Providing Varying Degrees of Guidance for Work-Integrated Learning

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Abstract. We present a work-integrated learning (WIL) concept which aims at empowering employees to learn while performing their work tasks. Within three usage scenarios we introduce the APOSDLE environment which embodies the WIL concept and helps knowledge workers move fluidly along the whole spectrum of WIL activities. By doing so, they are experiencing varying degrees of learning guidance: from building awareness, over exposing knowledge structures and contextualizing cooperation, to triggering reflection and systematic competence development. Four key APOSDLE components are responsible for providing this variety of learning guidance. The challenge in their design lies in offering learning guidance without being domain-specific and without relying on manually created learning content. Our three month summative workplace evaluation within three application organizations suggests that learners prefer awarenss building functionalities and descriptive learning guidance and reveals that they benefited from it.

Keywords: Work-integrated learning, learning guidance, informal learning, adaptive system, personalized retrieval, contextualized collaboration.

1 Introduction

In current business practice and eLearning research projects, most money is devoted to improving knowledge transfer of formal training interventions to the workplace. For instance, Haskell [1] informs us that in 1998, US$ 70 billion were spent on formal training. On the other hand, studies have shown that in today's economy only a small amount of knowledge that is actually applied to job activities comes from formal training. On average, people only transfer less than 30% of what is being learned in formal training to the professional workplace in a way that enhances performance. This is independent of the kind and quality of the courses taught, but is caused by not considering work environment needs during and after formal training efforts [2].

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In the light of these findings, the CIPD – the professional body for both trainers and HR managers in the UK – has clearly articulated the need for a shift "from training to learning" (see [3] and [4]).

The question remains how this new type of workplace learning could look like and how it can be supported. Our approach builds upon the notion of Work-Integrated Learning (WIL, see Section 2) which has the potential to contribute to the above mentioned shift from training to learning by addressing continuous competency development during work. We engaged in a four year quest for building a computational environment which supports WIL. This quest was undertaken within the integrated EU-funded Project APOSDLE[1]. Applying a multitude of participatory design methods (shortly sketched in Section 3) we identified three key challenges: learning within real work situations, utilization of real work resources for learning, and learning support within real computational work environments.

This paper specifically addresses the first challenge (real time learning) and focuses on the open research question of "How much and what kind of learning guidance do people engaged in workplace learning desire, need, and actually use". Our participatory design studies indicated that learners require varying degrees of learning guidance in different situations. Section 4 introduces three different learning situations in the form of three WIL scenarios. These scenarios range from low to high learning guidance and introduce the different learning guidance functionalities provided within the APOSDLE environment.

Following this argumentation line a new research question on the more technical level arises: "How can we provide varying degrees of learning guidance without having to manually design all of them?" That is, we are looking for an environment which can provide varying degrees of learning guidance independently from the application domain and which utilizes knowledge resources from within an organization for learning – thus keeping costs and efforts for learning material generation low. Section 5 offers a conceptual view on the APOSDLE environment which represents our ontology-based approach to designing domain-independent learning support and offers varying degrees of learning guidance. In other words, we present a *design environment* [5] which enables the creation of environments for WIL support specifically tailored to the unique needs of a company and concrete learning domain. We see the "APOSDLE solution" as consisting of (a) modelling the learning domain and the work processes, (b) annotating documents and other sources of information available in the company repository, (c) training the prospective users of the APOSDLE environment, and (d) using the APOSDLE environment with its varying learning guidance functionalities at the workplace.

We have evaluated our approach to WIL by embedding the APOSDLE environment for three months into three application organizations – not only technically but also socially by building the relevant processes around it. Section 6 shortly summarizes the results of our summative workplace evaluation and discusses modelling efforts needed during APOSDLE instantiation in a specific application domain.

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[1] Advanced Process-Oriented Self-Directed Learning, www.aposdle.org

2 Work-Integrated Learning

Building on theories of workplace learning (such as [6] and [7]) we conceptualize *learning as a dimension of knowledge work* which varies in focus (from focus on work performance to focus on learn performance), time available for learning, and the extension of learning guidance required. This learning dimension of knowledge work describes a continuum of learning practices which starts at one side with brief questions and task related informal learning (work processes with learning as a by-product), and extends at the other side to more formal learning processes (learning processes at or near the workplace). This continuum emphasizes that support for learning must enable a knowledge worker to seamlessly switch from one learning practice to another as time and other context factors permit or demand.

