AMBIENT LEARNING SPACES: THE ROLE OF DISTRIBUTED KNOWLEDGE MEDIA MANAGEMENT SYSTEMS FOR COMPUTER-SUPPORTED TEACHING AND LEARNING

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Abstract

There are different types of digital platforms and support systems for teaching and learning processes. Some of these systems are called Learning Management Systems (LMS) and School Management Systems (SMS). An important part missing in these mainly organizational platforms is support for the combination of knowledge and media to Knowledge Media (KM) within an environment for contextualized learning processes. Such environments have been called Knowledge Media Management Systems (KMMS). As a model and research system for a KMMS we implemented Ambient Learning Spaces (ALS), an integrated modular multimedia teaching and learning platform for post-constructivist learning inside and outside educational institutions. ALS is a distributed cloud-based KM repository connecting different interactive learning applications using current interaction devices like wearables, mobiles, tangibles, and other interactive multimedia frontend systems. ALS can be seen as a kind of interactive "Digital Knowledge Media Machine" that enables learners mapping the world of real life situations to KM providing different modalities for creating, modeling, transforming, recombining, annotating, and reflecting the content during the learning processes. ALS installations have been used, studied, and improved for more than 10 years in schools, museums, and other contexts like urban and industrial spaces, or biotopes in a variety of teaching and learning settings. This contribution describes the concept and architecture of ALS seen as a KMMS.

Keywords: Ambient Learning Spaces, Integrated Media Infrastructures, Didactic Infrastructures, Learning Management Systems, Knowledge Media, Knowledge Media Management Systems.

1 INTRODUCTION AND OTHER RESEARCH

Today we have different types of digital support systems and platforms for teaching and learning processes. Many of these systems are called *Learning Management Systems (LMS).* They support the organization of teaching and learning typically in course structures. They sometimes have been further differentiated into LMS and *School Management Systems (SMS)* when separating the structure of courses and materials from the user management, especially the role and access rights of teachers and learners. LMS together with SMS are currently seen as the relevant and most needed constituents for the digitization of teaching and learning. However, in this mainly technology- and organization-centered approach support for the content-related learning processes themselves is missing, i.e. fine-grained knowledge entities (KEs) instead of large topic-related courses.

As learning and teaching is based on media as means for representation, communication, and interaction, we need platforms to manage interactive media in these processes. Steps in this direction were *Learning Content Management Systems (LCMS)* constructed to manage *Media Objects (MO)* without representing much of their role in respect to context, meaning, or interaction. We use the term *Knowledge Media (KM)* and call the platforms *Knowledge Media Management Systems (KMMS)* if KEs and MOs have been combined. The more general term *Learning Objects (LO)* is often used in the area of LMS in the sense of smaller parts of courses focusing more on reuse and standardization.

We implemented the KMMS *Ambient Learning Spaces (ALS),* an integrated modular multimedia teaching and learning platform for post-constructivist authentic and contextualized learning inside and outside educational institutions like schools and museums ([1], [2], [3], [4]). ALS uses a distributed cloud-based media repository connecting a variety of interactive learning applications using interaction devices like wearables, mobiles, tangibles, and large screens. This digital media platform is a kind of open interactive *"Digital Knowledge Media Machine"* that enables learners mapping the world of real life contexts to diverse interactive KM providing interactive applications for modeling, transforming, recombining, annotating, discussing, and reflecting learning topics along the learning processes. Denoting the approach we earlier called KM *Multimedia Enriched Learning Objects (MELO)* [5].

2 TYPES OF EDUCATIONAL PLATFORMS

The process of digitization of teaching and learning was accompanied by the development of digital platforms supporting certain activities and storing teaching and learning materials.

2.1 Learning Management Systems (LMS)

In the last 20 years the main type of support platform in the area of computer-supported teaching and learning, have been *Learning Management Systems (LMS)* supporting mainly the following activities:

- User and role management
- Course management, including scheduling, tracking and reporting
- Storage of course materials together with authorships
- Communication and notifications
- Discussion groups and forums
- Archiving and restoring courses

LMS have a long history. They started to be developed in the 60s of the last century with systems like PLATO. With the availability of internet- and cloud-based solutions like WebCT, Blackboard, and Moodle, more flexible and widely available platforms have taken over and allowed the use of LMS through a variety of internet-connected devices like PCs, notebooks, tablets, and smartphones. The basic goal, and at the same time, the main drawback of LMS is their course-centered approach. Learning and teaching is oriented along classes, courses, and schedules. LMS are reflecting this strongly organizational and technical perspective to learning in educational institutions and proposals for their redesign have been made (e.g. [6]).

