiencing competence, autonomy, and relatedness – which cannot be achieved in the context of top-down systems. To realize that, *personal learning environments* [2] have been proposed, 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 according to his own needs and preferences and readily interoperate with others' personal learning environments to account for the social nature of learning processes.

One of the challenges the MATURE IP (http://mature-ip.eu) is facing, is embedding the paradigm of personal learning environments into organizations. To that end, we need a new form of organizational guidance, realized through a complementary organizational learning environment. Such an environment has a two-fold purpose: (1) It is supposed to give the individual the possibility to view their contributions in an organisational context and encourage participation toward organization goals. (2) It should give the organization 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 goals, enable the breeding of strategically important communities, and help enriching existing knowledge resources so that they can be readily reused as learning objects.

Such environments need to be flexible, and personalized, which calls for an infrastructure providing reusable knowledge services that can be easily recombined. But the notion of service also goes beyond components; it usually assumes that the granularity of functionality as well as packaging is motivated by usage patterns (e.g., by personal and organizational learning environments) and not purely technical (software engineering) considerations. Engineering of such knowledge and learning architectures thus requires a thorough understanding of individual and organizational learning and its effective support.

In this paper, we present an approach to conceptualizing knowledge services based on the knowledge maturing model [14]. This model helps to understand the flow of knowledge and its barriers within and across organizations from a macroscopical point of view. 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) and give examples for such services.

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, [25], [14]):

- **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.

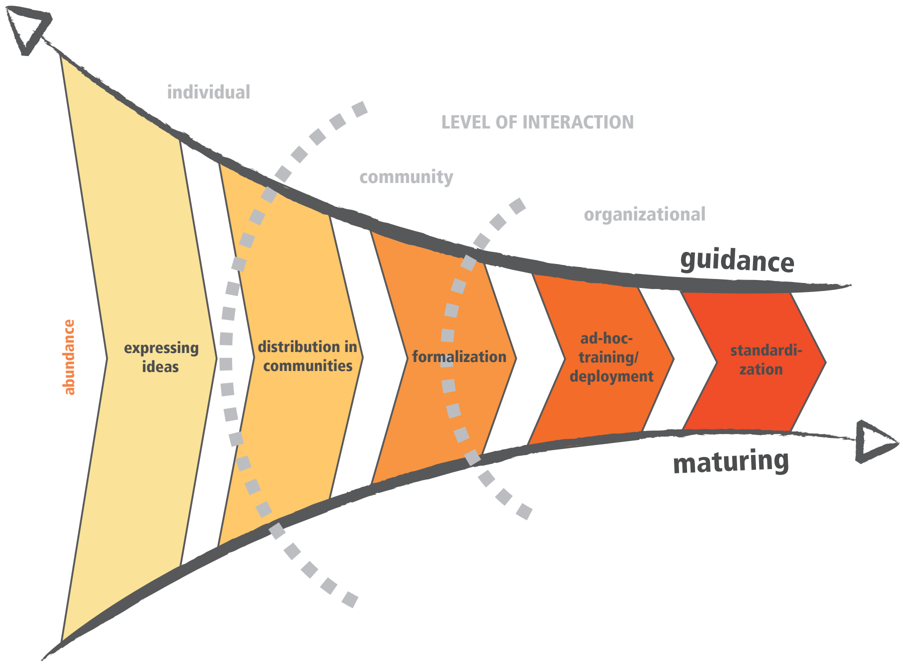

Fig. 1 Knowledge Maturing Process model

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 [21]:

- **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.