Research on supporting workplace learning and lifelong learning so far has focused predominantly on the formal side of this spectrum, specifically on course design applicable for the workplace and blended-learning. In contrast, the focus of our work is on the informal side of the spectrum, specifically covering work processes with learning as a by-product and learning activities located within work processes. In order to refer to this type of learning practices, we have coined the term work-integrated learning (WIL). By using this term we emphasize that we investigate *informal learning* at the workplace such that it is truly integrated in current work processes and practices. WIL is relatively brief and unstructured (in terms of learning objectives, learning time, or learning support). The main aim of WIL activities is to enhance task performance. From the learner's perspective WIL can be intentional or unintentional, and the learner can be aware of the learning experience or not [8].

WIL makes use of existing resources – knowledge artifacts (e.g., reports, project results) as well as humans (e.g., peers, communities). Learning in this case is a by-product of the time spent at the workplace. This conceptualization enables a shift from the training perspective of the organization to the learning perspective of the individual.

3 Distributed Participatory Design

This section gives an overview of the activities and their settings leading to the development of the APOSDLE environment. The development process involved three prototyping iterations lasting one year each and involving in-depth requirements elicitation, conceptual design, implementation, and evaluation phases.

3.1 Application Domains and Settings

The APOSDLE environment was designed in close cooperation and involvement of five different, knowledge intensive application domains of different enterprises. Three application domains were chosen in collaboration with enterprises participating in the project: simulation of effects of electromagnetism on aircraft (EADS - European Aeronautic Defence and Space Company, Paris), innovation management (ISN - Innovation Service Network, Graz), and intellectual property rights consulting (CCI Darmstadt - Chamber of Commerce and Industry, Darmstadt, Germany). Two additional domains refer to general methodologies that can be used in different settings and disciplines: the RESCUE process for the thorough elicitation and specification of consistent requirements for socio-technical systems, and the domain of Statistical Data Analysis (SDA).

3.2 Design and Development Process

The employed design process is an example of distributed participatory design, which has been carried out in the context of real-world project constraints on time and cost. The process consisted of instances of synchronous and asynchronous, distributed and non-distributed design activities, and also integrated activities designed to stimulate creative inputs to requirements. For example, the activities included workplace learning studies [9] and surveys [10], iterative use case writing and creativity workshops [11] resulting in 22 use cases and more than 1000 requirements, formative evaluations of the second prototype [12], a re-design of APOSDLE using the personas approach [13], extensive usability studies with students, application partners in real world settings and usability labs, and a variety of evaluations of individual components. A final summative evaluation spanning three months of real-world application concluded the process. The main findings of this summative evaluation are reported in Section 6 below.

3.3 Challenges for Supporting WIL

Based on the described participatory design and development activities, three major challenges for WIL support can be identified: real time learning, real knowledge resources, and real computational environment.

Real time learning: WIL support should make knowledge workers aware of and support them throughout learning opportunities relevant to her current work task. WIL support needs to be adapted to a user's work context and her experiences, and should be short, and easy to apply.

Real knowledge resources: WIL support should dynamically provide and make users aware of available knowledge resources (both human as well as material) within the organization. By providing 'real' resources the effort for learning transfer is reduced and the likelihood for offering opportunities to learn on different trajectories is increased.

Real computational environment: WIL support should be provided through a variety of tools and services which are integrated seamlessly within the user's desktop and allow one-point access to relevant back-end systems of her organization. These tools and services need to be inconspicuous, tightly integrated, and easy to use. They must support the knowledge worker in effortlessly switching between varieties of learning practices.

Concerning real time learning our participatory design activties and workplace learning studies suggest that learners need different support and guidance within different work situations. Specifically, it became apparent that learning guidance is needed on varying levels ranging from descriptive to prescriptive support. While *prescriptive* learning guidance has the objective of providing clear directions, laws, or rules of usage to be followed, *descriptive* learning guidance offers a map of the learning topic and its neighbouring topics, their relationships, and possible interactions to be explored. Specifically, prescriptive learning support is based on a clearly structured learning process which imposes an order on learning activities while descriptive support does not do so.

The learning guidance discussed here is applicable to WIL situations and covers the more informal side of the learning dimension of knowledge work. Clearly the spectrum of learning guidance could be extended to much more formal learning guidance approaches such as predefined learning modules and enforced learning processes. However, this is beyond the scope of our work and this paper. The learning guidance we consider and explore ranges from building awareness over descriptive learning support (exposing knowledge structures and contextualizing cooperation) to partially prescriptive (triggering reflection and systematically developing competences at work). The following section illustrates how these different degrees of learning guidance were realized within the APOSDLE environment.

