

A Competence-based Approach for Formalizing Learning Goals in Work-integrated Learning

Tobias Ley
Know-Center, Graz, Austria
tley@know-center.at

Barbara Kump
Graz University of Technology, Graz, Austria
bkump@tugraz.at

Armin Ulbrich
Know-Center, Graz, Austria
aulbrich@know-center.at

Peter Scheir
Know-Center, Graz, Austria
pscheir@know-center.at

Stefanie N. Lindstaedt
Know-Center, Graz, Austria
slind@know-center.at

Abstract: The paper suggests a way to support work-integrated learning for knowledge work which poses a great challenge for current research and practice. We first present a Workplace Learning Context Model which has been derived by analyzing knowledge work and the knowledge sources used by knowledge workers. The model specifies an integrative view on knowledge workers' work environment by connecting learning, work and knowledge spaces. We then focus on the part of the context which specifies learning goals and their interrelations to task and domain models. Our purpose is to support learning needs analysis which is based on a comparison of tasks performed in the past to those tasks to be tackled in the future. A first implementation in the APOSDLE project is presented including the models generated for five real world applications and the software prototype. We close with an outlook on future work.

Introduction

This paper focuses on learning in an increasingly important field of work. We are seeking to support learning in knowledge work where the critical work resource within value creating tasks is knowledge (Drucker, 1994). Knowledge work operates in a constant tension between personal goals and organizational constraints. Because of ever changing work environments, and due to decreasing half-life periods of knowledge, persons engaged in knowledge work have to permanently acquire new knowledge and skills. In order to maintain and augment the productivity of knowledge work, learning as well as the application of knowledge has to take place directly at the workplaces. According to Haskell (2001), work-integrated learning aims at fostering the learning transfer (i.e. the application of what has been learnt to current job activities). Furthermore, aligning learning to organizational goals and task requirements is an important factor, which even poses challenges for traditional personnel development instruments and trainings. How this alignment can be addressed within knowledge work, remains an open issue even more (Elkjaer, 2000).

It is obvious that, work-integrated learning cannot merely rely on pre-defined development plans and on learning resources, which are specifically designed and produced for dedicated learning situations. Therefore, many approaches to work-integrated learning seek to reuse results of work tasks as learning material. As a positive side-effect, reusing content that has been produced in a concrete work situation would enhance the potential learning

transfer for the learner. Very often, learning is triggered when workers are facing a challenging situation, for instance a task they cannot perform without help (Kooiken, Ley & de Hoog, 2007). In such a learning situation, the workers have to actively look for learning resources that could be accurate for satisfying their learning need. This means, work-integrated learning happens mostly in an informal and self-directed manner (Pinchot and Pinchot, 1996). As the accuracy of learning content might be influenced, e.g., by the workers' actual tasks, personal competency disposition and work domain, detecting the own learning need is one crucial precondition for efficient work-integrated learning. Since the main part of knowledge work happens at computer-based workplaces, technology has been seen as a valuable means to support the workers in selecting the most appropriate learning content in a learning situation.

With this paper, we present an approach to technology-enhanced work-integrated learning that is currently being developed in the course of the APOSDLE¹ project. In brief, by offering knowledge workers easy access to relevant knowledge artifacts and persons in a workplace learning environment, they still have considerable freedom to work and learn in a self-directed manner. In order to address organizational issues in self-directed work-integrated learning, we take into account the context in which the knowledge worker operates. The context is made up of several elements which address aspects of the task and the organizational setting (such as the process or domain the person currently works in, and the competencies required for performing the work).

The purpose of the current paper is to first introduce a context model for workplace learning which has guided our understanding of the relevant constituents that make up a user's work environment and the relationships between them. We will then focus on one of the aspects of this model and show how a formalization of competencies and learning goals allow us to perform learning needs analysis which is embedded in the work context.