2.2 School Management Systems (SMS)

As more digital teaching, learning, and management applications found their way into schools and universities, it showed that identity and role management has to be refined and separated from the LMS and other application platforms. So-called *School Management Systems (SMS)* played this role for the different teaching and learning applications. Another important role of SMS is a "Single Sign-On"-capability that saves the users of several applications to login and logoff from each of the systems separately. Typical functions of SMS are:

- User profiling
- Admission management
- Management of exams, assessments, grades, and academic progression
- Monitoring rewards, scholarships, qualifications, certificates, and graduations
- Access rights for contents
- Authorization for applications
- Network access functions
- Attendance and activity logs

SMS have been based on the general user and identity management systems like LDAP and others with less modeling capability for the special purposes and roles of teaching and learning situations.

2.3 Learning Content Management Systems (LCMS)

Learning and teaching is always based on media as the means for communication and external representation. We therefore need *Media Management Systems (MMS)* to support and reflect the contents and didactic methods themselves. Steps in this direction are *Learning Content Management Systems (LCMS)*. LCMS functions comprise mainly the following:

- Upload, download, and management of contents (assets)
- Support for different media types like documents, presentations, images, videos, 3d objects
- Authoring tools for the different media types

– Digital rights management (drm)
– Search functionality in storage and archives
– Markup for media mainly for search purposes

LMCS have been built in various ways often tightly connected to certain technological solutions, platforms, or operating systems. A special goal was to foster *Reusable Learning Objects (RLO).*

2.4 Knowledge Media Management Systems (KMMS)

LCMS are mainly used to manage media objects (MO) for teaching and learning without explicitly reflecting meaning, knowledge, and context. As media are anchor and reference points and carriers of knowledge to be acquired, discussed, and enriched, we use the notion *Knowledge Media (KM)* and call such platforms *Knowledge Media Management Systems (KMMS)*. Typical functions for KMMS are additionally to those of LCMS:

– Semantic markup to create KM from MOs
– Browsing in semantic networks, knowledge-based search functions, and editors
– Interactive applications to support teaching and learning with KM
– Reasoning with KM and automatic creation of changed or new KM
– Versioning and reuse of KM
– Distribution and community functions for KM

3 STRUCTURE, FUNCTIONS AND ROLES OF KMMS

As already discussed, a KMMS is a kind of LCMS with capabilities for knowledge representation and reasoning with media. KMMS therefore combine media management and artificial intelligence (AI) methods. Such combinations of knowledge and media have been called *Knowledge Media (KM)* [7] and the process of KM modeling has been called *Knowledge Media Design (KMD)* [8]. KM and their interactive applications can be structured like shown in Figure 1. Additionally to the concept of KM we will talk about interactive *Knowledge Applications* for teaching and learning that can also be viewed as higher order KM constructed with lower order KM with possible reuse.

