Modeling competencies for supporting work-integrated learning in knowledge work

Tobias Ley, Armin Ulbrich, Peter Scheir, Stefanie N. Lindstaedt, Barbara Kump and Dietrich Albert

Abstract

Purpose – The purpose of this paper is to suggest a way to support work-integrated learning for knowledge work, which poses a great challenge for current research and practice.

Design/methodology/approach – The authors first suggest a workplace learning context model, which has been derived by analyzing knowledge work and the knowledge sources used by knowledge workers. The authors then focus on the part of the context that specifies competencies by applying the competence performance approach, a formal framework developed in cognitive psychology. From the formal framework, a methodology is then derived of how to model competence and performance in the workplace. The methodology is tested in a case study for the learning domain of requirements engineering.

Findings – The Workplace Learning Context Model specifies an integrative view on knowledge workers’ work environment by connecting learning, work and knowledge spaces. The competence performance approach suggests that human competencies be formalized with a strong connection to workplace performance (i.e. the tasks performed by the knowledge worker). As a result, competency diagnosis and competency gap analysis can be embedded into the normal working tasks and learning interventions can be offered accordingly. The results of the case study indicate that experts were generally in moderate to high agreement when assigning competencies to tasks.

Research limitations/implications – The model needs to be evaluated with regard to the learning outcomes in order to test whether the learning interventions offered benefit the user. Also, the validity and efficiency of competency diagnosis need to be compared to other standard practices in competency management.

Practical implications – Use of competence performance structures within organizational settings has the potential to more closely relate the diagnosis of competency needs to actual work tasks, and to embed it into work processes.

Originality/value – The paper connects the latest research in cognitive psychology and in the behavioural sciences with a formal approach that makes it appropriate for integration into technology-enhanced learning environments.

Keywords Competences, Learning, Workplace learning, Knowledge management

Paper type Research paper

Introduction

Knowledge workers are workers whose critical work resource within their essential value-creating tasks is knowledge (Drucker, 1994). In order to enhance the productivity of knowledge workers, their competency enhancement and learning has to take place directly at their 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).

Work-integrated learning does not merely rely on pre-defined development plans and on learning resources, which are specifically designed and produced for dedicated learning situations. Work-integrated learning instead mainly considers knowledge workers’ actual tasks, personal competency disposition and work domain as being relevant for deriving...
current learning needs. Work-integrated learning also seeks to reuse the results of the work task as learning material.

Knowledge work operates in a constant tension between personal goals and organizational constraints. On the one hand, knowledge workers increasingly learn in an informal and self-directed manner (Pinchot and Pinchot, 1996). In our approach to workplace learning, this is addressed by offering knowledge workers easy access to relevant knowledge artifacts and persons in a workplace learning environment, and thereby giving them considerable freedom to work and learn in a self-directed manner. On the other hand, aligning learning to organizational goals and task requirements is an important factor. This even poses challenges for traditional personnel development instruments and trainings. How this alignment can be addressed within knowledge work remains an open issue (Elkjaer, 2000). In order to address these organizational issues, we look at the context in which the knowledge worker operates. The context is made up of several elements that 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 first to suggest a model of a person's context with regard to workplace learning in order to better understand the relevant constituents that make up a user's work environment and the relationships between them. We then focus on one element of the user context, namely the competencies required to perform the work successfully. Competencies are used as a guide to suggest relevant learning interventions. The paper then presents a formal model for competencies and suggests a methodology of how competencies can be modelled in a specific organizational case. A case study illustrates the methodology and provides a possibility for testing its applicability.

**Context in workplace learning**

Tight integration of working and learning in a workplace learning environment relies on a clear computer-interpretable conception of what content the material in question actually conveys. A clear conception can be provided by annotating material with metadata taken from a sufficiently expressive model base (Sicilia, 2006). For reuse purposes, metadata is analyzed during the process of assembling learning material. Assembling learning material not only consists of selecting mere content, but also of putting it into new usage contexts and the contexts of other material presented (Heiwy, 2006). To integrate working and learning, far-reaching strategies need to be considered. This is especially true for the technological foundations (Lytras and Pouloudi, 2006) and the metadata models to be developed or chosen. In order to allow for the greatest flexibility in reusing material, often a number of different metadata models are chosen. In this case measures need to be taken in order to align different models with each other (Cruz et al., 2004). In order to consider the topics raised by the aforementioned modeling issues, we propose a formal model that connects competency development and work execution and is in alignment with metadata used for annotating learning material.

