Enabling Learning on Demand in Semantic Work Environments: The Learning in Process Approach

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1. Introduction

The new flexibility of workers and work environments makes traditional conceptions of training in advance, in rather large units and separate from work activities, more and more obsolete. It is not only the problem of inert knowledge (i.e., knowledge that can be reproduced, but not applied; Bereiter, 1985), but also the degree of individualization of learning paths these traditional methods cannot cope with. What we actually need is a learning on demand, embedded into work processes, responding to both requirements from the work situation and from employee interests, a form of learning crossing boundaries of e-learning, knowledge management and performance support (Schmidt, 2005). Many see self-steered learning as the salvation for that new paradigm (in contrast to course-steered learning activities), but this ignores the fact that guidance is essential – both for the learner (reducing her cognitive load) and for the company (enabling the manageability of learning processes). As a consequence, we have elaborated a concept in between: context-steered learning in which learners get contextualized recommendations of learning opportunities.

Implementing such a method requires a semantic work environment infrastructure that allows computer systems for getting hold of work situations and the learning needs arising out of them. Especially crucial is a semantic model of human resource development in such a setting just at the right level of complexity (not simplifying too much, but still manageable), a set of services and a user context management component for capturing and maintaining the information about what the user is currently doing and what's her state.

2. Background and State of the art

The idea of a learning on demand at the workplace has been very popular for the last threes years. However, this has not resulted in a well-defined (research) community for investigating the means to support it, but is rather scattered among various disciplines. There is not even an agreed term for this form of learning. Terms range from "embedded learning" (Richard Straub, 2005), via "work-integrated learning" (Lindstaedt, 2006) up to "workflow learning" (Cross, 2005).

In our research, we coined the term "context-aware workplace learning support" (Schmidt & Braun, 2006) to denote any automated means of learning supported which are based on the situation of the user in her work processes. It builds upon experiences and results in many different fields among which the most important ones shall be summarized in the following:

– **Business-process-oriented knowledge management** (BPOKM, e.g., Abecker, 2004) has realized the importance of the process context for context-aware delivery and storage of knowledge assets. Recently, the approach was further developed towards informal learning techniques, e.g. in (Farmer 2004). While it is true that business processes are an important element of the work context, they definitely are too narrow, although there are some approaches extending it like Hädrich (2005). Furthermore, BPOKM has so far ignored the concept of pedagogical guidance completely, viewing the problem mainly as a retrieval problem of the right content.

– **Just-in-time Information Retrieval.** The approach is similar to BPOKM with the difference that is does not particularly focus on business situations, but rather on a general task context (Rhodes, 2002). By its generic nature, it allows only for a shallow consideration of context, usually only keyword-based query generation.

– **Macroadaptive e-learning approaches** like Woelk (2002) or Davis (2005) mainly adapt to the learner in terms of delivery. They filter the learning content based on the learner's competencies and the knowledge requirements of the current position or business process context. While this is an important step into the direction of context-aware learning support, they

only consider rather static elements of the context, which does not allow for deeper integration of working and learning processes. Interesting developments are in the direction of context-aware recommendations like in Lemire (2005), but they have still a notion of context too limited for holistic workplace learning support.

- **Microadaptive e-learning approaches** and adaptive hypermedia approaches are probably the area of research with the longest history and highest activity (Brusilovsky 2001, Park 2004). They focus primarily on the learning object behavior itself and how to adapt it to the learner and her characteristics. Recent approaches include capturing the learner's context with the help of eye-tracking (Gütl 2005). The main problem of current adaptive e-learning approaches is that they do not consider learning in a work context, but rather set up artificial contexts in learning labs. They allow for a deep contextualization on the personal level, but neglect the organizational context completely.

- **Intelligent tutoring systems** (ITS) rely on AI techniques to provide complex adaptive behaviour. These systems have mostly focused on supporting and scaffolding of problem solving in learning (Brooks et al. 2006). In contrast to the microadaptive approaches in the previous paragraph, their adaptive behaviour is based on rich knowledge representations, and they use cognitive diagnosis and user modelling techniques to respond to the needs of the learners. The key problem of ITS is that they usually require a closed domain for which the system is built and thus do not integrate well into working processes.

All these approaches tackle the problem from a certain perspective, but so far, an integrated perspective with a holistic notion of context and with a clear understanding of learning-related problems is still missing. In the following section, we will present a method framework for learning on demand (context-steered learning, section 3) before investigating the technical means to realize it (model and services, section 4 and 5). Finally, the problem of user context management is briefly sketched (section 6). To round off the picture, a walkthrough of the system is given in section 7 before the chapter concludes with a summary (section 8) and future research direcions (section 9).

