Re-Conceptualizing Learning Environments:  
A Framework for Pervasive eLearning

Reinhard Keil-Slawik  
Heinz Nixdorf Institute  
University of Paderborn  
Fürstenallee 11  
33102 Paderborn  
Germany  
rks@upb.de

Thorsten Hampel  
Heinz Nixdorf Institute  
University of Paderborn  
Fürstenallee 11  
33102 Paderborn  
Germany  
hampel@upb.de

Bernd Eßmann  
Heinz Nixdorf Institute  
University of Paderborn  
Fürstenallee 11  
33102 Paderborn  
Germany  
bernd.essmann@upb.de

Abstract

Pervasive eLearning requires a novel media perspective on learning objects. Instead of viewing handhelds or smart phones as minimized PCs we would like to propose a perspective on the notion of learning objects as active semiotics. We illustrate the use of such learning objects in distributed knowledge spaces which are a key concept for building up pervasive learning environments. We will sketch a framework for implementing knowledge spaces and show how we use this framework for setting up learning environments. Finally, we will discuss how we intend to extend this framework to cope with distributed knowledge spaces as part of distributed server environments as well as mobile ad hoc networks. We regard this extension as a key to build up real pervasive learning environments that transcend today’s eLearning frameworks.

1. Introduction

Pervasive eLearning may just be viewed as an extension of classical eLearning environments where students connect with small and medium sized mobile devices to traditional computer networks on the basis of client server architectures. Although this approach definitely has its advantages it falls short of addressing the full potential of digital media, because it is too strongly tied to the idea of reproducing a PC architecture and resizing applications such that they fit into mobile devices (e.g. “documents to go”). Even if technological progress may help improving the performance of small devices it seems doubtful whether they can ever catch up with the power of desktop machines or large server racks.

Another argument against such a procedure is the fact that the document and application concepts – which are at the heart of personal computing – do not carry up to the notion of pervasive or ubiquitous computing. To illustrate the differences we will first sketch the potentials of pervasive computing by re-conceptualizing the notion of interactivity. We will then show how distributed knowledge spaces can be used as a shop floor area for manipulating learning objects cooperatively. Finally we will sketch out a solution for maintaining the identity of such objects in mobile ad hoc networks (manets).

2. Interactivity Re-Considered

Although interactivity seems to be an essential quality of digital media, it is difficult to find a clear, precise and well-accepted definition. This is largely due to the fact, that this concept has many facets, ranging from time sharing, virtual machines and multitasking architectures – up to the concepts of handling screen objects with a pointing device, navigating through Hypermedia, or successively refining search queries through specifying filters [1]. Many definitions are inconsistent with each other or even contradictory. Even worse, in some application domains such as eLearning, system developers neglect the intentions which the initial designers had in mind. Widespread examples are web-based hypermedia learning environments or courseware systems in which authors create learning materials, only readable by students, with authoring tools. Of course, in doing so learners can decide which link to follow, but Hypertext was defined by Ted Nelson as “non-sequential writing” [2]. Non-sequential reading, however, can be accomplished with any kind of printed material.
We can take this argument a step further by comparing traditional analogue with digital media. With analogue media we inscribe our signs and symbols into the carrier material by a mechanical, chemical, electrical etc. process. Once the material is imprinted, we cannot manipulate the signs or symbol anymore; we can only manipulate the carrier (cutting film, arranging card boards, etc.) not the signs we are interested in. Thus, eLearning environments in which material can only be accessed via a reading tool are simply digitized versions of the printed counterpart (passive semiotics), possibly enriched by feedback mechanisms such as checkboxes for multiple choice tests, numerical value input for simulations, or a string input for a search query. As a consequence students cannot manipulate the material, but select different parts for reading/viewing only. In this sense, nowadays learning environments are mostly digitized versions of traditional media.