4 Providing Varying Degrees of Learning Guidance

Within this section we present varying degrees of learning guidance functionalities in the form of three scenarios based on the ISN application case. These scenarios also provide an overview of the overall APOSDLE environment from the user's point of view.

ISN is a network of small consultancy firms in the area of innovation management. Consultants at ISN support customer cumpanies in the introduction of innovation management processes and the application of creativity techniques. Please meet Eva, a consultant for innovation management. Eva has been assigned to lead a new project with a client from the automotive industry. The objective is to come up with creative solutions for fastening rear-view mirrors to the windshield.

4.1 Building Awareness

Eva is in a hurry. She needs to plan the kick-off meeting for her new innovation project within the next hour. As Eva begins to create the agenda using her favorite word processor, APOSDLE automatically recognizes the topic of Eva's work activities, namely "moderation". A notification unobtrusively informs Eva that her work topic has been detected and that relevant information is available. Over the years the APOSDLE knowledge base has collected a large variety of resources (e.g. project documents, checklists, videos, pictures) about innovation management which Eva and her colleagues have produced or used. In the background, APOSDLE proactively searches the knowledge base utilizing the detected work topic together with information from Eva's User Profile (see User Profile and Experiences) to form a personalized query. Eva is interested in getting some help to speed up her work.

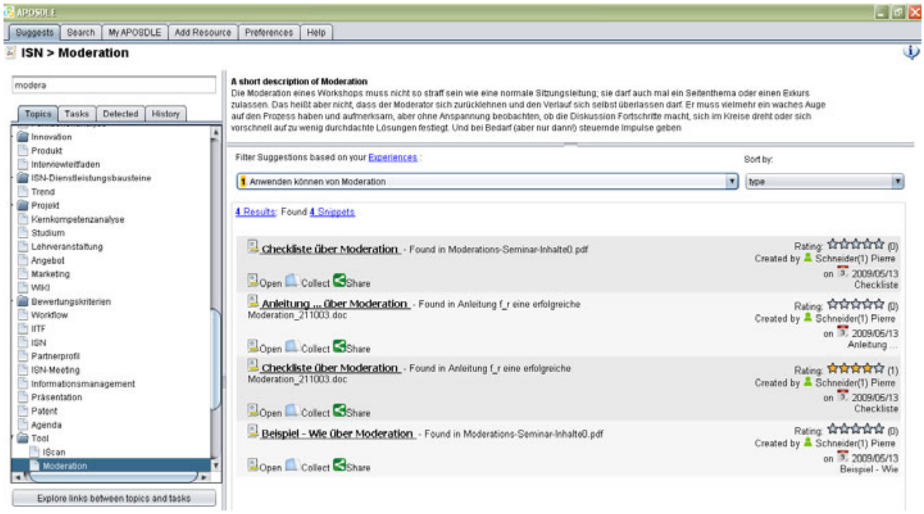

Fig. 1. "APOSDLE Suggests" recommends Knowledge Resources for Eva's current context (Topic "Moderation"). The tree view of Topics in the Browse Tab is shown on the left.

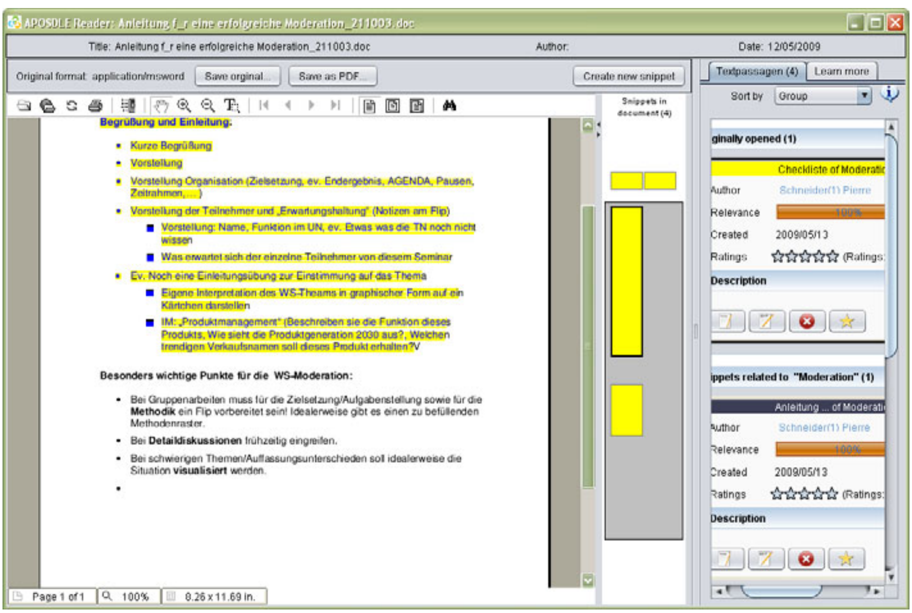

Fig. 2. APOSDLE Reader showing relevant information for Eva's context. It highlights the relevant part in a document (left), suggests other relevant parts (Snippets) throughout the document as a ThemeRiver (center), and offers a more detailed list view of Snippets (right) which can be sorted according to different criteria.