3. Method: Context-Steered Learning

Context-Steered learning draws from experiences both in e-learning research (see above) and from information behaviour research (e.g., Niedzwiczka, 2002 and Kuhlthau, 2004) and tries to (a) lower the barriers to learning activities and (b) to avoid frustration of learners because of subjectively irrelevant learning offers (because it does not fit the task at hand or because it cannot be understood with the current competency level). Here, the system observes the (potential) learner's work activities, while she interacts with her everyday applications. The system deduces from its domain knowledge and the learner's knowledge potential knowledge gaps. For these gaps, the system can compile small learning programs from available learning resources and recommend them to the learner, who can decide whether to learn now, to postpone it, or to discard the recommendation completely. The system can also recommend other colleagues (e.g., having been in a similar situation recently or being an expert for the current competency gap) for informal learning.

Context-steered learning can be visualized as a process cycle, which appears as an on-demand 'detour' of the working processes and can be broken down into the following system primitives (see fig. 1, see Schmidt & Braun, 2006):
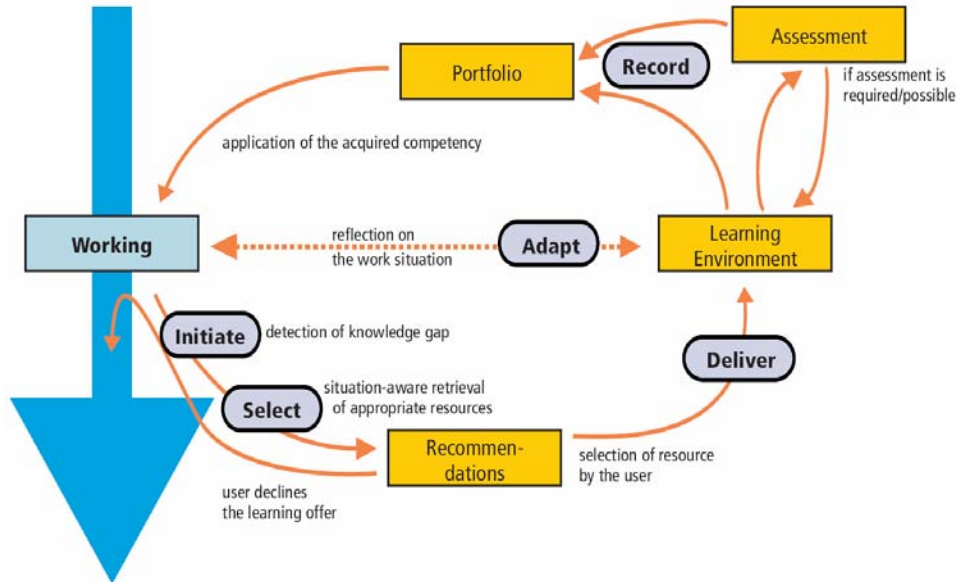
Figure 1: Context-Steered Learning and System Behavior Primitives (Schmidt 2006)

– **Initiate.** In the first phase, the system detects based on observations of the work context and background knowledge if there is a learning opportunity. This functionality refers to the timing *(when)* and modality *(how)* of interventions. The latter is important to consider avoidance of the negative effects of interrupting.

– **Select.** Appropriate learning resources helping to satisfy the learner's knowledge need and that fit to the learner requirements are selected.

– **Deliver.** It may seem that recommending learning objects (or other documents) already imply that we have determined what to recommend. But this is only partially true. Certain resources cannot be understood by the learner because she does not meet the prerequisites. So it is often necessary to compile longer learning programs that incorporate the prerequisites.

– **Adapt.** This is the domain of classical micro adaptivity in e-learning. This incorporates the adaptation of navigation (between different content parts of one learning object or between learning objects) and of presentation and behavior of (active) learning

content. The latter refers to complex and very specific forms of adaptation of individual learning objects (so-called "context-aware learning objects"), like reflecting the actual work situation in a simulation.

– **Record.** One often neglected aspect in the business context of classical formal training are certificates that can be obtained after successfully attending training activities. As a replacement in more informal context where no certificates exist, electronic portfolios can take the role. They can both record results of assessments (where they are available) and the learner's reflections After completion of this micro learning process, the learner returns to his working process and has the possibility to apply the newly acquired competencies—and to return to the learning process if it has turned out that learning was not as successful as expected.