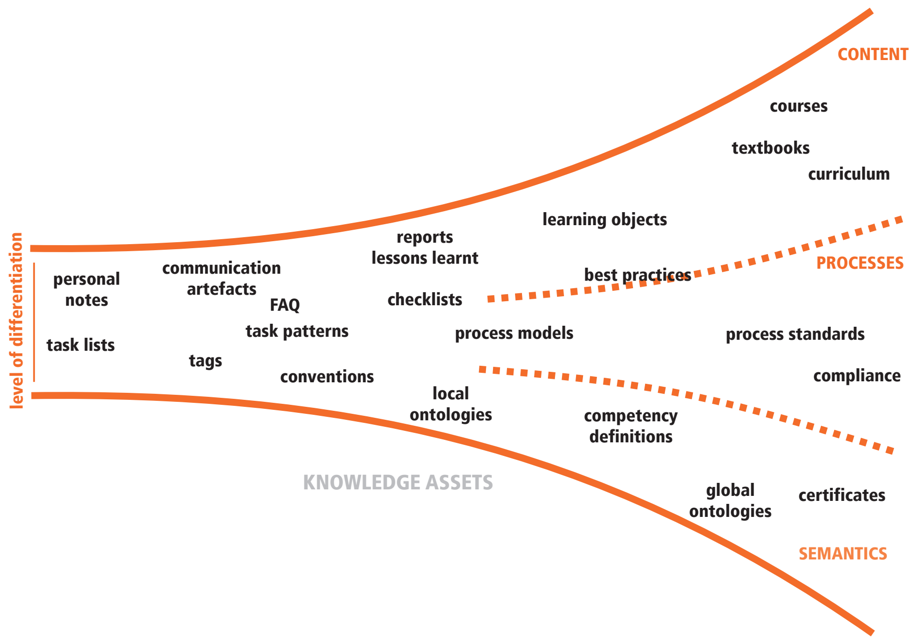

Fig. 2 Knowledge Maturing Process model

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 [5]. 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 2 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

In order to describe the individual steps of the maturing process in more detail, we applied Fischer's Seeding, Evolutionary growth, and Reseeding (SER) model [6]. The SER model was originally developed to describe and help to understand the evolution of complex software environments. Instead of viewing a software environment as the final product of the software development process which led to its existence, the SER model views the software system as the starting point (seed) for a complex, socially driven, evolutionary further 'development' process. In this process, users interact with the environment, its units, its structures and its tools - and thus develop them further. New units are built during these interactions, new tools are developed (by adaptation or end-user programming capabilities), and a variety of relationships or structures are discovered and expressed. The better the provided tools afford the creation of new and the combination of existing units, structures, and tools, the more the users have the opportunity to express their creativity and to satisfy their needs. Community activity leads to evolutionary, undirected (and often confusing) growth of the original software system. Fischer observed that typically such an evolutionary growth phase is followed by what he calls a reseeding phase: At some point in time, the environment becomes too complex to be managed. Many new units and tools have evolved and structures have become frizzled. Restructuring and redesign of the environment is initiated by some triggering event (e.g., design breakdown). This reseeding can happen in a form of consolidation and negotiation processes in which the variety of units, structures, and tools are pruned. In traditional software systems, this reseeding has to be accomplished by programmers, since the end-users will not be able to do so themselves. Fischer argues that in order to build and maintain useful software systems, we need to provide the end-user not only with tools which support evolutionary growth activities (e.g., combine, specialize) but also with tools which enable her to participate in the reseeding phase (e.g., visualization of structures, negotiation).

In order to reflect on applying the SER model to the knowledge maturing process consider for example the maturity phase 'distributing in communities'. First, a community 'space' is seeded with an initial idea or topic. This involves creating an initial knowledge structure together with its knowledge units and their capabilities and characteristics. This community environment needs to be equipped with tools for combination, analysis, and change of the structures and the units themselves in order to enable evolutionary growth. Such tools enable the 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 maturity phase "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.