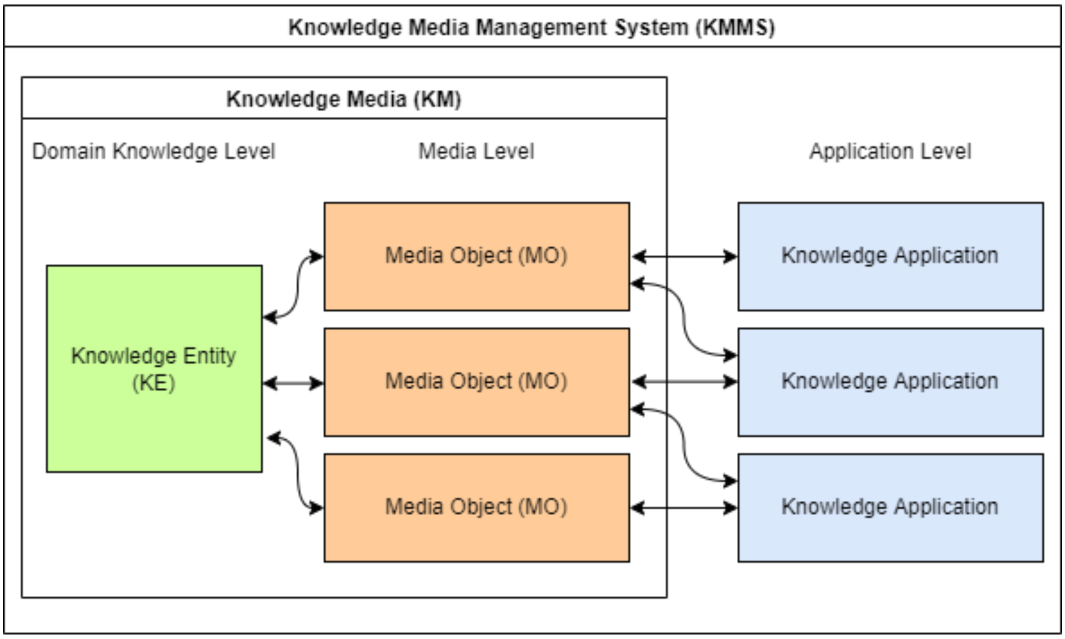

Figure 1. Knowledge Entity with several Media Objects accessed through Knowledge Applications.

3.1 Semantic Markup

The construction of a KM from plain MOs can be done through *Semantic Markup.* There are methods with differing strengths and weaknesses to define KM and higher KM structures:

- *Tagging* is a method of associating meaningful terms to MOs. Tagging has been used widely in the area of social media networks. It is simple, but already supports search, clustering, statistics, and many other semantic methods.
- *Thesauri* can be seen as catalogs of predefined meaningful tags with references to synonyms and antonyms. The use of controlled thesauri will lead to well-defined knowledge structures, like applied in professional collections of museums, archives, and literature.
- *Classification* is used to create abstraction hierarchies, called *classes*. This allows type sensitivity and is an economic way of defining attributes when building higher structures.
- *Semantic Networks* are relational networks for associative knowledge structures.
- *World Concepts* are a way of defining and delimiting knowledge domains.

3.2 Browsing, Searching, and Editing Knowledge Structures

Large or complex knowledge structures need to be inspected to understand their meaning. A typical generic method is browsing KM through textual or graphic displays. Besides the structural properties, the content of the KM will be accessed by displaying associated MOs. Besides browsing, the semantic markup will help to find entities through standard search methods. Using search methods like approximate search or pattern-matching, more intelligent search processes can be implemented. With editing function the structure and content may be changed.

3.3 Interactive Knowledge Applications

As already outlined, knowledge browsers, search methods, and editors are generic knowledge applications. When it comes to didactic methods in certain teaching situations, more specific interactive knowledge applications need to be tailored to content-specific visualizations and functions using context-dependent interaction devices.

3.4 Reasoning with Knowledge Entities

If there are knowledge-based inference models, reasoning on KM can be applied. Typical reasoning techniques will be production systems (rule-based), constraints (formal dependencies), or general logic- and frame-based reasoning (classification, induction, deduction, abduction). This also allows (semi-)automatic classification and creation of new KM out of existing ones.

3.5 Versioning and Reuse of Knowledge Media

It will be helpful or in larger educational organizations even necessary to develop KM for different users in different versions. This supports their reuse over different learning applications to save effort and allow connectivity through content between knowledge applications and knowledge domains.

3.6 Distribution and Community Functions

In many cases communities of users are creating and managing semantic worlds collaboratively. Therefore KM need to be available in distributed data clouds. Data-driven modeling and inference can be used for communication between KMMS and users to notify about new or changed KM. This will be useful in educational and community building contexts.

4 AMBIENT LEARNING SPACES (ALS) – AN EDUCATIONAL KMMS

As a model and example for a KMMS we implemented *Ambient Learning Spaces (ALS)*. ALS is an integrated modular multimedia teaching and learning platform for teaching and learning ([1], [2], [3], [4]). It contains a cloud-based, semantically modeled multimedia repository connecting various interactive learning applications using current interaction devices like wearables, mobiles, tangibles, media walls, theaters, and even large domes [9]. ALS enables learners mapping world knowledge of real life contexts into digital media through different modalities for modeling, transforming, combining, annotating, discussing, and reflecting knowledge during the learning processes ([5], [10], [11]). ALS installations have been developed over 12 years in a variety of teaching and learning contexts in schools, museums as well as in urban, industrial, or natural spaces [1].

4.1 ALS Knowledge Applications

ALS is a digital ecosystem providing modularized interactive knowledge applications *(ALS Modules)* for teaching and learning with stationary and mobile interactive computer systems [9]. Each of these frontend modules is connected to the semantically modeled knowledge multimedia backend storage called *Network Environment for Multimedia Objects (NEMO)* ([5], [12]). ALS can be easily extended by new modules through flexible interfaces. ALS Modules themselves can be understood as higher order didactic KM using dynamic lower order fine-grained KM representing the learning domains.