The Workplace Learning Context Model

We refer to the context in which a person operates as the Workplace Learning Context. It is comprised of information relevant to a person's workplace. Given the case of a typical IT-based workplace of a knowledge worker, the Workplace Learning Context needs to take care of at least three conceptual spaces that are considered to make up the workplace in terms of the resources and structures to access knowledge (Lindstaedt and Farmer, 2004): the *work space*, the *learning space* and the *knowledge space*. Each of these three spaces provides specialized tools and structures supporting one of three roles a knowledge worker typically fills at the knowledge based workplace (Figure 1):

- *Worker*: This role is typically supported by the *work space*. The work space contains work-relevant tools and resources. Resources and information contained in it is structured according to work processes and tasks.
- *Learner*: This role is typically supported by the *learning space*. The learning space contains resources and measures for individual competency acquisition. The learning is structured according to learning topics but often does not provide information about the relationship between work tasks and learning resources that contribute to competency development.
- *Expert*: The expert role is typically supported by the *knowledge space*. The knowledge space represents the knowledge that is stored within organisational memories and covers structuring, relationships and semantics of that knowledge.

It should be noted that all three individual spaces are normally structured differently (mutual structural disconnection) and are implemented by heterogeneous systems (mutual technical disconnection) (Lindstaedt and Farmer, 2004).

¹ <http://www.aposdle.org>

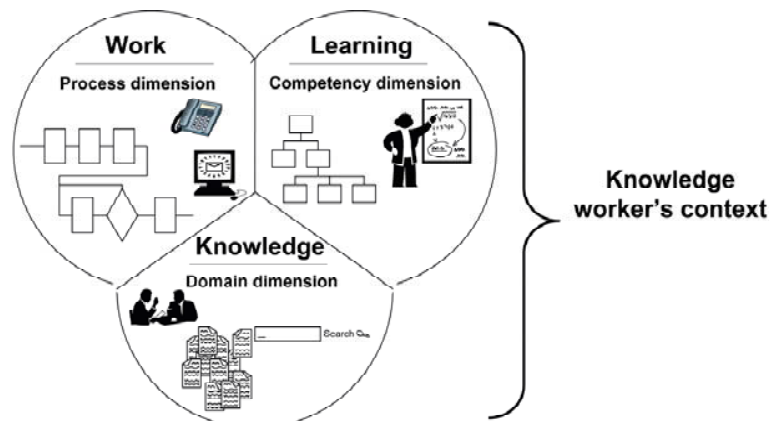


Figure 1: The context of a knowledge worker (adapted from Lindstaedt & Farmer, 2004)

In order to support work-integrated learning all three roles a knowledge worker can fill need to be supported. The Workplace Learning Context conceptually wraps the three roles in terms of their different needs to access resources and serves to integrate them in a unified model, which in the following is referred to as *Workplace Learning Context Model*. The Workplace Learning Context Model represents the three roles of a knowledge worker and provides a mapping from the three spaces onto a unified context model. The Workplace Learning Context Model thus spans the user's *work context*, the *competency profile* and the current *knowledge domain* in focus.

A comprehensive Workplace Learning Context Model needs to cover a broad knowledge spectrum from organizational knowledge to knowledge of individual employees. Because employees are the main target and beneficiaries of the model, modeling *competencies* of knowledge workers is a key requirement for providing appropriate support for work-integrated learning. Knowledge workers can be regarded to be individuals that generate, operate on, access and manipulate organizational knowledge and act within this broader organizational knowledge context. Therefore, it is crucial that the Workplace Learning Context Model deals not only with individual knowledge but also with the organizational knowledge context. Organizational knowledge can be regarded to consist of *procedural* and *declarative* aspects (Hartlieb, 2000). This distinction is of highest importance, especially in the light of latest research on process-oriented (procedural, see for instance Remus, 2002) and ontology-based (declarative, see for instance Gronau et al., 2003) knowledge management as well as in the light of latest standardization efforts in industry that include e.g. standards for process management (ISO, 2000). Each of the three spaces introduced above can be mapped onto one of these aspects of knowledge: Individual knowledge finds its representation in the learning space since both of them cover the acquisition of competencies. Procedural organizational knowledge is related to the working space and declarative organizational knowledge is related to the knowledge space.

In the Workplace Learning Context Model, each of the separate spaces is taken care of in its own dedicated package: The competency package, the process package and the domain package. Each package is subsequently described in more detail (for a more thorough discussion, see Ulbrich et al., 2006).