Therefore, she accesses APOSDLE Suggests by clicking on the notification or the APOSDLE tray icon. APOSDLE Suggests (Fig. 1) displays a list of resources related to the topic "moderation" (see Section 5.2). This list of resources is ranked based on her expertise in moderation techniques. Eva finds a checklist for moderating a meeting or a workshop which was put together by a colleague in the past. She opens the checklist in the APOSDLE Reader (Fig. 2) which highlights the most relevant parts (Snippets) for her. Eva finds some ideas suitable to her current project and integrates them into her own workshop preparation.

APOSDLE supports Eva in performing her work task without her even having to type a query. Moreover, her own expertise level is taken into account when making suggestions. This unobtrusive proactive information delivery raises awareness of knowledge resources (documents as well as people) which Eva would not have searched for otherwise. It provides learning guidance in that it highlights possible learning opportunities within the current work task without imposing constraints on the learner.

4.2 Descriptive Learning Guidance: Exposing Structures and Contextualizing Cooperation

After the kick-off meeting Eva prepares for the next step in the innovation project, namely a creativity workshop. Since she has never moderated such a workshop herself, she takes some more time to explore different possibilities and their implications. Eva opens APOSDLE Suggests and starts searching for the keywords "creativity techniques" and "creativity workshop". Eva selects the task "applying creativity techniques in a workshop". Eva refines the list of recommended resources by selecting a specific (predefined) Learning Goal (e.g. basic knowledge about creativity techniques in Fig. 3). She opens a video which contains an introduction about creativity techniques and creativity. The APOSDLE Reader again highlights relevant parts of the video and provides an overview of the video by displaying a theme river similar to the one shown in Fig. 2. The video helps Eva to get a better understanding of basic creativity theories and methods. But she still has some more concrete questions in particular in the context of the snippet she has found.

By simply clicking on the snippet, Eva contacts Pierre (another consultant in her company) to ask him about his experiences. APOSDLE supports Eva in selecting a cooperation tool by knowing Pierre's preferred means of cooperation (e.g. asynchronous vs. synchronous, tools he uses, etc.). APOSDLE also provides Pierre with the parts of Eva's work context which are relevant to her question. That is, Pierre can review which resources Eva has already accessed (assuming Eva's privacy settings allow this). Pierre accepts Eva's request and Pierre and Eva communicate via Skype (Pierre's preferred means of communication). Eva can take notes during the cooperation, and can reflect on the cooperation afterwards in a dedicated (wiki) template. If Eva and Pierre decide to share this cooperation results with other APOSDLE users, the request, resources, notes and reflections will be fed into the APOSDLE knowledge base. After talking to Pierre, Eva continues with preparations for the upcoming creativity workshop.