Authentic education through social activities in context is a post-constructivist approach to build up individual knowledge within cultural settings [1]. Learners discover live spaces like urban, industrial, or natural environments or collections like museums and archives. Built as networked mobile applications on smartphones, tablets, or modern wearables, the computing devices can be with the learners in the sense of BYOD [13] like the following interactive learning applications MoLES and InfoGrid.

The *MoLES (Mobile Learning Exploration System)* app provides a task-based teaching framework to guide learners through tasks and challenges along a path of learning in one of the real-world contexts mentioned above (Fig. 2 Left) ([13], [14], [15]). A task can be to collect MOs at certain places by taking pictures or videos and adding semantic tags to start the KM construction. Then the learners have to proceed to the next task until the whole tour has been completed. MoLES will store or transmit data media to the NEMO backend system for later use to build up KM to present and discuss the findings.

InfoGrid is a mobile *Augmented Reality (AR) app* that allows studying an environment by searching for active objects (targets) activating digital visual or auditory overlays in form of images, audio or video clips, static or animated 3D models (Fig. 2 Right) ([13], [16], [17]). The learners visit certain places and direct the camera towards objects, e.g. artifacts in a museum. Learners take pictures or videos of the objects found to markup and use them later as new KM. They will be guided through the environment by signs or digital plans. InfoGrid has also been tested for semi-automatic *Digital Story Telling* [18].

Figure 2. Left: ALS MoLES with tasks and challenges to collect and create KM in the field.
Right: ALS InfoGrid for AR-based KM in the Museum of Nature and Environment, Lübeck, Germany.

To integrate several knowledge applications on large interactive touch-screens, the *InteractiveWall (IW)* can be used ([19], [20]). Besides the IW there is an *InteractiveTable (IT)* that supports other spatial setups. Additionally to an IW, the IT will allow the use of *tangibles (fiducials),* i.e. physical objects that can be placed on the IT to interact with the applications, for example as physical tools for tagging or semantic filtering of KM. IWs and ITs have been placed in social areas within school or museum buildings like group spaces or foyers motivating social interaction and collaboration.

MediaGalleries are knowledge applications displayed on IWs as KM collections as grouped and tagged MOs. There are two types of MediaGalleries, one for static collections with predefined MOs and the other for dynamic collections of MOs depending on a given set of semantic tags (Fig. 3).

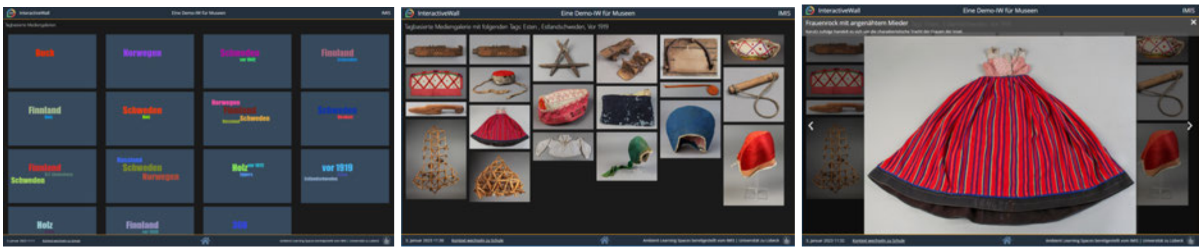

Figure 3. Tag-based ALS MediaGallery: Tag Clouds (left), Tag Filtering (middle), single MO (right) from the Ethnographic Collection Lübeck, Germany.

TimeLine is an interactive knowledge application embedded within IWs ([10], [21]). It displays along a time axis KEs with chronological meaning and dependencies (events) (Fig. 4). Events represent a point or a period of time on the chronological graph. They can be enriched to KM attaching MOs like text or tagged image, audio, or video from the central media repository. In TimeLine users can navigate by touch interaction in the chronological graph and explore time-based KM. A TimeLine consists of one or more sub-timelines along one chronological axis, i.e. semantic dimensions over the same period of time. For example, political events can be shown in parallel to economical or technological developments. This allows multiple perspectives on history and helps to identify, discuss, and explain causalities and other dependencies or even to reflect and better understand the cultural construction of history itself.