4. Model: Conceptualizing Learning on Demand

In order to actually provide learning support for the sketched context-steered learning method, the system needs to know (a) about the learner and her competencies, (b) about the characteristics of the situation the learner is in and (c) about available learning opportunities. This requires a deep understanding of the domain of the user. Ontologies have proven their usefulness for representing domain semantics in a formal way so that it is usable in a machine-processable way.

For conceptualizing context-aware workplace learning support, we have developed the Professional Learning Ontology[1] (Schmidt & Kunzmann, 2006) based on the LIP ontology (Schmidt, 2005). It is structured into three main parts (see fig. 2):

- **Learning opportunities** encompass both traditional pedagogically-prepared learning material like small learning objects and more informal learning opportunities like colleagues or documents used within work processes. These opportunities have to be described with respect to their contributions to the development of the learner's competencies. These contributions are different depending on the type of learning opportunity: while we cannot assume much more than colleagues or documents helping on a certain topic, pedagogically prepared learning

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[1]   Available under http://www.professional-learning.eu

objects are expected to have a learning objective to be expressed as a competency. The acquisition of these competencies can also be assessed using specific assessment objects. Describing objectives (or topics) is usually not sufficient (except for communicating with a colleague where in the course of interaction prerequisites can be explained), but has to be complemented by prerequisites that have to be met in order to understand the learning opportunity.

- **Users.** The second part of the ontology is directly concerned with the users (both in the role of an employee in work processes and of a learner) and their respective context. This context can be divided into a personal context (containing competencies, learning preferences, mid- and long-term learning goals, among others), a social context (containing relationship to others), an organizational context (describing the user in terms of organizational entities like department, roles, business processes, tasks) and a technical context with the capabilities of the technical equipment.

- The **Domain ontology** provides the glue between the user (and her situation) and the learning opportunities. The domain ontology consists of a competency catalog (specifying competencies with differentiated competency levels and their relationships like containment and subsumption), an organizational model (consisting of processes and organizational units) and requirement profiles attached to elements of the organizational model.
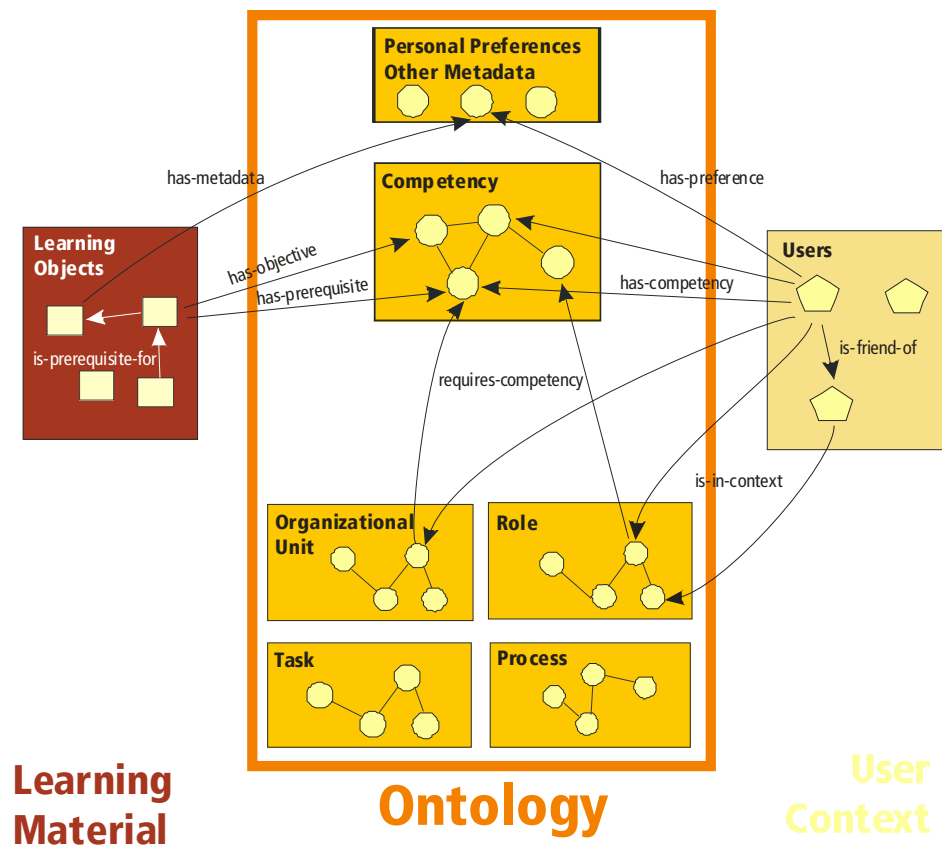
**Figure 2: Ontology-based Conceptual Model for
Learning on Demand**