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 the at least three conceptual spaces that are considered to make up the workplace (Lindstaedt and Farmer, 2004):

1. the work space;
2. the learning space; and
3. the knowledge space.

These spaces are unified conceptually using the abstraction of the so-called "3spaces". Each of the spaces of the 3spaces provides specialized tools and structures supporting one of three roles a knowledge worker typically fills at the professional workplace (Figure 1):
1. **Worker** – This role is typically supported by the *work space*. The work space contains work-relevant tools and resources. It is structured according to work processes and tasks.

2. **Learner** – This role is typically supported by the *learning space*. The learning space contains resources and measures for an individuals’ competencies acquisition. The learning is structured according to learning topics but does not provide information about the relationship between work tasks and learning resources that contribute to competency development.

3. **Expert** – The expert role is typically supported by the *knowledge space*. The knowledge space represents the knowledge that is stored within organizational memories and covers structuring, relationships and semantics of that knowledge.

It should be noted that all three individual spaces of the 3spaces are normally structured differently (mutual structural disconnection) and are implemented by heterogeneous systems (mutual technical disconnection) (Lindstaedt and Farmer, 2004).

In order to support work-integrated learning, all three roles that a knowledge worker can fill need to be supported. The workplace learning context mentioned above serves to wrap up all three roles conceptually and also serves to integrate them in an unified model, which in the following is referred to as the "Workplace Learning Context Model". The Workplace Learning Context Model represents the three roles of a knowledge worker and provides a mapping from the 3spaces 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.

**The Workplace Learning Context Model**

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 the competencies of knowledge workers is a key requirement for providing appropriate support. Knowledge workers can be regarded as individuals that generate, operate on, require and manipulate organizational knowledge and act within this broader organizational knowledge context. Therefore, the development of models that deal not only with individual knowledge but also with the organizational knowledge context is crucial. Organizational knowledge can be regarded to consist of procedural and declarative aspects (Hartlieb, 2000). This distinction is of the highest importance, especially in the light of latest research on process-oriented (procedural; see, for example, Remus, 2002) and ontology-based (declarative; see, for example, Gronau et al., 2003) knowledge management as well as in the light of the latest standardization efforts in industry, which include, for example, standards for process
management (International Organization for Standardization, 2000). Each of the spaces from the 3spaces 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.

Based on this argument, this contribution introduces the three-dimensional Workplace Learning Context Model for conceptualizing a knowledge worker’s context, which consists of individual (competency), procedural (work) and declarative (knowledge) spaces, each of which is taken care of in its own dedicated package, i.e.:

- the competency package;
- the process package; and
- the domain package.

The competency package

Our attention focuses on the human user who has several attributes, among which her competencies appear to be rather important. The model in Figure 2 (in UML notation) shows that competencies are assigned to users. In this simple model, competencies are structured according to relationships, which are called “surmise”. Thus it is assumed that a hierarchical relationship between competencies exists, where simpler competencies are assumed to be predecessors of competencies of higher complexity. We will show later that, despite the simplicity of the approach, this is in line with the formal competency framework we are introducing with this contribution.

With the competency package we are covering those aspects of a knowledge worker’s context that are related to her personal knowledge. 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. Schmidt (2004) gives an introduction to the Learning in Process (LIP) project[1]. In this approach, 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. After an investigation of existing models and schemas for competencies, the major drawbacks of previous research are identified and formulated as follows. One drawback of most existing approaches is that often too little consideration is
dedicated towards the semantics of the composition of competencies. 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 these drawbacks.

The process package

Contrary to many existing process modeling approaches (e.g. Gronau et al., 2003; Scheer, 2000), the intention of this meta-model is not to model 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, but to identify and deliver available resources that support a knowledge worker with respect to the competencies required to execute her task.