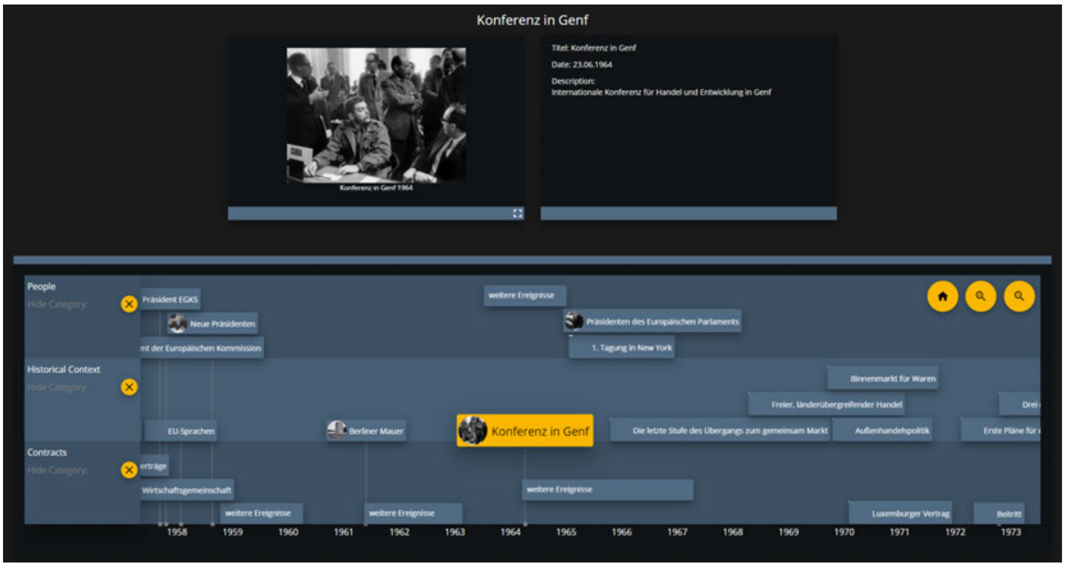

Figure 4. A TimeLine about the development of the European Union constructed by a school class of the Hanseatic School of Business, Economics and Administration in Lübeck, Germany.

SemCor is a learning application for active search and knowledge creation within an IW [11]. It supports interactive exploration of semantic correlations between KEs and allows inspecting KM in a semantic web. Learners can provide a KE (maybe a name) as a starting seed and specify a topic (like places or people) to explore filtered semantic correlations. SemCor connects to a semantic repository to search for related KEs. Once related entities are found, they are grouped into categories and are visualized in a force-directed graph (Fig. 5). KEs can be selected in the graph to expand the visualized knowledge space. The learner can open a KE and further detailed content will be shown and can be explored. SemCor will deliver automatically and dynamically new KEs in the graph that can be selected by the learner. KEs are internally searched and selected through certain algorithms and filters. SemCor reflects the mesh and complexity of world knowledge and motivates explorations through the *serendipity phenomena*. The semantic repository SemCor is connected to, can be self-constructed or chosen from available ones. The basic SemCor system works with DBpedia and Wikipedia. External repositories for certain knowledge domains, which provide public interfaces, like the Europeana for cultural heritage, can be connected as well.

Figure 5. A SemCor graph visualizing semantic correlations for a seed KE displayed as the center of a dynamic force-directed graph. Nodes of the graph represent related KEs (diamonds) or KM (thumbnails), whereas lines between nodes represent semantic relations. The screenshots shows a semantic network about Thomas Mann created from DBpedia and Wikipedia in the Buddenbrookhaus (Heinrich-und-Thomas-Mann-Zentrum) in Lübeck, Germany.

HyperVid is a knowledge application that allows creating semantic networks consisting of KM like tagged video, images or 3D objects [22]. Hypermedia networks can be created through a hypermedia editor (Fig. 6 Left) [23]. After the hyperstructure has been defined with MOs attached, the result can be seen in a player providing the links as options to proceed (Fig. 6 Right).