Digital objects may help us to overcome these limitations. The framework we propose is based on two basic concepts: interactivity and responsiveness. **Responsiveness** refers to a digital processor which continually analyzes the input sequence of symbols and provides feedback such as highlighting spelling errors, showing additional information on a mouse over event (e.g. tool tips), etc. **Interactivity** refers to the fact that algorithms executed by the processor allow the direct manipulation of individual symbols so that the perceivable gestalt becomes a manipulable object. In this sense responsiveness is a prerequisite for two kinds of interaction, the physical manipulation of symbols (primary media functions) and the evaluation of symbolic expressions such as the execution of a calculation. This holds true for all media types with their respective evaluation functions such as numbers, text, graphic, animated creatures, etc. In contextual computing or mobile ad hoc networks these kinds of interaction can be executed indirectly or implicitly as part of other human activities. Smart devices as well as RFID tags may start to react by just passing by. Since the symbols start to act we call it active semiotics. Only within a framework of active semiotics we may be able to freely arrange, sort, modify, or evaluate symbolic expressions. However, most of these operations are still limited to specific applications nowadays, because processing them requires knowledge about the internal data representation of that object. If we want to typeset a mathematical expression we use LaTeX, if we want to see the function plot we enter it into a computer algebra system, if we want to calculate its functions’ values, we … and so forth. Although the expression persists, we have to re-create the object according to the formats required by specific applications. This creates numerous media discontinuities.

Once we have identified document-based learning environments as a semiotic prison for active semiotics we must conclude that in the sense of “constructionism”, [3] learning, especially pervasive learning must allow for the use and combination of all primary media functions to the possible maximum. Although, overcoming the respective limitations embodied in the concept of traditional applications is far from finished, creating virtual knowledge spaces is a first step. They contain different objects (e.g. documents) defined in standard exchange formats such as xml. This allows manipulating them cooperatively and independent of a specific application. The stronger the operations of an active semiotic element can be standardized, the more we will be able to define virtual knowledge spaces in which objects can be executed in respect to the actual context.

The context may be defined by software, but it could also be a special device which can perform a limited set of functions. Imagine a mathematical formula that can be moved, viewed as a two dimensional shape, executed to view a graphical plot or evaluated as an algebraic expression.

Today, we cannot even send a square root symbol via chat. Pervasive eLearning, in the long run, can only be accomplished if we are able to cope with active semiotics on any device. The notion of objects manipulated in a virtual space and the concept of securing an object’s identity across different knowledge spaces are first steps in this direction and thus problems of paramount importance.

### 3. From interaction with machines to interaction with people

When learning environments are based on the production, dissemination and reading of documents they fall short of opening up the full potential of digital media in general and pervasive eLearning in particular. Authors define the learning environment whereby administration and communication functions are clearly separated and conducted via separate channels (e.g. by starting standard internet services such as chat, mail, news, etc.) We argue that for pervasive eLearning an integrative approach is needed which uses virtual knowledge spaces rather than documents as its starting point. Furthermore we argue, that learning objects should be designed according to the notion of active semiotics rather than being digitized versions of traditional media objects such as books, articles, videos, etc.
The metaphor chosen for our approach of cooperative knowledge organization is borrowed from the idea of virtual rooms but designed to remain distinct from it. Knowledge spaces represent the structural unity of a number of materials, persons and structural relations. Users can occupy such areas and move between them by means of connections we call gates. Containers and sub-areas can be used for further structuring within these areas.

Objects (materials) possess different attributes and access rights that structure any cooperative actions on them. The aim is – if possible – to encapsulate functions of cooperative actions (e.g. media functions of an object) in the object itself. Knowledge spaces therefore are the conceptual viewpoint of cooperative actions and the spatial structuring of materials.

As indicated above, a key focus of our research is the development of mechanisms supporting the self-organized structuring of material by learners. The underlying concept of cooperative media functions [4] is designed to enable the technical utility of media usage to be specified, thus helping to derive factors pertaining to the suitability of system support, irrespective of embedment in a concrete teaching situation.