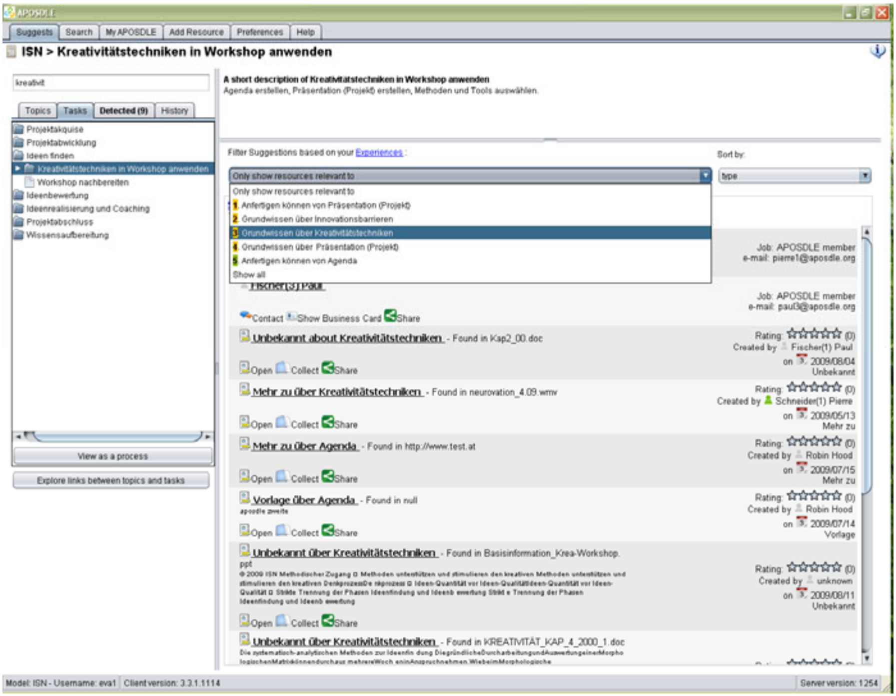

Fig. 3. Recommended resources can be refined according to a user's Learning Goals listed in the drop down box. Learning Goals allow narrowing down large lists of resources to specific needs of users.

By exposing the relationships between topics and tasks of the application domain the learner is enabled to informally explore the underlying formal knowledge structures and to learn from them. Specifically, users can be made aware of topics relevant to the current task. These might constitute relevant learning goals for the future. In addition, APOSDLE supports communication between peers by helping to identify the right person to contact, to select the preferred communication channel, to contextualize the cooperation, and to document it if desired. It is up to the user when, in which situations, and in which order to take advantage of this support.

4.3 Partially Prescriptive Learning Guidance: Triggering Reflection and Systematically Developing Competences at Work

Eva has some additional time which she wants to spend on acquiring in-depth knowledge about creativity techniques. She opens the Experiences Tab (find details in Section 5.5) of APOSDLE and reflects on her past activities. This tab (Fig. 4) visualizes her own User Profile indicating which topics she routinely works with (green, middle layer), which topics she needs to learn more about (orange, top layer), and in which topics she has expertise (blue, bottom layer).

Fig. 4. The Experiences Tab provides users with an overview about their experiences with topics in the domain. APOSDLE uses three levels (Learner [orange, top layer], Worker [green, middle layer], Supporter [blue, bottom layer]) to indicate different levels of knowledge.

She realizes that she is learner in many of the common creativity techniques and therefore she decides to approach this topic systematically by creating a personalized Learning Path. Eva opens the Learning Path Wizard and browses through the task list. She selects the task "applying creativity techniques in a workshop". Based on this task, the Learning Path Wizard suggests a list of topics to include in her Learning Path (see Section 5.1.1), and Eva adds some more creativity techniques Pierre mentioned in their last conversation. Eva saves the Learning Path and also makes it public so that other colleagues can benefit from it. To execute the Learning Path Eva then activates it in APOSDLE Suggests. At this time APOSDLE Suggests recommends relevant knowledge resources for the topic she selected from her Learning Path. Eva now follows her Learning Path in dedicated times during her working hours. Whenever new relevant resources are added to the knowledge base Eva is made aware of them.

APOSDLE explicitly triggers reflective learning depending on learner activities (formal part) while the reflection process itself is not formally supported but left to the user's description. In addition, the creation of semi-formal Learning Paths for longer term and more systematic competency development is supported and partially automated. However, the time and method of Learning Path execution is not predetermined and can be performed flexibly.

5 A Conceptual View on the APOSDLE Environment

As was illustrated in the above scenarios the APOSDLE environment provides varying degrees of learning guidance. Within this section we present the four key components which implement them: APOSDLE Suggests, the APOSDLE Reader, the Cooperation Wizard, and the Experiences Tab. All four components have been designed and are implemented in a domain-independent fashion. That is, none of the components embody application domain knowledge and thus constitute a generic design environment for WIL environments. In order to create a domain-specific WIL environment for a specific company, all application-specific domain knowledge has to be added to APOSDLE in the form of three ontologies and the different knowledge resources within the knowledge base.

5.1 Knowledge Resources in APOSDLE

Different types of Knowledge Resources are presented to the user within APOSDLE: Topics, Tasks, Learning Paths, Documents, Snippets, Cooperation Transcripts, and Persons. All of these resources can be organized into Collections which can be shared with others and thus may serve as Knowledge Resources themselves.

5.1.1 Topics, Tasks and Learning Paths

Topics, Tasks and Learning Paths are structural elements which are presented to the users and which can be used for accessing further Knowledge Resources. All of them are encoded within an integrated OWL ontology within the Knowledge Base and provide the basis for intelligent suggestion of resources and for inferences on user's competencies [14].