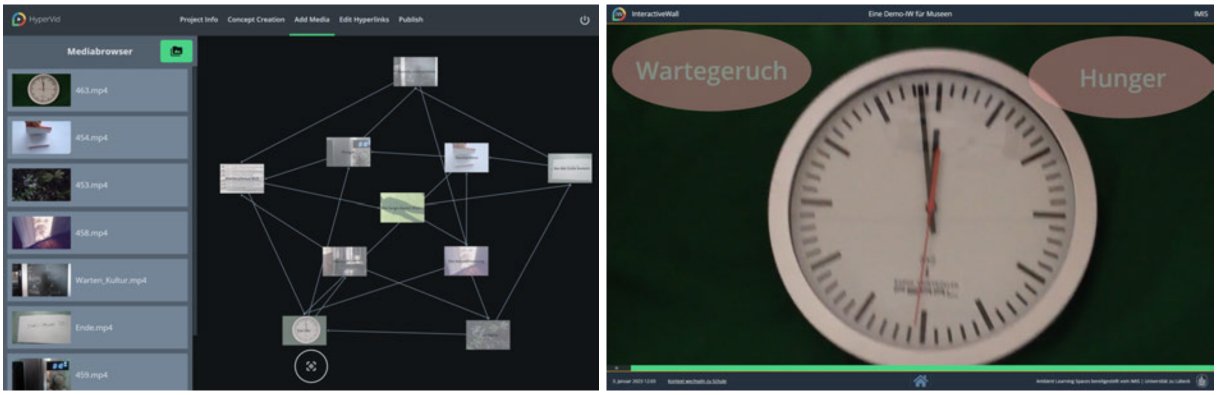

Figure 6. Left: A HyperVid mesh with MOs being attached,
Right: the hypervideo providing alternatives to follow through semantically linked MOs.

4.2 ALS Portal

To manage the contents of all ALS applications as well as the users in the sense of a simple SMS platform, the ALS Portal has been build. The semantic tagging can be applied to any MO that has been stored in the system to create KM during usage of the ALS knowledge applications as well as later in a kind of knowledge modeling phase using the Portal.

4.3 ALS Content Creation and Editing Tools

To simplify the production of KM ALS comes with its own integrated and web-based media authoring tools. This has shown to be very helpful for most users that like to create or change media without the need of using any other authoring system that needs to be bought and installed on their computers. The first authoring tools provided were ImageEdit, VideoEdit [23], and 3DEdit [24] to work on typical media like images, videos, and 3D objects.

4.4 System Architecture of ALS

ALS is based on a central cloud-based backend system, the *Network Environment for Multimedia Objects (NEMO)* ([5], [12]). The basic system architecture of ALS is shown in Figure 7. The applications are decoupled from the backend through web-services. Most of the frontend applications and authoring systems are web-based for maximum flexibility without the need of client installations. The backend system NEMO contains the KM. It can be installed and operated at any place inside or outside an educational institution only depending on internet web access and sufficient bandwidth, depending mainly on the number and size of digital media used.

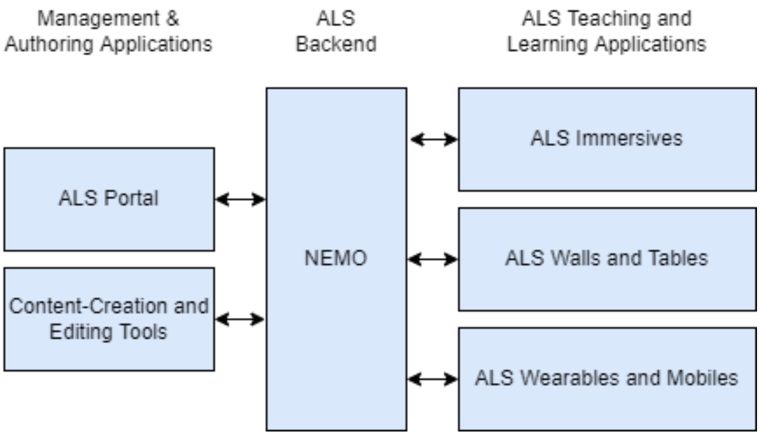

Figure 7. Basic system architecture of ALS.

4.5 Application Model of ALS

The Application Model of NEMO represents the KM information structures. It is implemented as an object-oriented class structure that provides the interfaces for the teaching and learning applications.

4.6 Service Layers and Functions of NEMO

NEMO has been implemented as a service-based layered architecture like shown in Figure 8.

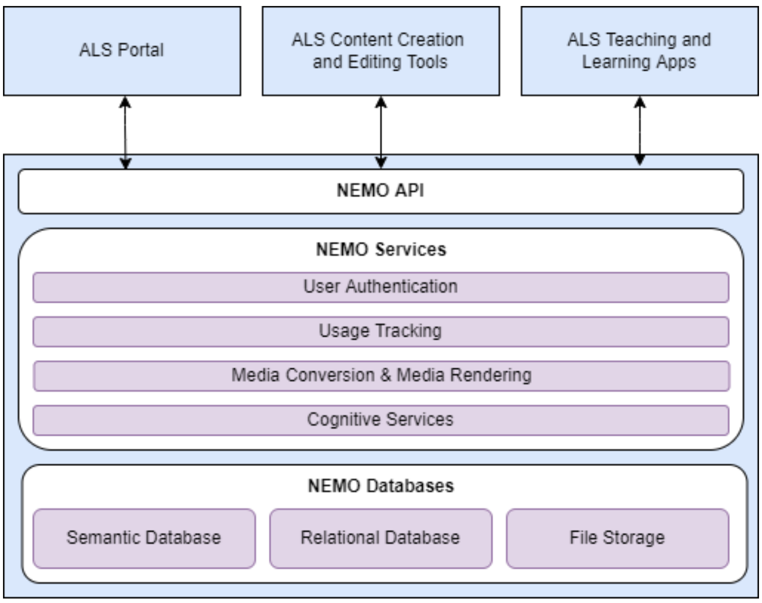

Figure 8. NEMO Service Layers.