For recommending learning opportunities, this ontology can be used as follows (see fig. 3): as soon as the system knows about the context of the user, it can derive from the user's context entities (like task, process context) via the attached requirement profiles the required competencies. After comparing with the user's current competencies, a competency gap can be identified. This takes into account competency relationships like part-of, is-a relationships and subsuming competency levels. Finally, the competency gap is matched with learning opportunities in order to compile a sequence of learning opportunities (a so-called learning program), taking into account prerequisites and learning preferences as well as simple pedagogical templates (like instruction, practice, assessment).
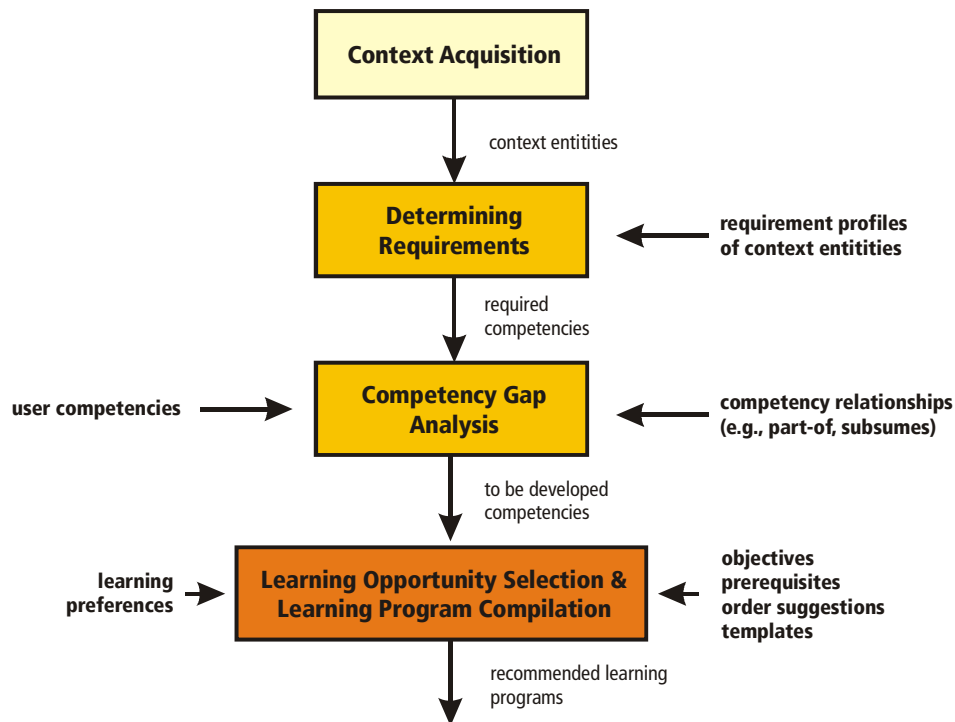
Figure 3: Using the ontology for context-steered learning

5. Technology: A Service-Oriented Infrastructure

The implementation is based on a hierarchically structured service-oriented architecture, decomposing the system functionality into loosely coupled components that allow for an easy exchange of selected components. This is required both for an integration into real-world corporate environments and for evolving research ontop of a common platform. The top-level services, organized into three layers, are given in fig. 3:

– **User-oriented services.** On the topmost level, there are services directly visible to the user/learner. This compromises a learning environment for interacting with learning objects and programs, e.g., an extended SCORM-based LMS that provides context information to learning objects. The second class of services are communication services like email, instant messaging, but also discussion forums. For the proactive system functionality, a learning assistant is responsible, recommending relevant learning

opportunities (both content and people) or learning programs embedded into the user's working environment (either as a tray application or directly embedded in applications).

– **Added-Value Learning Services** are a family of services responsible for detecting competency gaps based on information from the enabling services layer, retrieving relevant learning objects or colleagues, compiling learning objects into personalized learning programs and negotiating interests between learners and informal teachers. These services are used by the user-oriented services to adapt to the context.