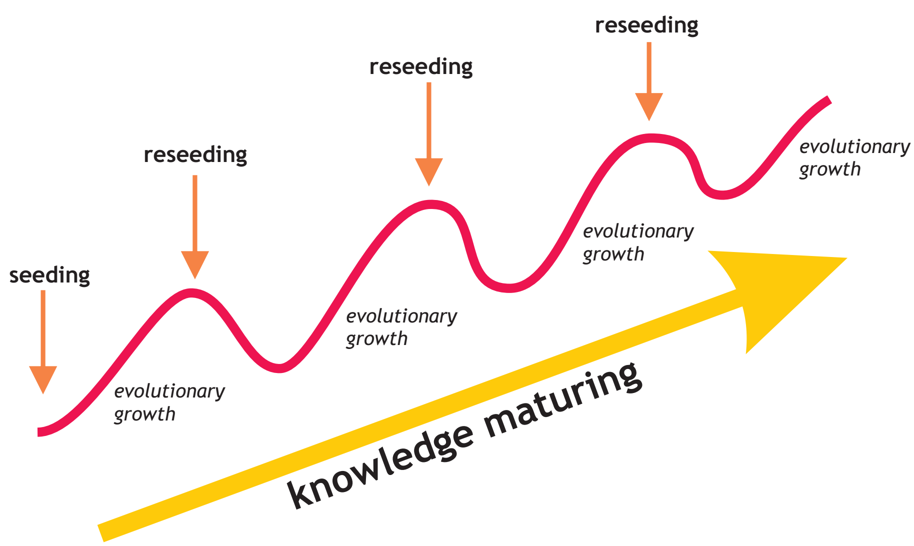

Fig. 3 The SER model and knowledge maturing

It is tempting to equate a SER cycle with a knowledge maturing phase. However, this conceptualization of knowledge maturing evokes the false impression that maturing is a collection of discrete steps which will happen in strict order. By applying the SER model, we not only stress that evolutionary growth and reseeding are important recurring phases of the maturing process, but that they are really inseparably interlinked and interwoven. That is, a user might engage in growth activities at one moment involving one knowledge asset type (content, semantics, process; compare fig. 2) while the same user might engage in reseeding activities in parallel. This interplay of growth and reseeding activities invokes the association to the interplay of assimilation and accommodation processes during knowledge construction in informal learning [20]. Here, a person integrates new knowledge into her own mental model of the topic by either adding the knowledge into already existing knowledge structures or this new piece of knowledge causes her to restructure her mental model in order to accommodate it.

Based on these insights, we treat maturing as an organizationally guided learning process which interweaves informal learning processes of many individuals - first on a group or community level, then on an organizational level. Since these individuals utilize different types of knowledge representations (content, semantics, process) to document the gained insights, tools are needed to do so with low effort and to identify relationships between them. Our future research will specifically focus on identifying the factors which influence assimilation versus accommodation activities and the barriers people experience when doing so.

When analyzing tools supporting knowledge work, we find a variety of (mostly) independent tools separated along two dimensions: (1) types of knowledge assets (content, semantics, process) and (2) level of interaction (organization, community/group, individual). The first dimension corresponds to different ways of knowledge construction and the second to the breadth of knowledge sharing. The separation of these tools reflects existing gaps in support of maturing processes (fig. 4).

Dimensions Levels of Interaction → Knowledge Assets ↓	**Individual**	**Community**	**Organisation**
Contents	contacts, notes, drafts	wiki pages, blogs	manufactured contents
Semantics	tags, conventions	local ontologies	global ontologies
Processes	tasks	task patterns	process models

Fig. 4 Separation of systems

4 Maturing Services

In the following, we will use the concept of *maturing services* to refer to integrated support for the maturing process. That is, maturing services will bridge the separation along both dimensions of knowledge construction and knowledge sharing as outlined in the previous section. They are needed not only to help knowledge workers to handle these different knowledge assets, but also to entice them in sharing and negotiating among them. Generally, a service consists of contract, interface and implementation. It has distinctive functional meaning typically reflecting a high-level business concept covering data and business logic [11]. 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. Service descriptions provide information about:

- *service capability:* conceptual purpose and expected result,
- *service interface:* the service's signature, i.e. input, output, error parameters and message types,
- *service behavior:* a detailed workflow invoking other services,
- *quality of service:* functional and non-functional quality attributes, e.g., service metering, costs, performance metrics and security attributes.