User Authentication: The Administrator of the ALS Portal can setup institutions and assign teacher accounts for a specific institution [25]. With their accounts, the teachers can create and change accounts for the learners and define project groups as needed in applications like MoLES.

Usage Tracking: The NEMO framework includes a tracking module that can be used to anonymously log and track user requests from all ALS applications. To inspect the tracking data the ALS Portal contains a tracking visualization module. This helps to understand preferences and possible usage problems. It offers statistics of applications used or media queries indicating where and how often KM have been requested.

Media Conversion: The NEMO 3D Object Converter can be used to automatically create 3D models out of a series of photographs taken of a physical object [24]. The user can upload photos and videos into the object converter, which then automatically processes all image files using photometrical methods. Media like images and videos will automatically be transformed into formats and resolutions fitting for the requesting devices.

Cognitive Services: When the ALS-Portal is used to upload media files into NEMO for any ALS application, it is necessary to provide semantic tags. To simplify and speed up the process of tagging, the Cognitive Services have been experimentally tested to analyze the selected media and provide suggestions to the user. The user could accept or reject the suggestions for tagging. The Cognitive Services layer uses AI-based methods.

4.7 The Storage and Database Layer of NEMO

The central backend storage is implemented by the NEMO Database Layer to provide persistent semantic storage of KM and any other data needed by ALS. NEMO allows reusing KM in different knowledge applications for related learning contexts. This is important for an educational institution to create and manage a growing and living repository of KM that can be abstracted and enriched through semantic markups.

NEMO makes use of a several databases (DB) to store the content. A semantic DB is used to store information in a semantic RDF information model. The BrightstarDB has been used for the implementation. The SPARQL and LINQ query languages can be applied to access content in the database. A standard SQL DB has been used for any further persistent information that is not directly connected to KM. A File Storage is used for the plain media files like images, videos, or other high volume content. Technically the semantic DB can be replaced by a faster standard SQL DB if higher performance is needed. Both databases types have been applied for KM storage.

NEMO can be hosted on physical or virtual machines in an IP network. Several NEMO instances may be connected and cascaded to provide content independently of its location. NEMO is a distributed cloud-based storage system for semantic teaching and learning content to serve any frontend application and satisfy requirements ownership, digital rights and security as well as those of a KMMS.

5 SUMMARY

The purpose of learning is individual and social construction of authentic knowledge about the world. Digital environments are able to support such post-constructivist teaching and learning processes. As current platforms like Learning Management Systems (LMS) are focusing on course structures and Learning Content Management Systems (LCMS) on plain media and documents we need additional functionality to combine learning media and knowledge. This leads to Knowledge Media and Knowledge Media Design. Platforms supporting this approach can been called Knowledge Media Management Systems (KMMS).

Ambient Learning Spaces (ALS) is an open teaching and learning environment for a wide variety of authentic learning contexts in schools and museums as well as urban, industrial, or natural spaces. It has been designed as a KMMS. A variety of modular interactive learning applications for mobile and stationary learning with current interaction devices like wearables, mobiles, tangibles, media walls, theaters, and even large domes have been built, used, and evaluated in real teaching and learning contexts. Teachers and learners applied semantic markups for media objects and combined them to knowledge media and higher knowledge structures.

Usability and pedagogical studies over more than 12 years showed that ALS applications can be used effectively and efficiently by teachers and learners in daily use in knowledge-building processes.

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REFERENCES

[1] M. Herczeg. “Education in the Digital Age: A Driving Force or a Lost Place – Post-Constructivist Digital Learning through Ambient Learning Spaces,” *i-com,* Vol. 20, No. 3, pp. 263–277, Berlin: De Gruyter Oldenbourg, 2021.

[2] M. Herczeg, A. Ohlei, T. Schumacher, and T. Winkler, “Ambient Learning Spaces: Systemic Learning in Physical-Digital Interactive Spaces,” in *Algorithmic and Aesthetic Literacy: Emerging Transdisciplinary Explorations for the Digital Age*, pp. 97–115, Leverkusen: Barbara Budrich, 2021.

