Potentials and Challenges of Context-Awareness for Learning Solutions

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Abstract

Current e-learning systems fail to take into account the situation of the learner appropriately although there is a big potential for improving those systems. This paper tries to summarize the potentials and highlight the key challenges of context-aware learning systems. It also presents some steps towards mastering the challenges.

1 Introduction

Despite the sustained interest in adaptive and personalized e-learning systems (especially for the academic sector), real-world learning support systems (e.g. learning management systems) still fail to acknowledge the situation in which the learner actually learns. This becomes most obvious when we look more closely at workplace learning, Instead of responding to the need of interweaving of learning and working processes and instead of leveraging on the pedagogic potential of the immediacy of purpose and applicability, these systems are still geared towards translating the classroom model into enterprises.

We can assume that the importance of context to the learning activity has been sufficiently articulated (e.g. under the heading of situated learning in [Lave and Wenger, 1991]), so the reason for the lack of consideration of context must be sought somewhere else. It lies in the complexity of the phenomenon of context and the inadequacy or immaturity of current methods to deal with context.

This paper tries to structure the problem of making learning systems context-aware. It first explores the potentials in a systematic way (section 2) before pointing to the key challenges (section 3). In section 4, a case study will be presented as one step to master the challenges.

2 Potentials of context-awareness

In a first step, we want to explore in a systematic way how the consideration of context can help facilitating learning, especially in a corporate environment. Here we understand "aware" basically as "taking into account", whereas in the following section we deal more with the problems of "aware" understood as "knowing about".

The functionality of an e-learning system can be roughly divided into three areas: the *delivery* of resources (which may include other humans as "resources"), the *usage* (or sometimes called execution) of resources, and the *authoring* of resources.

2.1 Delivery

The most visible functionality of a learning support system is the delivery. Here the system selects appropriate resources from its repository and presents it to the user. These "resources" may consist of both traditional learning material (like learning objects) and informal resources (colleagues, wiki entries, discussion forums, document snippets). The delivery functionality itself can be divided into three aspects, which can be enhanced by context-aware system behavior: *what*, *when* and *how* to deliver learning resources. Whereas traditional learning management systems typically only address the first aspect and consider the other two fixed by design, context also opens new potentials to be more adaptive to the latter ones.

What to deliver

The most obvious application of context-awareness to e-learning systems is the *selection or filtering* of resources in order to make the results more relevant and suitable for the learner in her situation. Relevance criteria can range from current competencies or the current task or role via information about the technical equipment up to personal learning style and preferences.

However, in contrast to traditional information retrieval & filtering, it is important to acknowledge that even for self-contained learning resources, it might be not appropriate to deliver just a single learning object because the learner cannot understand it without learning other topics first. So the "what"-aspect of delivery cannot be restricted to simple filtering, but must also consider the *aggregation* of smaller parts into a delivery unit. Here the context provides the constraints of this aggregation problem by specifying the prerequisites. This consideration of semantic constraints represent a form of pedagogical guidance [Schmidt, 2005a], which avoids overstraining the individual with the unknown and thus helps to reduce (or at least not increase) the feeling of uncertainty typically associated with an information or knowledge need [Kuhlthau, 1993].

When to deliver

Current e-learning systems mainly work in a reactive manner. The user logs into the system and looks for pre-assigned courses (e.g. by the human resources department) or searches actively for learning material satisfying her needs. These two interaction paradigms are basically either too much guidance – or no guidance at all. They dominate mainly not because of their pedagogical appropriateness, but rather due to the fact that the system does not know anything that could enable it to be proactive in a reasonable way.

A context-aware system on the other side can monitor the situation of the user and listen to changes of the situation, e.g. beginning a new task that leads to a knowledge gap. Together with background knowledge about the requirements of a specific situation, the system can recommend potentially relevant resources before the user actually formulating (or being able to formulate) her need. This new type of learning process has been explored under the concept of "context-steered learning" [Schmidt, 2004]. This form of guidance reduces the cognitive load and reduces the emotional uncertainty in new situations. It also allows for easy transition between working and learning mode.

In order to avoid annoying the user, the strategy has to be carefully crafted and it has to distinguish between context changes that ought to trigger new recommendations – and context changes it records silently. And it has also to take into account whether the user actually has sufficient time to learn (and how much of it) before recommending. Nothing can be more annoying that recommending learning resources in situations of high time pressure.