In Figure 3, the classes of the process package are presented as well as their relations within the process package and between the process and competency package. A task is potentially composed of sub-tasks. To each task (or sub-task respectively) a number of resources may be assigned, which either are needed for task execution (relationship “uses”) or produced during task execution (relationship “creates”). A task is executed by a role, which is impersonated by an actor. An actor from the process package is semantically equivalent to a user from the competency package.

The domain knowledge package

The purpose of modeling the domain knowledge is to represent the environment the knowledge worker operates in. Hence we aim at conceptualizing those entities of the worker’s domain that are relevant for work-integrated learning and modeling the relations between the domain’s concepts by defining semantic dependencies between them using ontologies (Gruber, 1993). The semantic metadata created (i.e. the concepts in the

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**Figure 3** Classes from the process package and their relationships within the package as well as across the boundaries between the process package and the competency package
ontology) is applied to artifacts present in the organizational memory. This is done to provide a way for the later retrieval of information items relevant for the current work situation.

Artifacts are resources stored within organizational databases. Artifacts are semantically equivalent to resources from the process package (see above). To each artifact, a number of concepts from a domain-specific ontology are assigned in the form of metadata. Concepts serve to describe the content of the artifacts by semantic annotations. Consequently, resources are placed within an ontology and can be found and retrieved using ontological concepts as search terms. Additionally, there is a close relationship between concepts and competencies from the competency package: concepts are used for labeling competencies. Hence, the concept(s) used for labeling competencies can be used as search terms for retrieving resources.

Nevertheless, when analyzing the Workplace Learning Context Model closely it appears that it is still not possible to conclude clearly what competency need a user actually has in a given task: the model – as it is now – only allows searching for resources utilizing competencies and concepts as search terms but does not allow a competency need to be inferred. In order to close this gap, a framework and methodology are introduced and presented hereafter which serve to lay out a conceptual foundation and a comprehensive methodology for inferring competencies needed based on a user’s past performance with respect to her work tasks.

**Competencies in workplace learning: a competence performance conception**

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 competency gap 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 first section presents a scenario of how we envision the use of competencies in a workplace learning environment. In the second section, potential problems of how competencies are traditionally being used in the context of workplace learning are identified. Thirdly, we introduce a formal framework for competency management which specifies the formalization sketched out in the previous sections and which helps to alleviate some of the problems. The framework is based on a close connection between competencies and task performance. The framework informs an implementation method which is then introduced in the subsequent section and illustrated by means of a case study.

**A scenario for performing a competency gap analysis**

This section introduces a scenario which illustrates the purpose of our approach. As mentioned above, the aim of the approach is to calculate a competency gap 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 on 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.

Traditional approaches to the use of competencies in workplace learning

In past research, competency frameworks have often been advocated as a way to deal with the challenges in human resource development (Green, 1999; Lucia and Lepsinger, 1999; Erpenbeck and Rosenstiel, 2003). In these frameworks, competencies are being used to more closely relate learning to organizational requirements, such as organizational strategy, goals or task requirements. As reviews such as the one by Lehner (2004) show, most of the current approaches have been implemented using a centralized database infrastructure. The suitability of such approaches for more dynamic and knowledge-based workplaces, such as the one from the scenario in the previous section, has recently been called into question (Athey and Orth, 1999; Ley et al., 2007). A special problem is the disconnection between competency descriptions and the actual task performance. This disconnect leads to unclear meanings of the competency descriptions and therefore to unclear assessment results. It also means that assessment is not connected to the working situations in which competencies are being applied.

Ley et al. (2005) have suggested that the competence performance approach (introduced by Korossy, 1997) serve as a model to formalize competencies and their connection to workplace performance for work-integrated learning. This approach will be presented in the next section. As we will see, the competence performance approach provides a framework that formalizes the relationship between competencies and the tasks specified in the process package of the Workplace Learning Context Model (see above).