The service concept has gained popularity with the advent of a set of standards for open interaction between software applications using Web services (such as WSDL, SOAP and UDDI). Whereas the technical definition of services is supported by standards, it is the conceptual part (i.e. defining types of services that are useful) that is currently lacking. Knowledge management (KM) services or knowledge services are a subset of services, both basic and composed, whose functionality supports high-level KM instruments as part of on-demand KM initiatives, e.g., find expert, submit experience, publish skill profile, revisit learning resource or join community-of-interest [13]. These services might cater to the special needs of one or a small number of organizational units, e.g., a process, work group, department, subsidiary, factory or outlet in order to provide solutions to defined business problems. KM services describe aspects of KM instruments supported by heterogeneous application systems.

For example, a complex KM service "search for experts" might be composed of the basic KM services (1) expert search, (2) keyword search, (3) author search, (4) employee search and (5) check availability. The (1) expert search service delivers a list of IDs, e.g., personnel numbers, for experts matching the input parameter of an area of expertise. The (3) author search service requires a list of keywords describing the area of expertise. Thus, the complex KM service search for experts also comprises an integration service for the task of finding keywords that describe the area of expertise, here called (2) keyword search. The keywords are assigned to areas of expertise either in a simple database solution or in a more advanced semantic integration system based on an ontology. With the help of an inference engine, these relationships together with rules in the ontology can be used to determine a list of keywords. The (3) author search service then returns a list of IDs of matching authors or active contributors to the CMS. An (4) employee search service takes the personnel numbers found in the expert search and the author search and returns contact details, e.g., telephone number, email address, instant messaging address. Finally, the (5) check availability service delivers the current status of the experts and a decision on their availability.

We conceptualize maturing services as complex services that are in turn composed of basic services either already offered in heterogeneous systems as part of an enterprise application landscape, implemented additionally to enrich the services offered in an organization or invoked over the Web from a provider of maturing services. In the following, we introduce three types of maturing service which we will consider in the future:

- **Seeding services** enable the user to set up and initialize knowledge units and structures within a community. Seeding services also include functionalities to use the instantiated structures.
- **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 a form of using the Web often cited as Web 2.0 in which users can produce their own content (user-generated content) and which utilizes collective usage data and user feedback to improve the system's value and performance due to network effects and phenomena which have been termed ”collective intelligence” or ”wisdom of the crowds” [28].
- **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 services offered under the umbrella term Web2.0 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 the rest of this section we present several examples for maturing services which help to illustrate the ideas we have put forward in the previous sections. In the following, we will briefly describe three examples, one for each of the three knowledge asset types (contents, semantics and processes).

4.1 Semantic Wiki Services for Career Guidance (Contents)

Wikis are prime examples of tools that allow a collective construction of knowledge in a community setting. There are certainly good examples of Wikis being used as tools for creating a collective online encyclopaedia, for teaching and learning purposes, and for organizational knowledge management ([10], [19], [15]). In our perspective, Wikis are very well suited for enabling the evolutionary growth phase, especially because of the ease of editing the content and the policy that everyone can edit anything. Additionally, they make the collective construction process traceable (utilizing their history functionality) and allow for discussion processes around artefacts.

A problem with Wikis, however, is their inability to deal with more formal content or structures. The way a standard Wiki works seems to suggest that any artefact is constructed basically from scratch in a community setting, and that there is no end to this construction process. This is an unrealistic proposition in most settings and especially in an organizational setting where knowledge generation uses artefacts that fluctuate between the informal and the formal pole. In this sense, the use of Wikis illustrates one of the barriers given in fig. 4, namely that between the community and the organizational level.