Topics are core concepts which knowledge workers in a company need to know about in order to do their jobs. For instance, Topics in the ISN domain are creativity technique or workshop. Each Topic has a description. A Topic can be added to a Collection, its relations with other Topics and with Tasks can be browsed or it can trigger suggestions in APOSDLE Suggests.

Tasks are typical working tasks within a specific company. Examples for ISN Tasks include "applying creativity techniques in a workshop" or "identifying potential cooperation partners". Each Task has a description. In addition, to each Task a set of *Skills* is assigned which are required for performing the Task successfully. For instance, for the ISN task "applying creativity techniques in a workshop" one required Skill might be basic knowledge about creativity techniques. Each of these Skills is related to one Topic. That way, Tasks and Topics are inherently linked. Tasks in APOSDLE can be added to a Collection, its relations with other Tasks and with Topics can be browsed and it can trigger suggestions in APOSDLE Suggests.

In essence, a *Learning Paths* is a sequence of Topics for which suggestions can be obtained in APOSDLE Suggests. The sequence of Topics about which knowledge should be acquired shall maximize learning transfer and follows a prerequisite relation computed on the Task-Topic-Skills structure based on competency-based knowledge space theory [15]. Learning Paths are generated by APOSDLE users themselves with the help of a Learning Path Wizard (Section 4.3) starting from a Task, a Collection, or a Topic. Learning Paths can be shared with others or added to a Collection.

5.1.2 Documents, Snippets, and Cooperation Transcripts

Documents, Snippets and Cooperation Transcripts are the actual "learning content" within APOSDLE. They constitute previous work results of knowledge workers in the company which can be accessed by APOSDLE users. Such context-related knowledge artifacts improve the likelihood of offering highly relevant information which can be directly applied to the work situation with little or no learning transfer required. In addition, they have the advantage that no additional learning content has to be created.

By *Documents*, APOSDLE understands both textual and multimedia documents which can be accessed in the APOSDLE Reader. Documents can be opened and saved, shared with others, added to a Collection or rated.

Snippets are parts of (textual or multi-media) documents annotated with one Topic which can be viewed in the APOSDLE Reader. Users can share Snippets with their colleagues, add them to a Collection, or rate them. In addition, APOSDLE automatically generates Snippets fitting to the domain ontology provided.

Cooperation Transcripts are textual documentations of information exchanged during cooperations. Cooperation Transcripts can be fed back into APOSDLE and made available in APOSDLE Search.

5.1.3 Knowledgeable Persons

All APOSDLE users are potential sources of knowledge and hence constitute Knowledge Resources. Knowledgeable Persons are identified for each Topic. For instance, a person can be knowledgeable with respect to the Topic "workshop" might have little knowledge about the Topic "creativity technique". The information of who is a knowledgeable person at a certain point in time for a Topic at hand is obtained from the APOSDLE User Profile (see Section 5.4). Persons can be contacted directly or be added to Collections for future contact.

5.2 APOSDLE Suggests and Search: Access to Knowledge Resources

APOSDLE basically has two main entrance points from where Knowledge Resources can be accessed, namely APOSDLE Suggests and Search. While Search offers text-based search functionality within APOSDLE, the Suggests tab employs intelligent algorithms for delivering Knowledge Resources which are relevant to the user's work context and to his or her previous experiences.

5.2.1 Suggestions for Topics, Tasks, or Learning Paths

Suggestions can be obtained for single Topics, for Tasks, or for Learning Paths. If suggestions are requested for a Topic, APOSDLE presents all kinds of Knowledge Resources related to this Topic. Knowledge Resources can also be other Topics. The suggest algorithm is based on an associative network which combines a concept-similarity measures with text-based similarity measures [16].

For suggestions starting from a Task, Knowledge Resources of all different types are presented for all Skills (and hence all Topics) linked to the Task. Thereby, intelligent algorithms are applied for personalizing the ranking of Knowledge Resources: Information from the automatically maintained User Profile (see below) is used to compute a learning gap for the Task at hand. The learning gap expresses the difference between Skills needed for the Task and Skills the user possesses according to his or her User Profile. Based on this learning gap APOSDLE suggests relevant Skills as Learning Goals which the learner could pursue within her current work situations. These Learning Goals are offered ranked according to the inverse learning gap. That is, Learning Goals which are relevant to Topics with a high learning gap are displayed on top of the list while Learning Goals related to Topics for which the user already possesses some knowledge are displayed at the bottom of the list. If no Learning Goal is selected by the user, APOSDLE makes suggestions for all Learning Goals and ranks them according to their importance for the user. If the user selects a Learning Goal, only Knowledge Resources relevant for this Learning Goal are displayed.