How to deliver

The problem of how to deliver is actually linked to the aspect of "when to deliver". The main question is: when the system decides to deliver, how much attention do we require from the user? Depending on the current task and how critical errors resulting from insufficient training are, the system can either decide to force the user to learn first before proceeding, or the system can act as a "peripheral attention" interface (e.g. balloon tips or notifications in the desktop tray) where the user may or may not shift his attention. Apart from the type of task, this can also depend on personal preferences, or the current "mood" of the user, measured by emotional contextual aspects.

2.2 Usage

Past research on adaptivity in the e-learning community has mainly concentrated on the usage phase. The functionality in this area can be divided into the following:

- **Navigation support.** Typically learning resources are not isolated, but formally or informally linked to one another (e.g. dependencies, topic similarity, etc.). Information about the user's situation can help to rearrange or reorder navigation possibilities according to the relevance to the current situation.
- **Adapting presentation.** A second area of adaptation lies in the presentation itself. Especially in the area of mobile learning, it was realized that learning resources must be presented in a different way depending on the device. But also learner types can motivate different presentation forms (e.g. more verbose and visual presentation vs. more dense and brief presentation).
- **Context-aware learning objects.** The most advanced form of context-awareness in the usage phase is probably the concept of context-aware learning objects. These type of objects can access the available context information and adapt their behavior to this context. This is especially promising for simulations at the workplace. The possibility of applying the newly learnt knowledge reinforces the learning success. If the simulation can act on the case currently at hand, this will e.g. allow for doing the work first in a simulation environment before carrying out the real task.

2.3 Authoring

Most of the presented potential improvements of learning systems with context-awareness require that already in the authoring phase contextual metadata needs to be provided to allow for efficient filter of resources. Awareness of the author's context can also help to acquire this metadata by considering the creation context of resources, which is extremely important for more peer-to-peer learning environments, where learning resources are produced within the working process.

3 Challenges

The main reason why context-aware functionality has not experienced wide-spread adoption in real-world products can be traced back to the fact that there are several challenges linked to it, which shall be briefly summarized in the following sections.

3.1 Context is hard to identify

Although it has been acknowledged in the learning community how important the situation is for the learning process, but still this has not been operationalized by identifying concrete aspects or features of the situation. This can be traced back to the fact that there is no elicitation method for context factors complementing traditional requirements elicitation methods.

The ongoing discussion about context features for learning has at least identified three main divisions [Schmidt, 2005b]: personal context (like competences, predispoisitions, preferences), social context (like relationship quality, presence information), and organizational context (like role, process, task). The problem is aggravated by the fact that the research is split across different communities, e.g. personal context is the domain of classical e-learning, and organizational context that of knowledge management.

3.2 Context is hard to acquire

After identifying relevant context features, another challenging problem arises: how to acquire the actual information about the user. Direct methods (like asking the user) can only be applied in very limited cases. So one has to rely on indirect methods that try to deduce the relevant features from observations of the user. The problem here is that

- these indirect methods yield imperfect results
- the needed observations can only be obtained by attaching to a wide range of applications or by pulling the data from a wide range of data sources

3.3 Context is hard to make use of

Even if we have acquired rich context information of high quality, it is still challenging to make use of it in a reasonable way. Empirical results on contextual influence on the learning processes are scarce and mostly scattered among various disciplines (e.g. [Abrahamian, 2003]).

Pedagogical theories and methodologies are also not prepared to provide the foundation for context-aware learning support. We currently do not know if and how which form of context-awareness improves learning efficiency.

3.4 What do we need?

After examining the challenges that are the obstacles of integrating context-aware functionality in learning systems: what do we need to overcome them?