The Domain Knowledge Package

Usually, knowledge artifacts and resources are stored within organizational databases. In order to administrate such databases, and to retrieve documents, a certain structure is required. Very often, this structure is realized using a formal model, such as a domain-specific ontology, for representing the domain knowledge and defining semantic dependencies among domain concepts (Gruber, 1993). To each artifact, a number of concepts from a domain-specific ontology can be assigned in the form of metadata. Concepts serve to describe the content of the artifacts by semantic annotations. The created semantic metadata (i.e. the concepts in the ontology) is applied to artifacts present in the organizational memory. This is done to provide a way for later retrieving information items relevant for the current work situation. Consequently, resources are placed within an ontology and can be found and retrieved using ontological concepts as search terms.

The general purpose of modelling the domain knowledge is to represent and structure the environment the knowledge worker operates in. With our approach of a Workplace Learning Context Model, we aim at conceptualizing those entities of the workers domain that are relevant for work integrated learning and modelling the relations between the domain's concepts, by defining semantic dependencies between them.

The Process Package

The process package plays a crucial role in our conceptualization of work-integrated learning. On the one hand, the task constitutes an organizational constraint: it has to be performed by a worker, usually within a certain period of time. On the other hand, it defines the personal learning need of a worker, as the worker's goal is to perform the task within the given time.

Contrary to many existing process modelling approaches (e.g. Gronau et al., 2003; Scheer, 2000), the intention of the process package in the Workplace Learning Context Model is not to define sequences of tasks with the purpose of giving a normative description of work (e.g. Hollingsworth, 1995). As we are dealing with a learning environment, the focus is not on supporting work execution in the sense of routing tasks and/or task-related resources. For enabling the learning environment to detect the work context with respect to a task at hand, the process package only has to depict all tasks that have to be performed within a domain.

The Competency Package

The attention of the competency package focuses on the human user who has several attributes among which her competencies appear to be rather important, or who needs several competencies for performing a task. In other words, the competency package contains the competencies that are relevant for performing all tasks in a learning domain. Obviously, the competency package is very much dependent on the two other packages: The process package defines the scope of competencies that potentially have to be acquired, whereas the domain knowledge package limits the number of competencies that can be acquired based on the existing resources.

With the competency package we are covering those aspects of a knowledge workers' context that are related to their personal knowledge, given the competency requirements of a task at hand. In van Elst et al. (2001), personal context information is created from stereotype role-based information and individual details. Individual details comprise a person's task-specific skills, which can be used for identifying knowledge needs when a person is about to perform a certain task. In Schmidt (2004), learning resources are compiled and presented according to the results of a competency gap analysis. Sicilia (2005) presents a thorough and detailed introduction into modeling ontologies for competency management. A user competency profile then takes care of the competencies available to a user.

One drawback of most existing approaches is that there oftentimes too little consideration is dedicated towards the semantics of the composition of competencies and their interrelationships. Another drawback is that many approaches do not distinguish between competencies inherent to human beings and observable activities which have been executed during work tasks (Ley et al., 2007). With the formal competency framework to be introduced below, we show how to overcome the stated drawbacks.

Modeling Learning Goals for Work-integrated Learning

For purposes of the present paper, we focus on the competency package introduced above, its relationships to the other packages, and how it can be utilized in a workplace learning environment. Specifically, our goal is to suggest ways in which a *learning need*² can be (semi-)automatically inferred from a comparison of a person's task performance in the past, and the tasks she is about to tackle in the future.

For illustration purposes, the next section presents a scenario of how we envision the use of competencies in a workplace learning environment. In the subsequent section, we introduce a formal framework for implementing the

² This has also been termed "competency gap" elsewhere (e.g. Sicilia, 2005).

competency package for work-integrated learning as sketched out in the previous sections. The framework is based on a close connection between domain knowledge and task performance.

A Scenario for Performing a Learning Need Analysis

This section introduces a scenario which illustrates the purpose of our approach. The aim of the approach is to calculate the learning need from a comparison of tasks performed in the past to those tasks to be tackled in the future. This analysis needs two steps. As a first step, a workplace learning environment needs information about the tasks that have been performed in the past and from this derives the competencies the person has available.