Similarly, if suggestions are made starting from a Learning Path, the Topics in the Learning Path are interpreted as a sequence of Learning Goals. However, here, suggestions of Knowledge Resources are automatically presented for the first Learning Goal in the Learning Path; the user can change the Learning Goal.

5.2.2 Triggering Suggestions: Automated Context Detection or Manual Selection

As it becomes obvious from this description, suggestions in APOSDLE Suggests are always somehow related to one or several Topics. The Topics(s) can be identified by automatic context detection (Section 4.1), by means of manual selection of a Task or Topic (Section 4.2) or by activating a Learning Path (Section 4.3).

The APOSDLE context detection is able to detect Tasks and Topics which the user is currently working on [17]. In other words, the worker does its daily work with APOSDLE sitting silently in the background. Once APOSDLE has detected a Topic or Task, a small notification is displayed on the right bottom of the screen. Clicking on the notification, the users can access APOSDLE Suggests where they get Knowledge Resources directly related to what they are currently working on.

A Browse window in APOSDLE Suggests facilitates different views on the domain, a tree view of Topics, a tree view of Tasks, a process view of Tasks and an integrated view of Tasks, Topics and their interrelations. Descriptions of Tasks and Topics are also shown in all these views. From there, an element can be selected and sent to APOSDLE Suggests.

Eventually, clicking Topics and Tasks anywhere in the system can trigger suggestions in APOSDLE Suggests. A Learning Path is activated in APOSDLE Suggests via its context menu.

5.3 APOSDLE Reader: Central Access to Snippets and Documents

Snippets and Documents are viewed in the APOSDLE Reader (see Fig. 2). The APOSDLE Reader is based on the ADOBE PDF viewer and a video player for all standard audiovisual formats. In order to view documents, APOSDLE Converts them into *.pdf files. While the underlying document can only be viewed and not modified in the APOSDLE Reader, annotations with Topics can be viewed, created or edited.

For navigation, a ThemeRiver highlights the location of relevant Snippets (again based on the associative network [16]) within the opened document and a Snippet List gives an overview over all Snippets within the document. By clicking on bars in the ThemeRiver or Snippets in the Snippet list, the viewer or video player jumps to the corresponding position in the document. Snippet boundaries in text are defined by character positions. Snippet boundaries in videos are defined by temporal start and end positions. In the case of video lecture videos, additional metadata and PowerPoint slides, if available, can be displayed in additional Resource Viewer tabs. Additionally, the APOSDLE Reader provides means of access to learning guidance through a "Learn more" tab. Within the "Learn more" tab, a learning hints pane is shown which contains different types of Learning Hints which are automatically generated taking into account the Topic of the Snippet and the assigned Material Resource Types. These learning hints constitute more prescriptive types of learning guidance since they encourage the learner to explore certain aspects of a Topic or to relate its usage to other situations.

5.4 User Profile and Experiences Tab: Access to User-Related Data

The APOSDLE User Profile builds the basis for the system's adaptation, that is, for the ranking of Learning Goals and hence the recommendation of information within APOSDLE Suggests. In addition, the information in the User Profile is necessary for identifying Knowledgeable Persons for a Topic or Learning Goal at hand.

The APOSDLE User Profile is designed as an overlay of the Topics in APOSDLE. In other words, for each of the Topics, it is decided whether or not the user has knowledge or Skills related to it. The APOSDLE User Profile is automatically maintained applying the approach of knowledge indicating events (KIE). In a nutshell, different types of naturally occurring actions of users are observed and inferences are made on the user's underlying knowledge level in a certain Topic. For each Topic, three levels of expertise are distinguished in APOSDLE's third prototype: Learner, Worker and Supporter. For instance, "carrying out a task" is a KIE for the "Worker" level. Thus, whenever a user executes a task (e.g. prepares a creativity workshop) within the APOSDLE environment, the counter of all Topics related to that Task within his or her User Profile for the "Worker"-level is incremented. At any point in time, a weighted algorithm in the APOSDLE User Profile Service decides in which level of expertise a user is with respect to every Topic in the domain. A more detailed description of the APOSDLE User Profile and its User Profile Services has been given in [14].