As part of the process of structuring knowledge cooperatively, students should be able to create, arrange and link material, as well as being able to exchange such material and generate shared views on it. To be more specific: Material is made available as part of a course; students must learn to relate this material to other sources and to reference them, as well as to annotate and structure in a group context. The core functions of cooperative media can thus be reduced to a series of activities that should be available to all learners at any time [5].

They include: Creating, generating, visualizing, symbolizing, arranging or modelling arbitrary materials in areas as well as generating areas and adding new material, deleting, removing material, annotations and gates as well as arranging areas and grouping material into units, generating containers and substructures, highlighting specific elements of material, annotating material, linking, physically connecting areas by means of gates and generating reference objects to external material.

In such a situation we want to point out that all primary media functions can refer to both materials intended for personal use and materials intended for use by a group of people, i.e. for a group awareness space. One could speak of private or public views of media functions. A number of characteristics of media functions specifically influence cooperative aspects and ways of handling media; these include, transferring, exchanging material among learners; authorizing: assigning user rights for material; or mutual awareness and synchronization: creating shared views on material (asynchronously: e.g. shared knowledge areas.

The implementation of our client/server eLearning platform sTeam (“structuring information in teams”) will not be treated here. For more detailed information on its architecture we refer to [4].

In this paper we will discuss the next generation of a pervasive architecture which takes the new opportunities of mobile devices and infrastructures into account. Actually, it is this extension which makes it worth calling it a pervasive learning environment.

4. Distributed Objects identity as prerequisite for pervasive eLearning

Mobility is a great chance for embedding CSCL in everyday life’s situations. The eLearning system encompasses learners in their movement and does not require them moving to special places where network infrastructures exist. Users in mobile environments however face several different problems. Without a central server the learning materials and services have to be located within the surrounding network environment. For cooperation via services or shared learning objects failsafe mechanisms for access are needed.

First of all objects have to be identified in a changing environment. A unique identification number often represents objects, which mostly only software systems can interpret. Humans identify objects by metadata like name, description, keywords, owner, creation and modification date and of course the content. This allow for search or identification of a document. The relation to other objects can also act as a means of identification. While these objects may be stored and distributed in the mobile environment, a distributed ontology may be useful for this purpose.

Users themselves act as very special objects from the learning environment’s perspective. Identity management includes the management of virtual user IDs including certificates, accounts and passwords. This identity management becomes the fundament of all security mechanisms in the corresponding software systems. In classical client/server architectures a server trusted by every participant of the system provides this management. Without this trusted server an anonymous identity management in which one does not have to know the real identity of a virtual user is impossible. Without trusted institutions anybody could illegally assume virtual identities or cloak their real identity. Like in real life trust networks between related
users can resolve this dilemma (“I trust you because my friend does so.”).

These trust networks are well known from their use in the cryptology software Pretty Good Privacy (PGP). However, they turned out not work too well because often its users only knew their partners’ virtual identity. Meeting one another in real life only to build a trust relation is mostly considered too much effort. So certification servers replaced trust networks.

This development might be reversed again in pervasive eLearning systems with support of face-to-face interaction. In [6] peer-to-peer architectures are found to reflect society structures best. Peer-to-peer allows us supporting face-to-face cooperation in an intuitive way. In face-to-face sessions with peer-to-peer systems users are able to meet in both real and virtual environments simultaneously. This enables the user to establish a private trust network along the face-to-face learning sessions. Once personally known, users gain trust in strict virtual eLearning sessions as well. The implicit face-to-face support in pervasive eLearning could be a new chance for trust networks. A technical discussion how to implement trust in peer-to-peer systems and ad-hoc-networks can be found in [7] and [8]. Of course identity management servers are still useful in case an official validation of an identity is needed.

The identity of an object is therefore inherited from the users’ identity. The user signs the object so that users trusting him automatically trust his objects as well. This is especially important concerning active objects. Thus objects in pervasive environments are assigned to users instead of hosts in client/server systems where mostly an URI identifies an object.