- **Context Ontology for Learning.** Currently, not even the concept of context is shared among different research groups. What is called context in this paper is also called learner model, learner profile, learner preferences etc. For wide-spread adoption, it is essential to develop a shared understanding for at least a core model of relevant context features, i.e. a context ontology. The work on this ontology can leverage on work already done, e.g. IMS Learner Information Profile or the ontology developed in GUMO [Heckmann et al., 2005].
- **Context Acquisition Framework.** Apart from very limited cases, context acquisition will probably always require the customization of acquisition techniques to the company's environment, i.e. specific applications, specific sources etc. As this can require a lot of effort, it is necessary that there is a framework that provides already a toolbox for integrating context sources. One starting point for such a framework in the case of desktop-based context acquisition could be the Gnowsis system [Sauermann, 2005]. But also frameworks for ERP systems are needed that are able to extract the rich context information about organization aspects.
- **Context Management Infrastructure.** As learning systems do not care about storing data like learning object metadata or information about learner progress etc., but rather rely on standard relational database technology, it should be the ultimate aim of research on context-awareness to provide a similar infrastructure with standardized interfaces (e.g. a "ContextSQL") and logical and physical data independence. This infrastructure takes care of all management problems like aging and imperfection [Schmidt, 2005c].
- **Methodological Framework for Context-aware Learning Support.** Not only on the level of technology, but also on the level of methodology we need a framework that allows for understanding how context affects the individual learning process and how individual learning processes are connected via a shared context within a company. Some work has been done on with analyzing the "knowledge maturing process" in [Schmidt, 2005b].
- **Integration into standards.** One of the key success factors of e-learning in the last years has been the standardization activities, especially the concentration on SCORM. Thus it is of crucial importance to include context aspects in the standardization activities, be it learning object metadata, learning design [Harrer and Mertens, 2004], or other parts of the standards.

4 Case Study

In this section, the project "Learning in Process" and subsequent research shall be presented as a first step towards mastering the challenges sketched in the previous section.

4.1 Overview

Learning in Process (LIP) is a project that was co-funded by the European Commission in the 5th Framework Programme. One major goal of the project was the design of a learning system enabling the integration of working and learning the personalization of the delivery of resources. LIP was conceived to support the ad hoc training phase in which fine-grained learning objects not yet consolidated into a larger body of knowledge are the main training instrument.

The central solution idea of LIP was to acquire information about the situation of the user and exploit it to interweave learning and working. As current didactical methods did not provide a methodological framework, a new learning process type was conceived: *context-steered learning*. The basic idea is as follows: The user works with his everyday applications, and the system monitors his activities in order to deduce from it the current context. The organizational part of the context (task, role etc.) has associated competence requirements. This allows for continuously determining a competence gap. The system can recommend learning programs, which are compiled on demand from individual learning objects, to the user which are relevant for the competence gap.

In contrast to traditional *course-steered learning*, this learning process type overcomes the separation of working and learning by providing in-process learning support. On the other side, it reduces the cognitive load of self-steered learning, where the learner is completely on her own in searching for appropriate learning material in case of knowledge gaps, which is particularly problematic as knowledge gaps are usually associated with the inability to describe the gap and emotions of uncertainty.

4.2 High-Level User Context Management

A key enabler for implementing context-steered learning was an appropriate context management infrastructure that is geared towards the special requirements of high-level context information. Most challenging in this context are the aspects of imperfection and dynamics. As it is typically not possible to acquire context information on a high abstraction level directly, the system has to use indirect methods with limited certainty and precision of its results. The combination of different methods (sometimes even one method on its) furthermore yields contradictory results. These problems are aggravated by the dynamic nature of user context information where different elements of the context change at different pace.

During the project, a generic user context management infrastructure for high-level context information was developed ontop of a relational database and the ontology management system KAON [Schmidt, 2005c]. The service provides access both according to the query-response (via a descriptive query language) and the publisher-subscriber pattern (via event notifications).

4.3 Architectural Decomposition: Providing Context to LMS components

The design goal of LIP on the architectural level was to provide a service-oriented reference architecture that allows for flexible reuse and integration into existing systems. The reference architecture defines the core components, how they interact with one another and where context information plays a role. The main components are the following:

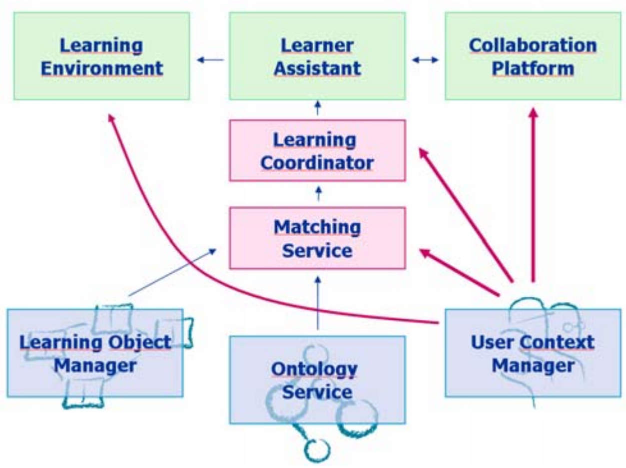

Fig. 1. Loosely coupled architecture of LIP

- The **Learning Object Manager** represents the functionality that is typically offered by a Learning Content Management System (LCMS). It stores learning resources and their metadata and allows for metadata-based retrieval.
- The **Ontology Service** allows for persistence storage and querying of the ontologies involved, i.e. the organizational structure, the competency catalog and the context schema.
- For managing the context, a generic **User Context Manager** was developed that can collect this information from various sources and support different services with a specific views.
- A **Matching Service** can compile personalized learning programs from the available learning material (*Learning Object Manager*), the user's current context (User Context Manager) and the context's knowledge requirements (provided by the *Ontology Service*).
- A **Learning Coordinator** decides based on context changes when to display suggestions about available personalized learning programs and communication or collaboration spaces. There can be several strategies to implement this behavior.
- The **Learning Assistant** represents the component that displays recommendations to the user and captures context changes from the user's interactions with her applications. This component typically resided on the user's machine, although some server-side processing is involved.
- Learning can be organized by the learner in the **Learning Environment**, which allows for finding, scheduling and executing learning programs. As sketched above, the possibility of simulation the application of newly learnt knowledge is a promising functionality. In order to enable learning management systems for such type of learning objects, LIP has extended the standardized SCORM API available to learning objects at execution time with direct access to context information. This is achieved through mapping the context features to the CMI data model of SCORM. This technically enables the creation of truly adaptive learning objects.
- A **Collaboration Platform** was "contextualized" with the help of this service by providing contextualized expert finder functionality, group formation and interaction spaces, where learners can themselves create "knowledge assets" which can be made available (e.g. by recommendation or in self-steered learning processes) to other learners based on the context in which they were created.

From the context-aware functionality sketched in section 2, LIP has implemented mainly the context-aware delivery methods. The Matching Service allows for providing learning programs that are relevant to the current situation of the user – both with respect to what the user currently is doing and with respect to other elements like prerequisites, preferences etc. The consideration of didactical relationships between learning objects (prerequisites, dependencies, order suggestions) makes up a main distinction to "simple" recommender systems. The Learning Coordinator encapsulates the strategies of when and how to present the recommendations based on context information and context changes.

4.4 Supporting the Knowledge Maturing Process

In corporate environments, the asymmetry of e-learning roles usually does not hold if we move away from standardized training courses towards more company-specific learning objects. "Teacher" and "learner" are often roles of the same person. Thus it becomes important to not only consider the delivery side, but also the authoring side. This was the starting point for broadening the scope of research on how to support learning processes with the help of context-aware systems.

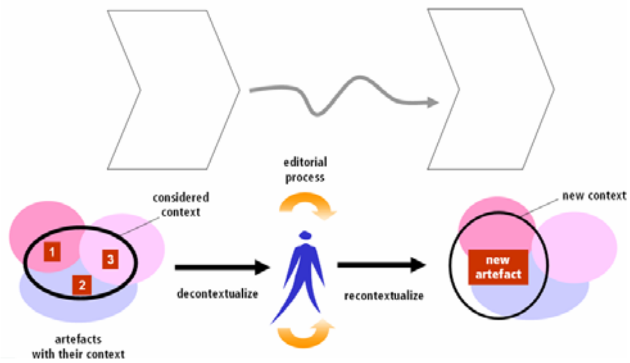

Fig. 2: A Knowledge Maturing Step

After closer inspection, it turns out that there is a "knowledge flow" within and across the borders of the company that is made up by a series of interconnected individual learning processes in which knowledge is learnt, transformed and taught. This phenomenon can be described by the metaphor of "maturing" (see also Fig. 2): a learner takes existing artefacts and resources (in whatever form) out of the original context and learns from them by extending and networking the knowledge structures in her mind. This can take place by following a discussion in forum, by reading a document or by discussing with a colleague. The next step is then applying this knowledge, i.e. putting it back into a new context, producing new artefacts that are suitable for others to learn from them.