Studies suggest that mirroring a learner's actions and their results can assist with the acquisition of meta-cognitive Skills which are important ingredients of self-directed learning. Therefore a visual component, the Experiences Tab (Fig. 4), was added where the users can reflect on their past actions and become aware of Topics which they might want to advance further in. This is in line with the idea of an open learner model as it has been suggested by a number of authors [18], [19]. Clearly, this overview also allows users to quickly check if the APOSDLE environment has inferred the right information from the observed activities and to provide feedback and corrections. Please note that the main goal of this functionality is not to "assess" the user in any formal or objective way, but to provide an overview of the past interactions with the systems in order to better make the user aware of and recommend activities in the future.

Figure 4 shows the Experience Tab for Eva, our consultant from above. The left hand pane of Experiences contains a tree view of the Topics with which Eva has been engaged in the past. The same Topics are also shown in the tree map visualization on the right where Eva's Topics are also grouped into three levels of expertise, Learner (brown), Worker (green) and Supporter (blue). The tree map view provides more details than the tree view: The size of a square related to a Topic summarizes the importance of the Topic for the user, frequency with which the user has been engaged with the Topic, the larger the square, the more frequent the engagement. The square of a Topic can be further subdivided into squares with different shades indicating different activities (KIE) the user has been engaged in.

6 Workplace Evaluation

As mentioned in the introduction, we see the "APOSDLE solution" as consisting of (a) modelling the learning domain and the work processes, (b) annotating documents and other sources of information available in the company repository, (c) training the prospective users of the APOSDLE environment, and (d) using the resulting domain-specific WIL environment with its varying learning guidance functionalities at the workplace. This means that a comprehensive summative evaluation of the APOSDLE solution requires a summative evaluation of each of these aspects. This is even more mandatory as the aspects depend on each other. If the domain modelling has not been done correctly, the annotation will fall short of what is needed; if the annotation is done badly retrieval of relevant information will be unsatisfactory; if the users are not well trained, their use of the APOSDLE system will be sub-optimal.

Within this contribution we shortly report on results of the workplace evaluation (step d) which were carried out at the sites of three application organizations and discuss the efforts required for model creation (step a). The modelling of the learning domain and the work processes were conducted over a period of two to three months. The workplace evaluation took about three months and involved nineteen persons. A multi-method data collection approach was followed using a questionnaire, interviews, log data, user diaries kept while working with APOSDLE, and site visits. This allowed for triangulation of results.

One conclusion of the workplace evaluation is that the APOSDLE solution has proven very useful for learners in highly-specialized domains such as EADS's Electromagnetism Simulation domain in which much of the knowledge to be learned is documented within work documents. In those circumstances, APOSDLE delivered an effective work-based learning solution that enabled relatively inexperienced knowledge workers to efficiently improve their knowledge by utilizing the whole spectrum of learning guidance provided. APOSDLE proved less effective for knowledge workers in broad customer-driven domains where knowledge was shared to a large extent in person and is typically not documented. One reason for this result probably was that in two domains the users worked in the same offices and thus there was no need for cooperation support.

Overall APOSDLE supported the acquisition of new knowledge by the users by making them aware of learning material, learning opportunities and by providing relevant material. In EADS especially, it was reported on numerous occasions in the user diary that explicit and implicit learning material enabled knowledge workers to gain useful insight, improve their knowledge and complete a task they were working on. In all application cases, users clearly favoured the awarness building and descriptive learning guidance (e.g. exposing knowledge structures) over the more prescriptive learning guidance (e.g. triggering reflection, learning paths). Learning Paths were only sporadically used and mainly to explore their functionalities; users did not use MyExperiences to reflect on their activities but rather to examine the environment's perception of their usage. On the other hand, learners extensively used the different functionalities to browse and search the knowledge structures (descriptive learning guidance), followed the provided content suggestions (awareness), and collected relevant learning content within Collections. Most other supporting facilities, like hints and notes, were rarely used. This suggests that prescriptive supportive measures derived from instructional theories which are focusing on formal learning contexts are not very relevant for learning at work.

Finally, we can conclude that the domain-independent WIL design environment approach was successful. Relying on existing material instead of tailor made learning material provided to be effective and cost efficient. Crucial for this is having good modelling tools, experienced modellers, and high quality annotations of snippets. EADS, CCI, and ISN reported modelling efforts between 59 and 304 person hours for domain, task, and learning goal models ranging from 94 to 145 Topics, 13 to 100 Tasks, and 59 to 291 Learning Goals. In a recent instantiation within a new application organization we were able to further reduce these efforts to 120 person hours for 51 Topics, 41 Tasks, and 124 Learning Goals. We believe that these efforts are quite competitive when comparing them to efforts needed to instantiate a traditional LMS at a site and to develop custom learning material.

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