5. A persistence layer for eLearning objects

Now that users are able to decide to trust eLearning objects in their environment, they might want to access and use them. Fundamental research points out major (technical) problems of mobile networks also fitting pervasive eLearning environments (cf. [9]). The main thesis is that mobile connectivity is highly variable in performance and reliability. This means that remote hosts and recourses may be not available when needed.

Redundancy is a major concept for a reliable access to services and objects in an unreliable environment. Redundancy always leads to a huge management overhead. Distributed and replicated objects have to be synchronized for cooperative use. To the user any copy of an object seems to be the original. Thus changes on an object have to be propagated to all copies. A possible solution is to propagate changes comparable to an epidemic. Every host synchronizes his copies of objects with their counterparts when reachable. So the host with the initial change does not need to be connected with every other host directly [10].

In this environment copies of an object may be changed asynchronously without knowing about changes on remote objects. This leads to conflicts between concurrent versions of the objects. Because of these possible conflicts concurrency control mechanisms are necessary. The simplest way of locking other copies when working on an object is not feasible because the lock has to be propagated epidemically as well. The other trivial solution only allowing to change the original object would render copies useless for cooperative use. Hence an optimistic locking [11] seems to be the only viable solution. It allows changing any copy until a conflict is detected.

Pervasive software environments are highly heterogeneous because of different hardware platforms, operating systems and network interfaces. Although platform independent applications are available, specialized applications fitted to the features and user interfaces of mobile devices are usual.

Direct communication between applications requires knowledge about the interfaces of foreign applications. This is a high effort to application developers wanting their application to cooperate with other applications. For this reason frameworks exist to facilitate the modification of applications to interoperate [12].

In our philosophy of deploying virtual knowledge spaces for cooperative eLearning, applications are just different views on knowledge rooms. Nevertheless views may provide different functionalities.

Our first approach of client/server architecture does not use the full potentials of this concept. Client applications access the virtual knowledge space by using several discrete protocols. This has some serious drawbacks: First, all protocols have to be implemented in the server as well. Second, protocols only make limited use of the potentials of virtual knowledge spaces. The most powerful access to objects on the server is a remote method invocation (RMI) protocol. Every application using this protocol has to manage the connections to the server itself. This management overhead grows in multi-server or even more in peer-to-peer settings.

In our opinion there should be no distinction between local and remote objects. The application itself should not be responsible for managing distributed persistence. It makes sense to shift persistence control towards the network layer. Distributed objects should be presented as if located in a local data repository. This allows us to implement views to access and change distributed objects like
local ones, similar to the concept of generative communication from parallel computing [13].

Thus the persistence layer is responsible to cope with the challenge of accessing and synchronizing distributed objects. Recapitulating the last two sections, the persistence layer has to provide support for redundancy, synchronization, epidemic propagation and optimistic concurrency control. This persistence layer has to be combined with a distributed trust management and access control outlined in section 4.

6. Conclusions

Traditionally, when talking about pervasive eLearning we tend to focus on extended accessibility to materials stored on servers and on new forms of contextual or local computing which are performed by using small mobile devices. Quite often, the underlying assumption is that pervasive eLearning is just an extension to traditional eLearning which is largely based on documents and additional communication functions. In our view, however, a next generation of eLearning environments is about to emerge no longer focusing on documents, but on manipulable and executable objects (active semiotics). To cope with such objects in a flexible manner in different contexts, we need to implement knowledge spaces in which we can arrange interactive operations. The concept of knowledge spaces is a transitional concept that serves both ends, active semiotics as well as documents with applications) and thus, allows us to migrate from today’s eLearning environments to tomorrow’s pervasive eLearning infrastructures. We have proposed a way of how we can secure the identity of an object in a distributed knowledge environment. This is a pre-requisite for building up infrastructures for pervasive eLearning in which it is easy to switch between traditional client server environments and mobile ad-hoc networks.

7. References