An example may help to illustrate our reasoning. We are currently examining the use of knowledge in a career guidance setting. Career advisors have the task to personally consult individuals (such as pupils or graduates or their parents) on their job prospects, and advise on potential careers given their interests and the general job situation in the region. In doing so, they make use of a large body of formally documented knowledge artefacts, for instance statistics and reports on job opportunities or labour market development in certain employment sectors and regions. Additionally, they draw on a considerable amount of informal knowledge derived from their experiences with concrete cases. This knowledge in use is more or less systematically applied in their job, and it is more or less systematically shared among practitioners.

We regard these processes of generation, application and sharing of both formal and informal knowledge as a knowledge maturing process. To support the practitioners in this process, we are employing a Semantic Media Wiki [12]. Several maturing services have been designed that try to bridge the gaps in the maturing process. First of all, an integrated search mechanism enables the practitioners to draw in a large array of different kinds of existing resources from a number of relevant sources (formal reports, statistics, videos etc.) - thus seeding the Wiki with relevant material. The Wiki then renders these existing resources so that discussions and knowledge construction in the Wiki can take place in the context of the formal documents. The idea being, that these informal discussions and knowledge construction draw in practitioners' knowledge in use, which documents experiences from their practice. This should enhance the evolutionary growth of the knowledge base.

We the explore some of Semantic Media Wiki functionalities to capture the context this informal knowledge has been applied to (such as the region, the target group or the employment sector). With some information extraction and classification algorithms, we are able to suggest semantic mark-up which might be applied to an article (see fig. 5). A visualization of the whole network made up of semantic categories, textual similarity measures, and links between articles provides an overview of the whole available content, and enables detection of similarities for some gardening or reseeding activities. In addition, we will be visualizing indicators for the use frequency of articles and text readability scores. This will allow the gardening activities to focus on parts of the content that are especially important (highly used), but of poor quality (low readability). Finally, the Wiki also provides a way to export a newly created article or a collection of articles as a report so as to document the current status on a higher level of maturity.

Fig. 5 Design study for markup suggestion

4.2 *From Collaborative Tagging to Emerging Semantics (Semantics)*

Tagging resources can be seen as a first step of providing semantic descriptions for these resources. The results of such activities are knowledge assets (tags) which are used on an individual level (see fig. 4). 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 can services be designed to facilitate the seeding and evolutionary growth in the community setting? We have basically taken two approaches to this problem: (1) improving the quality of the folksonomy by providing tagging support, and (2) supporting the creation of ontologies from folksonomies as part of the community process.

In the first approach, 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 [1] 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. What we are aiming to do is to describe knowledge maturing in an organisation as a distributed cognitive process. This cognitive process 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 [27]. 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 folksonomy in this way for a flickr data set [17]. 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 upload 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) [24]. First experiments have shown that this service reduces the overall number of tags people apply as they make use of existing tags. In our view this helps to emerge a shared understanding, as the system grows evolutionary.

There is recently also growing empirical research into how information from such an associative network of tag co-occurence allows the emerging of semantic relations between tags such as discovering broader or narrower terms or synonyms ([26], [9]).

The second, complementary approach aims at community tools to engineer taxonomies or ontologies in a collaborative and lightweight manner [4], building on, but also extending the tagging paradigm. Here, the collaborative tagging environment is enhanced by providing a (lightweight), collaborative ontology editor that allows for introducing *broader*, *narrower*, and synonym relationships to cover for the most common problems in folkosomies. It is assumed that an ontology evolves or matures based on community activities. For that process, we want to provide the community with supporting services that help them to consolidate part of the folksonomy into an ontology by spotting candidates for merging or heavily used tags (where it would be worth consolidating), and by facilitating the consolidation task as such (e.g., by proving argumentation support [18]). Here, analysis services particularly help in reseeding activities. First experiments have been made as part of the semantic social bookmarking application SOBOLEO [29], and in approach to collaborative building of competence models based on people tagging [3]. Evaluation results have shown the general feasibility of the approach and indicated required supporting services.