– **Enabling Services.** This layer consists of a learning object repository (which holds all content — formal and non-formal — and its metadata), and a user context manager responsible for collecting information about the user's current context from various sources (context sensors). Because of the sensitivity of the information, the user context manager often is not implemented as a central service, but rather distributed on the individual user's machines. The user context manager offers both query-response and publish-subscribe interaction patterns. Finally, the ontology service keeps background knowledge about the domain, which comprises among other things a competency catalog, organizational structures like business processes, organizational units, tasks etc. and their respective competency requirements.
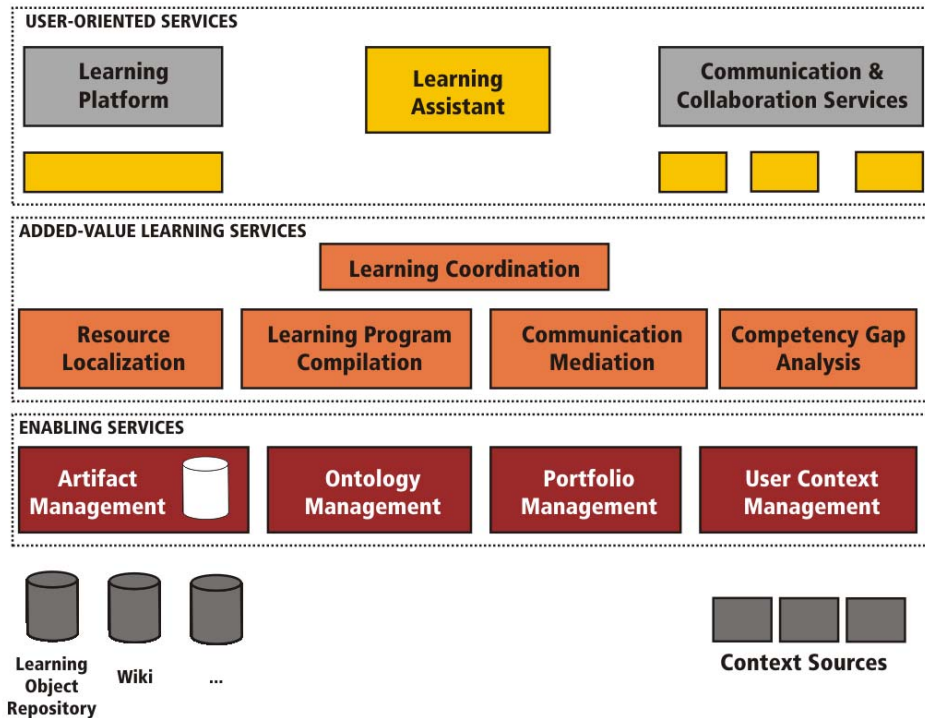
**Figure 4: Service-Oriented, Context-Aware Infrastructure
for Learning on Demand (Schmidt 2005)**

6. User Context Management as an Enabling Technology

What was presented so far depends for its credibility and technical realizability on the availability of user context information: what the user knows, what she does, and what constraints for the appropriateness of resources are. Closer inspection (Schmidt, 2006a) reveals fundamental challenges. Most of them can be traced back to the problem that the system cannot *sense* the usage situation (as the subset of the state of the real world relevant to the interaction with the system) directly, but has to rely on the usage context as a model for that situation. This model is the result of a mapping which is highly imperfect in its nature: it is incomplete, uncertain, and possibly inconsistent. This is aggravated by the problem of dynamics. On the one side, it is often not possible to determine context on demand, but rather the system has to collect its pieces in advance *(asynchronicity of acquisition and usage).* But on the