Laura is a requirements engineer. She works for a medium sized software consultancy. In her past job activities she was often concerned with the very early stages of requirements projects in which a rough conceptualization of the system boundaries are usually sketched in a first rough context model. She has performed tasks such as “1.1 Build a first cut Context Model to identify System Boundaries” and “1.2 Carry out an initial stakeholder analysis” which are specified in the company’s process model. Laura’s history of task executions is stored in her user profile. As the tasks in the process model are related to the competencies needed, the user profile has automatically determined that Laura has available the following competencies: “B Knowledge of different types of system stakeholders” and “C Knowledge of building Context Models”.

As a second step, the environment needs to know which tasks the person is required to perform in the future and relate competencies needed in these tasks to those the person has available.

Laura has recently been assigned to a large project in which she is required to perform a more formal approach to modelling the context of the system. This requires her to embark in task “1.4 Allocate functions between actors according to boundaries”. The workplace learning environment detects that according to her user profile she is lacking the competency “A. Knowledge about actors, tasks, goals and resources”. As a result, the environment presents her some training material which explains these concepts and gives examples of how they are interrelated.

Interrelating the Packages of the Workplace Learning Context Model for Performing a Learning Need Analysis

In the following, we suggest an approach for performing a learning need analysis as described in the previous section, that is based on an interrelation of the process package, the domain knowledge package and the competency package. It is obvious that for inferring which competencies are required for performing a task at hand, a formal linkage between the process package and the competency package is required. This is realised by assigning to each task all competencies that are required for performing the task. Given this assignment, on the other hand, from performing a task can be inferred that the worker has available all competencies that are required for the task.

Once the learning need is defined, relevant learning resources shall be retrieved. Therefore, a link between a competency and one or more domain model elements, i.e. a link between the competency package and the domain knowledge package is needed. Consequently, if the competency is known, learning resources can be retrieved according to their metadata. These relationships are sketched in figure 2.

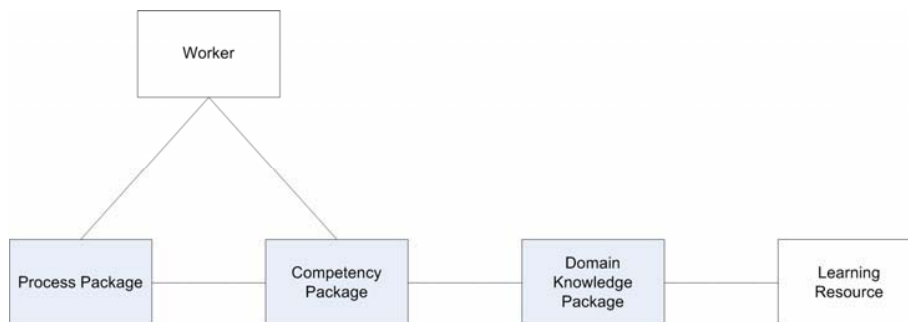


Figure 2: Interlinking packages of the Workplace Learning Context Model

Implementation of the Workplace Learning Context Approach in the APOSDLE project

We have implemented the Workplace Learning Context Approach in the APOSDLE project. A simplified view on the competency package is shown in Figure 3. In line with the focus of our paper, components referring to the competency package and their relations will be described in more detail below.