4.3 From Task Management to Process Management (Processes)

Almost all knowledge assets a user is working with are related to some work activities. For example, a travel plan might be related the organization of a business trip or a report might be related to the regular administration activities in a project. There is also a semantic dimension of this relation [7] since semantic technologies can be applied to formally describe these connections in order to use them later for information retrieving.

Generally the representation of work activities in tasks can be considered as the first step to monitor the actual processes that take place in an organization. However, isolated tasks do not allow for the analysis of collaborative processes so that the specific relations between individual tasks must be represented. The main relation in this respect is the task-subtask-relation which describes that a specific (sub)task contributes to the accomplishment of a larger task. For example, the provision of a travel plan is only one task among others contributing to the task that describes the entire business trip. The collaborative character of tasks is expressed by the fact the executor of a subtask is not necessarily identical to the executor of the task to which this subtask belongs. Including task-subtask-relation we obtain a network of related activities conducted by various users with different dependencies that provides a detailed picture of the activities in an organization.

The individual task with the involved people and the used resources do not only describe the actual processes in an organization but are also first-class knowledge assets. They contain the information how specific work has been conducted and can help other employees to better perform their work. They can be used to derive general task patterns, i.e., descriptions how a specific type of task can be accomplished. The feedback that is provided by employees who use these patterns can directly be incorporated in this pattern resulting in a task pattern lifecycle [16]. This lifecycle represents a typical maturing process that is to be supported by additional services. For example, this concerns the identification of similar activities in order to streamline the pattern portfolio or the support in augmenting the patterns by additional information and services.

Coming to the organizational level further development is possible. Here we find automated processes such as workflows that significantly increase the productivity of an organization. However, especially in the realm of knowledge work it has been found that workflow approaches face significant problems since they do not provide the flexibility that is required here ([8], [22]). This opens opportunities for the analysis of task patterns and concrete work process in order to identify exactly those process aspects that are suited for process automation. Usually the underlying process models are developed by conducting interview with employees and managers on the work process. Process maturing services can provide information to which extend process models correspond to realistic work activities and where people had to deviate from the given schema in order to cope with particular circumstances. In this way old processes cannot only be updated but also completely new process can be derived from the actual work activities. The integrated process framework does not only provide opportunities for the design of new processes but can also help to bring existing process support to the individual users due to the semantic relations by which information and processes are related.

5 Conclusions

In this contribution we have presented conceptual foundations for a service-oriented infrastructure to support learning activities in organizations. These foundations consist of a combination of two models:

- The knowledge maturing process model describes how individual learning processes are interlinked within an organizational context and the different forms of knowledge and assets involved.
- The SER model describes interventions into collaborative processes to foster a goal-oriented development.

From these two theoretical approaches, we can categorize the services according to (1) the phases of maturing and barriers/transitions they address (and the types of knowledge assets) and according to (2) the type of intervention. Additionally, we can distinguish services that address content, process, and semantic knowledge assets.

Within the MATURE IP (which has started in April 2008), this categorization will be developed into a general knowledge and learning architecture. This architecture does not only contain reusable maturing services, but will also provide flexible toolsets to the end user based on the mashup paradigm, which empowers the end user to perform situation-dependent integration between different tools (and thus create *situational applications* for learning). These toolsets can be arranged into two families:

- a **Personal Learning and Maturing Environment** for supporting the individual's learning processes embedded into work processes and for fostering the individual's engagement in maturing processes.
- a **Organizational Learning and Maturing Environment** for taking the organizational perspective or intervening into individual learning processes from an organizational perspective

The maturing services will co-evolve with these environments in a participatory design approach. Within the first year, several design studies have been prepared and have been evaluated with various end users, bringing end users, experts on individual and organizational learning, and developers into an intensive and creative discussion process.

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