other side, some parts of the context change often quite quickly, others are rather stable *(variability in the rate of change)*.
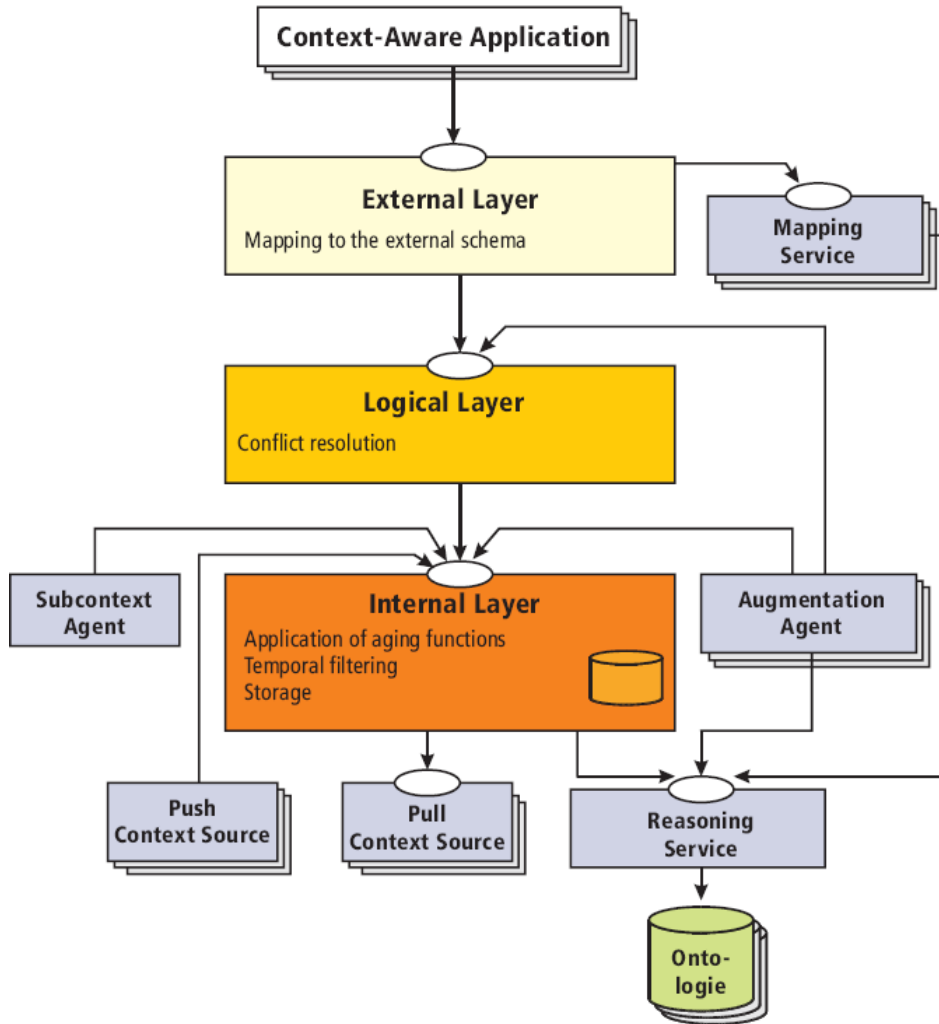

Figure 5: Architecture of the User Context Management Service (Schmidt 2006a)

This demands for a user context management service that handles transparently the uncertainty and dynamics. Our context management infrastructure is divided into four layers to keep the complexity of the task manageable.

The lowermost layer consists of the *context sources* which can either push the relevant context information into the management service or from which the user context management service can pull information by querying. Examples are ERP systems or IDEs (for organizational context, depending on the environment), or personal information managers like Outlook or instant messaging clients (for personal and social context).

On top is the *internal layer* that provides a temporal database of context facts. These facts take the form of *user x has-context-feature Y*, annotated with timestamp, validity interval and confidence. Key to solving the problems of managing context information on this layer is the introduction of the concept of aging into user context management, which combines the aspects of uncertainty and dynamics. Aging of context facts means that the confidence in acquired context facts decreases over time, starting with the initial confidence of the context source. This results in a controlled forgetting of context facts. It should be obvious that aging has to be specific for different features of the context: while the *current task* may change quite quickly, other features like role, but also personal preferences are slow to change. So the context schema is annotated with aging profiles.

The *logical layer* takes care of providing a uniform and consistent view on the context of a user. If we deduce the current task of a user heuristically from a variety of sources, this usually does not yield a consistent result. Additionally, the competencies of a user also have to be determined via indirect methods based on observations of the user's behaviour so that at one occasion the system has a fact that a user has a competency while at another instant in time, the system comes to the conclusion that she does not have the competency. The logical layer takes care of these conflicts, i.e., contradictions between context facts (positive and negative facts, or multiple values for a single valued feature). This can be done using the temporal and confidence information. The system can be configured to use different strategies for conflict resolution, also based on the context feature.

The *external layer*, finally, provides mappings into application-specific context schemas. That way, the same context management infrastructure can be used for different applications.

Within our prototypes (Schmidt, 2005, Schmidt & Braun, 2006), we have connected a wide range of context sources on two platforms (Windows and MacOS X): browser plugins for Internet Explorer and Mozilla for browsing activities (and Windows explorer actions on the file system), a

Microsoft Office plugin for information about active documents, Microsoft Outlook plugin for access to calendar and contacts, Jabber-based instant messenger plugin for presence information, a plugin for the Apple iCal application for tasks and appointments, an extractor for the Apple Address Book application to extract social relationships, environmental sensors like door, phone, and speech sensors, mouse and keyboard activity sensors, among others. Low-level sensor data was — where required — aggregated to higher level context information with the help of Bayesian networks.