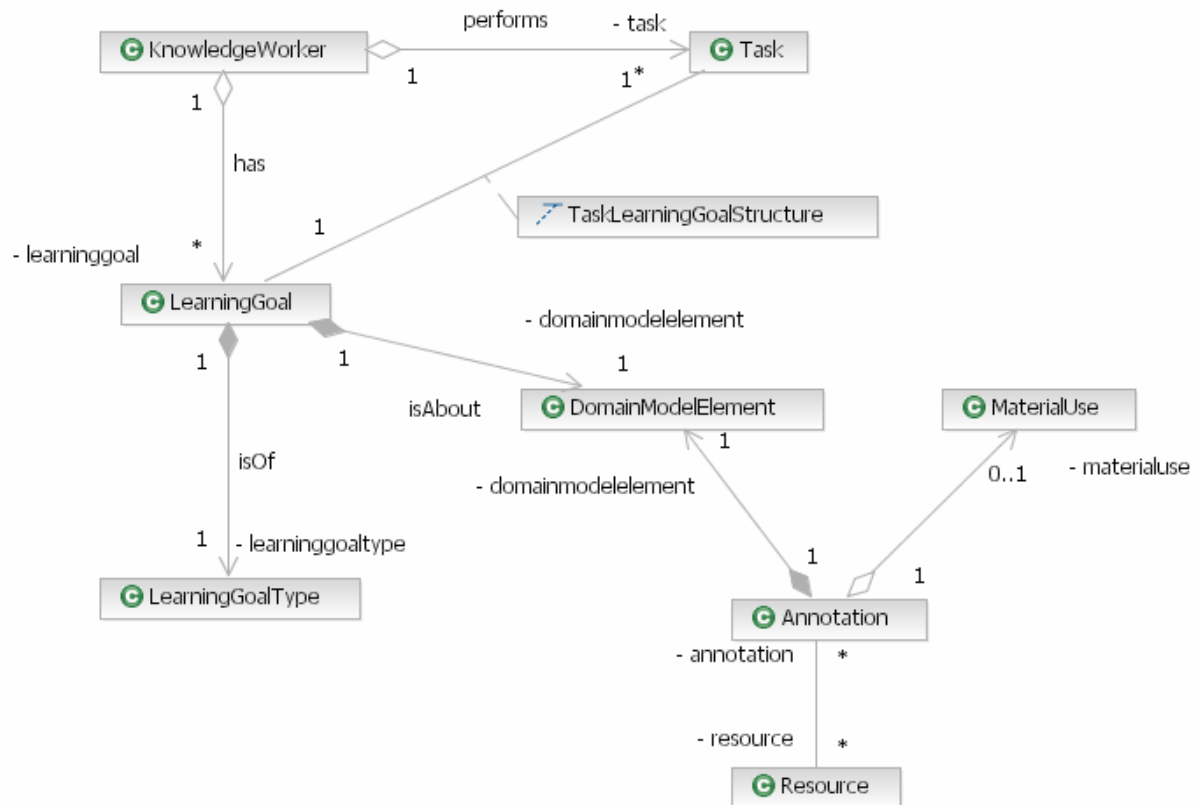


Figure 3: Competency Package as implemented in the first APOSDLE prototype

The <Task> is a task that the <KnowledgeWorker> has to perform in the workplace. It is related to the tasks specified in the process package, which is structured by a Task Model in APOSDLE. A <LearningGoal> is a single element of knowledge or a skill that has to be acquired by a user. In other words, a learning goal describes the cognitive process with regard to the domain model element which is instrumental for performing the task. A learning goal is modelled as a discrete element, either as one unit of knowledge or one single skill which a knowledge worker needs to learn. A learning goal is related to one <LearningGoalType> and one <DomainModelElement> in the domain ontology, and it constitutes the link between the competency package and the domain knowledge package. A <LearningGoalType> is an instructional attribute of a learning goal. It describes the cognitive process involved in dealing with a domain model element. The chosen learning goal types are adapted from Anderson & Krathwohl's (2001) learning (sub) processes (*remember, understand, apply, and create*). We use the cognitive process dimensions to establish the procedural component of a learning goal. So for example, a learning goal from the domain of requirements engineering could be *understand use case*, a learning goal with a more procedural focus might then be *apply use case*. This conceptualization is in line with recent developments in other FP7 projects, such as the iClass project (see, for example, Albert et al. 2007 or the Calibrate project, van Assche, 2007).

The <TaskLearningGoalStructure> is a formal mathematical model, of which the conceptualisation follows the *competence-based Knowledge Space Theory* introduced by Korossy (1997). With this theory, Korossy has introduced an extension of knowledge space theory (Falmagne et al., 1990; Doignon and Falmagne, 1999).