It should be clear that the nature of knowledge changes along the maturing process. At the beginning, very immature ideas are communicated among fellow co-workers. Then communities arise before the first formalizations in form of documents become available. Only after sufficiently understanding the subject area, it is possible to produce ad hoc Learning Objects. The final stage of maturity is the availability of standardized courses and text books. This "knowledge maturing process" can be divided into five phases, which are described in more detail in [Schmidt, 2005b] (see also Fig. 3): Emergence of Ideas, Community Formation, Formalization, Ad Hoc Training, and Formal Training.

From this macro model, two conclusions can be made. The first one is that with the changing nature of knowledge also the appropriate learning process types and appropriate facilitating measures change. This is an important step forward in structuring the learning landscape and in bringing together different disciplines like e-learning and knowledge management. The second one – which is more important here – is that this maturing is currently not smooth, but rather characterized by inefficiencies caused by discontinuities in the process which manifest in the maturing steps:

- Typically the learner does not have an overview of the relevant artefacts *and* suitable artefacts from which she can learn. In determining the considered context and the relevant artefacts, the system can help the learner in making best use of existing pieces.
- After adding new knowledge pieces to the structures in the learner's mind, there is typically no connection to the artefacts used to construct this knowledge. So there is no traceability of newly constructed artefacts back to their "origins".

A context aware learning infrastructure can help here by deriving artefact context metadata from the author's current context, by storing this artefact context and by providing highly selective interfaces for locating and making use of existing artefacts for learning. These methods can further take into account the maturity as an additional context feature.

First steps are currently being made in understanding more deeply the knowledge maturing phenomenon and the different learning types involved (formal and informal), and in providing a technological infrastructure to support this.

5 Conclusions

Research in recent years has made considerable progress in understanding the phenomenon of context and in exploring the potentials of context-awareness. However, there are still several issues to be solved before context-aware functionality can be rolled out on a large scale. This paper has tried to give a consolidated overview of what we can expect from such applications and what we still need to do.

The case study of the research conducted within LIP and the subsequent knowledge maturing research has demonstrated important steps both on a conceptual level and technical level. However, despite first successes in transferring context-awareness for learning into commercial practice, there is still a lot of interdisciplinary research required for optimal technology support for learning in organizations.

Acknowledgements

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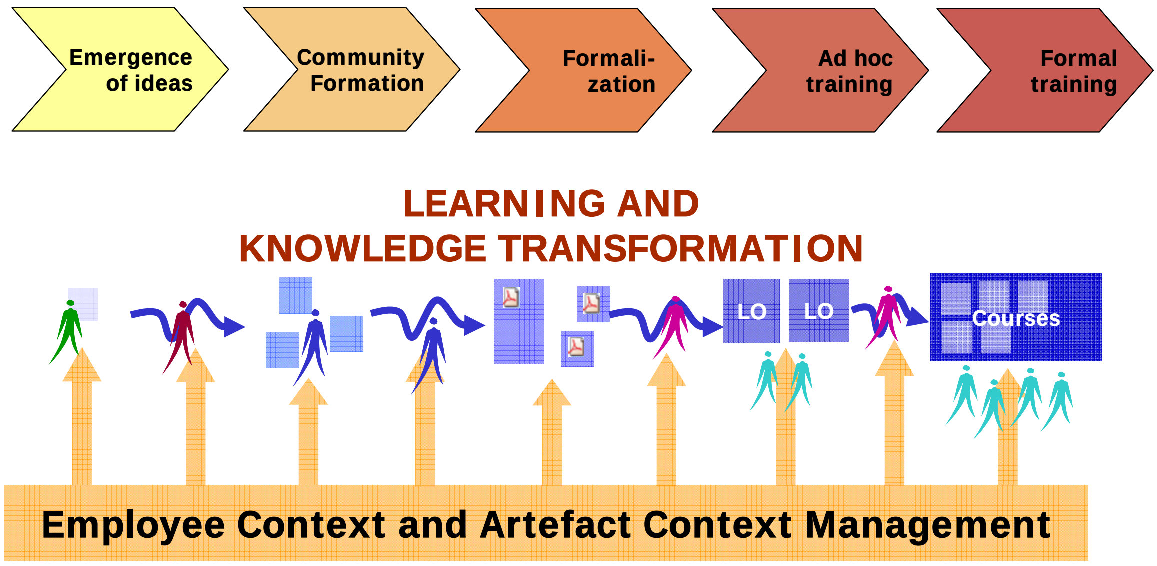

Fig. 3: The Knowledge Maturing Process

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