8. A Brief Walkthrough

In order to have a clearer picture how the sketched learning-on-demand system actually works, let us take the example of Esther, a project manager for small- and mediums-sized projects. Yesterday, she was informed that she is supposed to take over a running European research project as well. When she logs into the project management system and switches to the research project, the system detects (via adapters to the project management system) her new project context. She then opens Microsoft Project to get an overview of the project's work plan and then Excel Sheet for EU Cost Statements. Based on the opened applications, the context management infrastructure concludes that Esther is in the task of EU Cost Statements with a confidence of 80%. The system also has some evidence that she deals with resource planning, but this has lower confidence so that it is not taken into account. In the domain ontology, it has been modeled that you need to be competent in *EU Project Reporting* and have intermediate experience in *Resource Planning*. From Esther's competencies (see also fig. 6), the system determines the gap: she needs to learn about EU Project Reporting. There is a learning object that intends to deliver intermediate knowledge of the subject, but it requires the learner to be already competent in EU projects so that she gets a learning program that consists of (1) an introduction to EU projects, (2) a learning object on EU Financial Reporting and (3) an assessment for the previous learning objects; this learning program is presented to her by the Learning Assistant in the system tray. She works through this SCORM-compliant learning program, and the outcome of the assessment as well as her personal notes are recorded in her portfolio.

When trying to start with the actual work, she discovers that the learning program was not sufficient to cope with the task in an adequate manner so that the system also offers colleagues that did the same task recently

(based on their context history) and some templates for doing calculations and asking partners for necessary data (based on the topic assignment of these documents). After asking a colleague and having a look at the documents, she makes some notes in her portfolio and then continues with her task successfully.
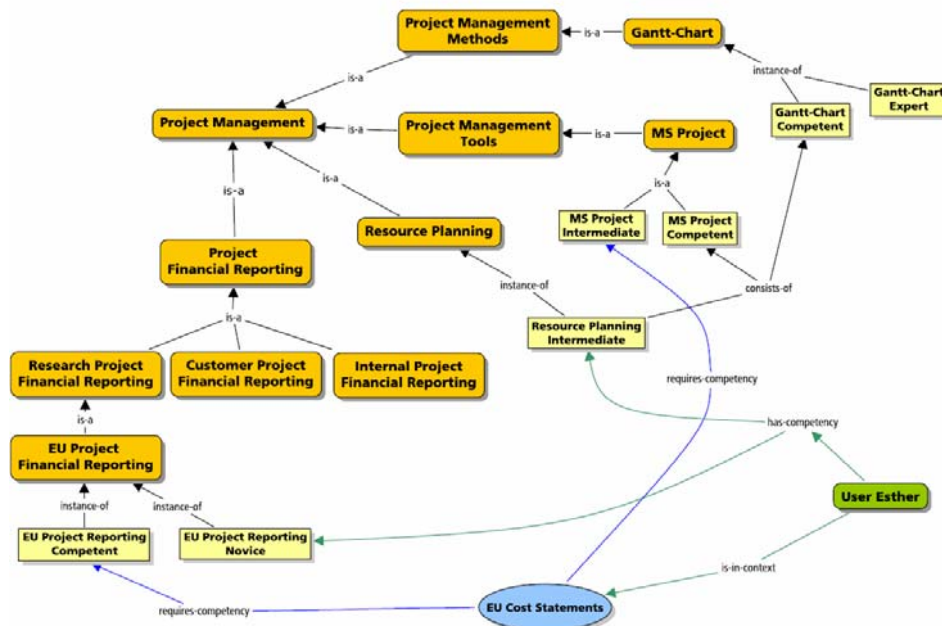
Figure 6: Example competence structure

9. Conclusion

Learning on demand is an important element for a modern work environment for knowledge workers. It allows for flexible learning embedded into work processes that combines self-directed learning with pedagogical and organizational guidance. In the light of current trends towards personal learning environments replacing organization-driven approaches, this seems to be an important element of a future learning ecology, reconciling individual and organizational perspectives: it does not constrain the flexibility of the individual while the organization still has the possibility to influence employees' learning processes, i.e., implement organizational guidance through specifying requirements for organizational entities like business process activities or roles..