Knowledge space theory has been developed in the 1980s and 90s as an attempt to model a person's knowledge state as closely as possible to observable behaviour. It is predominantly concerned with the diagnosis of knowledge and has been applied in adaptive testing and tutoring systems (e.g. ALEKS Corp., 2003; Hockemeyer et al., 1998). For formalizing the relationship between learning goals and tasks, a tool (the Task Learning Goal Mapping Tool) was developed, where the modeller could specify one or more <LearningGoals> (each consisting of one <DomainModelElement> and one <LearningGoalType>) for a task. The task learning goal mapping thereby provides the interpretation function in the sense of Korossy, and a <TaskLearningGoalStructure> can be derived from it (Ley et al. 2005). The task learning goal structure serves as a connecting element between the process package, and the domain knowledge package, and it constitutes the core entity of the competency package. One of the major advantages of Korossy's competence-based Knowledge Space Theory is that it allows for deriving prerequisite relations on both, tasks and learning goals, which is relevant in case that learning paths (sequences in which several different learning goals should be acquired) are to be computed. Here, the term prerequisite means that a learning goal should be tackled if all its prerequisites have sufficiently been engaged with before. The prerequisite relation is derived automatically from the task learning goal mapping.

For completeness, we have also depicted <Annotations> which link a <Resource> to its <MaterialUse>, and the <DomainModelElement> it is referring to.

Real-World Applications and a Prototype

In the course of the APOSDLE project, the Workplace Learning Context Approach has been implemented for five realistic knowledge intensive application domains: The first domain is that of *Simulations of Aircraft Lightning*. This domain was selected because simulations are becoming increasingly important, and therefore the operational performance of engineers in the simulation domain is a crucial factor for the company. The second domain was on specialized know-how in the area of *Innovation and Knowledge Management*. In the course of the APOSDLE project, we have built the domain knowledge package, the process package, and the competency package for supporting the entire process of innovation management, from project acquisition to the documentation of outcomes.

Thirdly, we have modeled an environmental consulting domain where we have focused on *REACH*, the new European regulation on the registration and authorization of chemicals. As it is important that REACH consultants are permanently up to date with laws and regulations, REACH has been chosen as knowledge domain for APOSDLE. The fourth domain was the *RESCUE process* (Requirements Engineering with SCenarios for a User-centered environment), a standardized process for eliciting and specifying consistent requirements for socio-technical systems. RESCUE employs approved knowledge elicitation techniques, as well as use cases, and scenarios. The outcome of RESCUE is a validated set of standardized requirements descriptions. Finally, we have modeled the domain of *Statistical Data Analysis (SDA)* from the process of defining the research question to the documentation of results. The focus of this model for APOSDLE is on the support of knowledge workers in various disciplines, who need support for performing statistical data analyses at their workplaces.

For modeling the domain knowledge, the process, and the competency and learning goals in these five application domains, we have run through a standardized five-step modeling process (Ghidini et al., 2008; APOSDLE Consortium, 2007). In a nutshell, the modeling process starts with knowledge elicitation from various sources. In these initial phases, the aim is on gathering as much information as possible about the application domain. Based on this information, the most relevant domain concepts are structured in a formal domain model (ontology) by a knowledge engineer, and later refined by a domain knowledge expert. In parallel, a formal process model is built by defining tasks, sub-tasks and a sequence in which the tasks have to be performed in the domain. The task model is also validated by a domain expert. Once the domain model and the process model are stable, the two models are interlinked. Therefore, the knowledge engineer assigns to each task in the application domain all learning goals that are required for performing the task well. As mentioned above, a learning goal is composed of a domain model element, and a learning goal type. In the course of APOSDLE, we have developed a tool for supporting the assignment of learning goals to tasks, and thereby creating the Task Learning Goal Structure for the application domain. After the models are stable, documents in the application domain are annotated with concepts from the domain ontology.

In the following, we will give a rough impression about the extent, and scope of the models for the five application domains. The number of tasks in the process models was ranging between 18 tasks (Simulations and SDA) and 58 tasks (RESCUE). The lowest number of domain model elements (70) was modeled for the simulations domain, and the highest number (144) for REACH. Depending on the number of tasks and learning goals, the assignment of tasks and learning goals took two hours to one half day. In total, the knowledge engineer in the Innovation Management domain produced 211 different learning goals, for the Simulations domain 99 learning goals were created, the REACH models encompass 304 different learning goals, for RESUCE 114 learning goals were built, and 50 different learning goals were generated for the SDA domain.