The competence performance approach

With the competence performance approach, Korossy (1997, 1999) has introduced an extension of knowledge space theory (Falmagne et al., 1990; Doignon and Falmagne, 1999). Knowledge space theory was developed in the 1980s and 1990s as an attempt to model a person’s knowledge state as closely as possible to observable behavior. It is predominantly concerned with the diagnosis of knowledge and has been applied in adaptive testing and tutoring systems (e.g. ALEKS Corporation, 2003; Hockemeyer et al., 1998). The fundamental idea of knowledge space theory is that a person’s knowledge state in a certain domain can be understood as the set of problems this person is able to solve. Since solution dependencies exist among the problems, it is possible to present a person only a subset of all problems of a domain in order to diagnose his/her knowledge state. The collection of all possible knowledge states is called a “knowledge space”. A knowledge space is a partial order and is stable under union.

In an attempt to develop knowledge space theory further, Korossy (1997) suggests that in addition to the set of problems, one should look at the set of competencies – i.e. the knowledge, skills and abilities – needed to solve the problems. This would give information...
on the reasons for different levels of performance, and thereby help to suggest learning measures. Similar to the set of questions, competencies are also structured in a competence space that results from a surmise relation on the set of competencies.

The relationship between the two sets (questions and competencies) is formalized by an interpretation function which maps each problem to a subset of competence states which are elements of the competence space. This subset of competence states contains all those competence states, in each of which the problem is solvable. The interpretation function induces a representation function, which assigns to each of the competence states all problems that are solvable in that competence state. Which problems are solvable is determined by the interpretation function.

The competence performance approach has been applied in technology-enhanced learning applications. For example, Hockemeyer et al. (2003) have assigned “competencies required” and “competencies taught” as metadata to a collection of learning objects. Thereby, prerequisite structures are derived for the e-learning content which allow for adaptive tutoring. New course content could easily be integrated, as metadata was only held locally.

Applying the competence performance approach to workplace learning

An application of the competence performance approach needs to take into consideration the following three concepts:

1. performance;
2. competencies; and
3. the interpretation function.

The term “performance” is understood to encompass all behaviors relevant for the accomplishment of a certain task in a specific situation (Schmitt and Chan, 1998). In the current approach, performance encompasses the set of all tasks that employees perform in the workplace. Each task that has been performed can be judged according to whether it was successfully or unsuccessfully performed. As defined here, the concept of performance has a close relationship to the tasks specified in the process package. For modeling competence performance structures (see the next section), we rely on the set of tasks specified in the process package. For assessment purposes (i.e. which employee has which competency), we rely on the instantiations of the tasks to determine which tasks have been performed by whom.

In the current approach, we define competencies as the personal characteristics of job-holders that they bring to bear in different situations. Competencies are hypothetical constructs that determine performance in a job. The set of competencies encompasses all knowledge, skills, abilities and other characteristics that are needed to successfully perform in the tasks. Competencies may be differentiated into knowledge, skills and other characteristics (KSAOs) (Lucia and Lepsinger, 1999; Schmitt and Chan, 1998). As can be seen from Figure 4, competency descriptions are linked to the domain ontology.

For formalizing the relationship between competencies and performance, the method of a competence performance matrix is used. This matrix assigns to each task all competencies needed to perform that task. This matrix thereby provides the interpretation function in the sense of Korossy, and a competence performance structure can be derived from it.

The matrix can be included within the Workplace Learning Context Model as shown in Figure 5. It serves as a connecting element within the competency package.

The newly added class task within the competency package (above) is semantically equivalent (but not identical) with the task-class from the process package. For practical reasons, we usually restrict the set of tasks used to construct competence performance structures to those tasks specified in the process package. In certain cases, it might make sense to include additional tasks, or to leave out certain tasks that are not relevant for learning.
The concept of the competence performance matrix as well as the way to derive competence performance structure is elaborated in the next section.

Modelling competencies: a methodology and a case study

This section introduces the methodology we use to model competencies within the competence performance framework. According to Ley and Albert (2003a), the methodology entails the following steps:

- derive a set of tasks (performance) for the position in question, and for the learning domain to be supported;
- determine competencies needed to successfully perform the tasks; and
- relate tasks and competencies (competence performance matrix).