Methods for learning on demand like context-steered learning rely on automated techniques to keep the flexibility manageable. Context-steered

learning implements pedagogical guidance (and thus goes beyond simple information delivery) by considering not only the current information/learning needs, but also prerequisites for understanding the provided resources and a limited form of meaningful (in the pedagogical sense) order. This loose form of guidance represents a compromise between strong (and thus also expensive) structural (in courses) or even personal guidance (in blended learning settings) and almost no guidance in pure information retrieval settings.

On the technological level, semantic modelling in the form of ontologies has demonstrated that it allows for (a) representing complex domains and (b) providing a sound basis for the architecture of loosely coupled service-oriented infrastructures. Combined with the crucial issue how the system actually finds out what the user does and needs, semantic work environments (like Semantic Desktop infrastructures) offer the potential of providing an infrastructure that already provides a lot of semantic information that is needed for learning on demand (Braun, Schmidt & Hentschel 2007). The presented service-oriented architecture can easily be integrated into a framework with a larger scope.

10. Future Research Directions

First user evaluations have shown that context-aware workplace learning support has proven to be a useful concept for learning support in semantic work environments. But the concept has still a long way to go to widespread adoption. This is mainly due to the effort needed to set up the required semantic infrastructure. Usually, standards are the vehicle that allows for reducing efforts to adapt systems to the respective environment. This has been the main focus of e-learning developments in the last years. Standards like SCORM and the related IEEE LOM metadata standard have, however, focused (a) on the content itself and (b) on describing decontextualized individual learning, rather than trying to incorporate the work context.

If these standards want to facilitate context-aware workplace learning, they have to

- closely align with standardization activities in the area of competencies (like IEEE Reusable Competency Definition)
- incorporate organizational metadata like the organizational context presented above

- extend their coverage to more informal and less mature learning opportunities

Moreover, it is essential that a reference ontology for describing context is developed so that the modelling effort is substantially reduced. The Professional Learning Ontology can be a starting point in these developments.

Another current trend is constituted by Personal Learning Environments (Attwell, 2007), which are an emerging paradigm for supporting the active side of learning (in contrast to "consuming" learning resources). These PLEs are currently mainly understood as a collection of communication, collaboration, and knowledge structuring tools and do not consider context-awareness at all. However, it seems to be natural to complement the PLE idea with context-steered learning in the future.

As far as the very concept of context-awareness is concerned: Although we have significantly broadened the notion of context for workplace learning support, we still see remaining challenges in the following areas, which will be the subject of our further research (especially within the scope of the FP7 EU Integrating Project MATURE, www.mature-ip.eu):

- **Socially-aware learning support.** In our approach of context-aware mediation of communication, we have started to address the social dimension of informal teaching. However, we see a big potential in exploring this issue further by developing a more differentiated social ontology (building on prior work like Masolo, 2004 and Matsuo, 2004) and by crafting more advanced elicitation methods (e.g. from email communication) for gaining this information. This approach must not be confused with social network analysis, which represents a macro perspective on social relationships (and often introduces difficult ethical issues), whereas we favor an approach focusing solely on the individual's rating of social relationships.

- **Maturity-aware learning support.** In contrast to school and university education, workplace learning has always been pragmatic with respect to the resources used for learning, ranging from pedagogically sound learning objects to casual documents and highly contextualized entries in discussion forums. Although the motto *anything helps* is better than insisting on a high level of quality, it should also be obvious that not everything is

appropriate for everyone. In Schmidt 2005a we have presented the notion of knowledge maturity, which has a direct impact on the teachability. Immature resources like discussion entries are only useful if you have a high contextual overlap, whereas learning objects or even courses are useful for (almost) anyone. Our context-steered learning method should thus be extended to capture and make use of maturity information about resources and also relate them to competency levels of employees (see Schmidt 2007).

– **Continuous evolution of the underlying semantic models.** Most approaches based on semantic technologies (including the presented one) rely on explicit models of the real world (in most cases in the form of ontologies). In order to ensure the sustainability of these approaches, these ontologies (like competency, or process ontologies) need to be continuously updated. However, current methods requiring specialized knowledge engineers introduce a considerable time lag until relevant changes to reality are reflected in the ontology (see Hepp, 2007). To cope with this challenge, we need to rethink ontology engineering as a bottom-up and work-integrated activity coupled with learning processes. A promising approach is ontology maturing (Braun et al., 2007), comprising a general phase model and lightweight work-integrated engineering tools.

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