The second prototype of the APOSDLE project was realized as a set of widgets which run on the desktop and displays knowledge artifacts, learning events and persons according to the context the user is in. The task is either manually selected or automatically detected, learning goals required are automatically determined from the underlying models and the user profile. In the example shown in Figure 4, the APOSDLE system has determined that the current user most likely lacks an *Understanding of Innovation Management* for the current task (see APOSDLE – Main). This learning goal is displayed together with the prerequisite learning goals and available learning events (see “Learning event Browser”), as well as several resources for learning purposes (“Resources”) and experts that may be contacted (“Experts”).

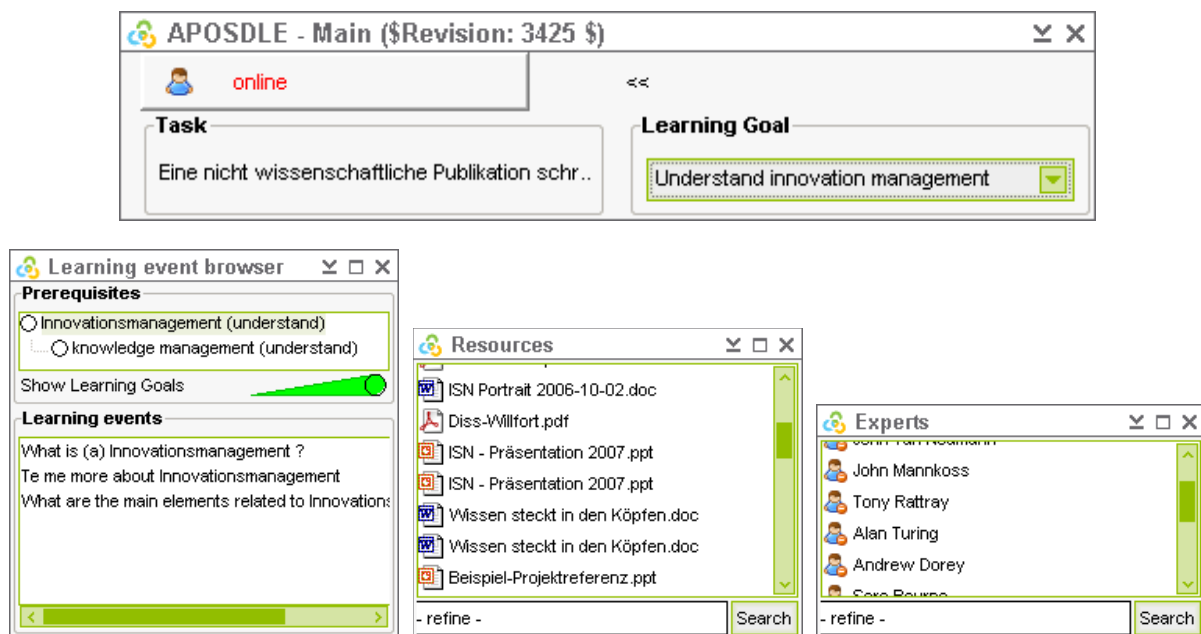


Figure 4: Widgets of the second APOSDLE prototype (APOSDLE Consortium, 2008).

Conclusions and Outlook

In this paper, we have presented a Workplace Learning Context Model. One of the elements is the competency package which was presented in more detail. A first implementation of the approach was demonstrated which allows for a work-integrated learning needs analysis. We presented data on the domains in which the approach has been introduced. We are currently conducting extensive evaluations to show the validity of the approach and its usefulness in work-integrated learning.

We are pursuing several subsequent developments to develop the competency package further. First of all, we are seeking connections of our work-integrated learning approach which generates learning goals on a very fine level of granularity, to a more general competency management approach (e.g. Ley et al., 2007). In the latter case, learning goals (competencies) are usually derived from demands of jobs (not single tasks) and are therefore on a higher level of granularity. Our approach is to model competencies as collections of related tasks and skills which are derived

from the task learning goal structure. We are currently conducting analyses with several industrial cases in which the plausibility of this approach is being researched.

A second current development we are pursuing is to extend the scope of competency assessment. In the current approach, this assessment is based on past task executions. We are currently including other “competence indicating events” (such as performing collaborations on a topic, or past engagements in learning activities) into the assessment procedure.

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