These three steps focus on the process “defining competencies” mentioned in the overall organizational competency management process presented by Ley et al. (2007).

The methodology has already been applied in different settings (i.e. in the automotive industry and in a research-based setting). We have recently conducted a further case study focused more directly on supporting workplace learning. We briefly introduce this case study here. It will then be used to illustrate the procedure employed for deriving competence performance structures in the subsequent sections.

A case study of requirements engineering

The case study has been conducted as part of the APOSDLE project[2]. The goal of APOSDLE is to create a process-oriented learning environment which supports knowledge workers to work and learn at the workplace. The learning domain for a first prototype is requirements engineering (RE). The learning environment targets persons with various levels of expertise in RE. They may be domain experts with little knowledge of RE who have been made responsible for eliciting requirements for a system to be built, or RE specialists who need only little guidance to conduct RE projects.

Specifically, we use the RESCUE process (Requirements Engineering with Scenarios in User-Centered Environments; see Maiden and Jones, 2004). RESCUE is an innovative process developed for the elicitation and specification of requirements for socio-technical systems. RESCUE supports a concurrent engineering process in which different modeling and analysis processes take place in parallel: human activity modeling is done to provide an
understanding of how people work in order to establish a baseline for possible changes. The aim of system goal modeling is to model the future system boundaries and dependencies between actors for goals to be achieved. The goal modeling is formalized with the i* notation. Use case modeling is the process of writing use cases for the future system, exploring it with stakeholders and carrying out impact analyses in order to obtain consistent and valid requirements. These sub-processes are aligned at designated synchronization points.
During the whole elicitation process, RESCUE provides guidance on requirements management. Furthermore the use of creativity workshops encourages requirements and design ideas to be discovered and elaborated together.

The purpose of the case study is to construct a competence performance structure for the domain of RE, and specifically for the RESCUE process. The structures should then be used to automatically predict a person’s competence state from the kind of tasks successfully performed in the past, to predict performance on future tasks, and to suggest learning resources that can be of help when facing new tasks.

**Deriving a set of tasks**

The tasks can be derived from a detailed analysis of the work to be performed in the chosen domain. It is important that tasks reflect the learning domain in question well, and that performance in these tasks can be assessed with regard to some quality criteria which are agreed within the organization (i.e. whether a task has been performed well or poorly).

We have previously employed hierarchical task analysis to find tasks employees perform in a certain position (Ley and Albert, 2003b). In Ley and Albert (2003a), we chose documents produced by the workforce as a way to reflect the more dynamic nature of the tasks.

In the present case study, the set of tasks is rather easily obtained as extensive documentation exists for the work to be performed in RESCUE. The set of tasks was derived by means of a detailed content analysis of the RESCUE process document (Maiden and Jones, 2004). We focused on the two streams of human activity modeling (HAM) and system goal modeling (SGM). As a result, a first list of tasks was obtained for these two streams and later reviewed by the authors of the RESCUE process. The final list of tasks was composed of 29 tasks in the HAM stream, and 18 tasks in the SGM stream.

**Deriving competencies needed**

When eliciting the competencies needed, we rely to a large extent on techniques for eliciting knowledge from domain experts with structured interviews or questionnaires. For instance, Ley and Albert (2003a) used the repertory grid technique to elicit competencies from documents which experts had written in the past. In the present case study, a first open-ended interview was held with the two RESCUE experts mentioned above. We considered the tasks obtained in the previous step and asked the experts to name the competencies (knowledge and skills) needed to perform well in these tasks. The interview data obtained was then complemented with data derived from analysis of existing documented sources from related research, such as Van den Berg (1998) and the National O*NET Consortium (2005). From these sources, an extensive list of competencies was obtained, cross-checked for consistency and then validated with the RESCUE experts. In total the list consisted of 33 competencies.

To exemplify the procedure, we selected a subset of tasks to be achieved in the sub-process of system goal modelling. Table I shows the lists of tasks and competencies selected for our example.

**Constructing competence performance structures**

To build the interpretation function, the experts were asked to assign to each task those competencies they regarded as mandatory for successfully accomplishing the respective tasks. This was done by means of a task competency matrix (see Ley and Albert, 2003a). In the present case, the experts were asked to give their assignments independently from each other. This way, agreement can be measured as one way to evaluate the methodology and the resulting structures (see below). In continuing the example form above, Table II gives the results of this assignment. The crosses in the matrix indicate the minimal interpretation for each task, i.e. the set of competencies that a person has to have at the minimum to be able to perform the task well.

To obtain the whole competence space, the competence states of the minimal interpretation were closed under union and the empty set was added. Furthermore, for every competence
state the representation function was built by assigning to every state the set of tasks a
person would be able to accomplish in the respective state, thereby obtaining the
competence performance structure.

The competence performance structure derived for the previous example can be seen in
Figure 6. In this example, a person who is in the competence state \{B, C, D\} should perform
well in tasks \{1, 2, 7\} (the respective performance state). A person who is able to accomplish
task 4 ("Allocate functions between actors according to boundaries") is assumed to be able
to also perform task 2 ("Carry out an initial stakeholder analysis") because any performance
state which contains task 4 also contains task 2. In other words, task 2 is assumed to be a
prerequisite of task 4, since the minimal interpretation of task 2 (\{B\}) is a subset of the
minimal interpretation of task 4 (\{A, B, C\}).

The purpose of this procedure is to limit the number of competence states (and performance
states) that can be expected to appear in a population as a consequence of the prerequisite
relationships. As a result, several adaptive procedures can be applied that can be utilized
when the structures are put to use (see below).

**Using and validating the structures**

Given a valid structure of the domain, one can diagnose the competence state of a person
by evaluating his/her performance in the tasks being performed, and thereby derive a
competency gap. Given certain tasks that were performed well, and others that were not

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**Table I** Tasks and competencies in system goal modeling

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1_1</td>
<td>Build a first-cut Context Model to identify system boundaries</td>
</tr>
<tr>
<td>1_2</td>
<td>Carry out an initial stakeholder analysis</td>
</tr>
<tr>
<td>1_3</td>
<td>Develop an extended Context Model</td>
</tr>
<tr>
<td>1_4</td>
<td>Allocate functions between actors according to boundaries</td>
</tr>
<tr>
<td>1_5</td>
<td>Identify intentional strategic actions</td>
</tr>
<tr>
<td>1_6</td>
<td>Model dependencies between strategic actions</td>
</tr>
<tr>
<td>1_7</td>
<td>Write different forms of dependency descriptions</td>
</tr>
<tr>
<td>1_8</td>
<td>Produce an integrated SR model using dependencies in the SD model</td>
</tr>
<tr>
<td>1_9</td>
<td>Check the * model for completeness and correctness</td>
</tr>
<tr>
<td>1_10</td>
<td>Validate the * SR model against the SD model (cross-check)</td>
</tr>
</tbody>
</table>

**Table II** Task competency matrix and minimal interpretation of tasks in SGM

<table>
<thead>
<tr>
<th>Task</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>Minimal interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1_1</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>{B, C}</td>
</tr>
<tr>
<td>1_2</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>{B}</td>
</tr>
<tr>
<td>1_3</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>{B, C, G}</td>
</tr>
<tr>
<td>1_4</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>{A, B, C}</td>
</tr>
<tr>
<td>1_5</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>{A, B, C, D, F, G}</td>
</tr>
<tr>
<td>1_6</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td>{A, B, C, D, E, F, G, H}</td>
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<tr>
<td>1_7</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
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<td>{D}</td>
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<tr>
<td>1_8</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<td>{A, B, C, D, E, F, G, H}</td>
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performed well, it is relatively easy to find the likely competence state this person is in. If a person consistently performs well in tasks 1, 2 and 7 in the above example, but fails to perform well in task 4, this would mean that competency A (“Knowledge about actors, tasks, goals and resources”) would be a relevant learning goal. In the case of such discrepancies, one could provide the person with tailored learning contents.

This competency diagnosis can make use of the adaptive potential mentioned previously. From knowing that a person can perform well in certain tasks, it can be inferred with some certainty that this person also performs well in other tasks. This seems to be especially relevant for structures that encompass a large number of tasks where it is unlikely that performance information about all tasks is available for each and every employee.

Judgments of whether a certain task has been performed well or not (performance appraisal) can be obtained in a number of different ways. Standard procedures of self- and supervisor rating known from competency management and other human resource instruments (such as assessment centers or performance appraisal schemes) can be obtained. An important advantage when compared to many of the standard practices is that appraisal can be based on task performance which is relevant for the job that is being performed. This avoids several biases known from the appraisal of competencies (Schmitt and Chan, 1998).

The procedures for diagnosing competence states from past performance, and especially the adaptive procedures, require that the structures are valid. This is not an exclusive requirement for our approach, but in fact is essential for any appraisal system that is being put to use (see, for example, Schmitt and Chan, 1998). A special benefit offered by the competence performance approach is that it makes validating easier and offers the opportunity to integrate validation directly into the modeling or assessment process (Ley and Albert, 2004). Criteria for validating competence performance structures are discussed in Ley et al. (2007). In the present case study, an initial comparison of the assignments made by the two experts resulted in an agreement coefficient (inter-rater reliability) of $r = 0.26$ for the HAM stream and $r = 0.53$ for the SGM stream.
Conclusions

The above structures map the learning domain in terms of learning goals and the related tasks derived directly from relevant working tasks. This means that learning is specifically tailored to the requirements of working tasks and processes. The Workplace Learning Context Model has been developed in order to provide a mapping between the process, knowledge and competency spaces relevant to a given user. Hence, several ways of supporting users during their work tasks can be realized. Among them are the following:

- **Task learning** – The Workplace Learning Context Model allows for deriving resources, which are considered relevant for executing a given task, and presenting them to the user.

- **Task execution support and domain-related support** – The Workplace Learning Context Model allows for deriving those concepts of a domain ontology which are directly related to the work domain, within which the task is going to be executed.

- **Competency-gap based support** – The Workplace Learning Context Model allows for computing the competency gap between the competencies that are necessary for executing the task at hand and the competencies a user possesses, and consequently for deriving those competencies that are necessary to fill the competency gap.

As a next step, we are intending to integrate the competence performance structures into the APOSDLE environment. The learning space within this environment can then make use of the structures when delivering tailored learning material to knowledge workers in the process of an RE project. We are then intending to evaluate learning outcomes that result from use of the system by means of a large-scale evaluation study in real-world settings. An important question in this evaluation will be the added benefit which the different models provide with regard to the learning outcomes.

Outlook

The initial results we have presented above suggest that there is plenty of room for future research aiming at making knowledge management and workplace learning more effective. In particular, measures applicable for augmenting knowledge workers’ learning transfer and hence productivity deserve special attention. It is known that approaches are urgently needed that allow for better alignment of learning material with a learner’s requirements, hence boosting workforce agility (Brakeley et al., 2004). It should be stated here once again that monolithic approaches are often not appropriate. They tend to gradually lose their agility and momentum when deployed in a real-world scenario. This inflexibility is mainly due to the fact that monolithic approaches are hard to maintain and unsuited to changes and adaptations. We therefore propose to research offering knowledge services for workplace learning that strongly consider a user’s context. We envision that the applications mentioned in the scenario above might be well be suited for such a service-based approach. One such a service is an analysis service, which infers information based on a user’s past behavior. An example of this is given in the scenario above, where Laura’s competencies are automatically inferred from her past task executions. Another service concludes users’ competencies gaps with respect to the task at hand and triggers a competency-sensitive retrieval for knowledge artifacts. An example of this is given in the scenario above. Still other services might offer recommendations of learning resources that have been considered appropriate by users in a similar context.

“A comprehensive Workplace Learning Context Model needs to cover a broad knowledge spectrum from organizational knowledge to knowledge of individual employees.”
Notes
1. See www.learninginprocess.com
2. See www.aposdle.org

References


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