[3] M. Herczeg, T. Winkler, and A. Ohlei, "Ambient Learning Spaces for School Education," in *Proc. of iCERi 2019*, pp. 5116–5125, IATED, 2019.

[4] M. Herczeg, A. Ohlei, and T. Schumacher, “Ambient Learning Spaces: A Connecting Link between Digital Technologies and Computer-Supported Pedagogy,” in *Proc. of INTED 2021,* pp. 6011–6021, IATED, 2021.

[5] B. Feldner, S. Günther, F. Schmitt, T. Winkler, and M. Herczeg, “A Dolphin is a Dolphin is a Dolphin? Multimedia Enriched Learning Objects in NEMO,” in *Proc. of ICALT 2009*, pp. 29–31, IEEE Computer Society, 2009.

[6] A. Molinari, “Learning Management Systems: Is it Time for a new Generation?,” in *Proc. of iCERi 2022,* pp. 2122–2130, IATED, 2022.

[7] F. de Matros Müller and M. V. de Souza, “The Role of Knowledge Media in Network Education,” *Intl. Journal for Innovation Education and Research,* Vol. 8, No. 7, pp. 76–93, 2020.

[8] M. Eibl, H. Reiterer, P.F. Stephan, and F. Thissen (Eds.), *“Knowledge Media Design,”* München, Wien: Oldenbourg, 2005.

[9] M. Herczeg, A. Ohlei, T. Schumacher, and L. Willer, “Context and Size Matters: Integrated Ambient Learning Spaces from Mobile to Immersive Media,” in *Proc. of iCERi 2021,* pp. 3945–3955, IATED, 2021.

[10] M. Herczeg, “Ambient Learning Spaces: Chances and Challenges of Interactive Knowledge Media Platforms for Schools and Museums,” in *Proc. of iCERi 2022,* pp. 2378–2388, IATED, 2022.

[11] M. Herczeg, T. Schumacher, and A. Ohlei, “Ambient Learning Spaces: Discover, Explore and Understand Semantic Correlations,” in *Proc. of iCERi 2020*, pp. 7990–7999, IATED, 2020.

[12] S. Lob, J. Cassens, M. Herczeg, and J. Stoddart, "NEMO - The Network Environment for Multimedia Objects," in *Proc. of the First Intl. Conference on Intelligent Interactive Technologies and Multimedia*, Allahabad, India, pp. 245–249, ACM, 2010.

[13] M. Herczeg, A. Ohlei, and T. Schumacher, “Ambient Learning Spaces: BYOD, Explore and Solve in Physical Context,” in *Proc. of iCERi 2020*, pp. 7979–7989, IATED, 2020.

[14] S. Günther, T. Winkler, and M. Herczeg, "Mobile Learning with Moles: A Case Study for Enriching Cognitive Learning by Collaborative Learning in Real World Contexts," in *Proc. of ED-MEDIA 2008*, pp. 374–380, AACE, 2008.

[15] T. Winkler and M. Herczeg, "The Mobile Learning Exploration System (MoLES) in Semantically Modeled Ambient Learning Spaces," in *Proc. of IDC 2013,* pp. 348–351, ACM, 2013.

[16] A. Ohlei, D. Bouck-Standen, T. Winkler, and M. Herczeg, “InfoGrid: Acceptance and Usability of Augmented Reality for Mobiles in Real Museum Context,” in *Mensch und Computer 2018 - Workshopband*, pp. 340–344, de Gruyter, 2018.

[17] A. Ohlei, T. Schumacher, and M. Herczeg, „An Augmented Reality Tour Creator for Museums with Dynamic Asset Collections,“ in *Proc. of the AVR 2020*, LNCS 12243, pp. 15-31, Springer, 2020.

[18] D. Bouck-Standen, A. Ohlei, T. Winkler, and M. Herczeg, "Narrative Semantic Media for Contextual Individualization of Ambient Learning Spaces," in *Proc. of CENTRIC 2018*, pp. 26–31, IARIA, 2018.

[19] T. Winkler, M. Ide, and M. Herczeg, "InteractiveSchoolWall: A Digital Enriched Learning Environment for Systemic-Constructive Informal Learning Processes," in *Research Highlights in Technology and Teacher Education,* pp. 117–126, AACE, 2012.

[20] T. Winkler, D. Bouck-Standen, M. Ide, A. Ohlei, and M. Herczeg, "InteractiveWall 3.1 - Formal and Non-Formal Learning at School with Web-3.0-based Technology in Front of Large Multi-touch Screens," in *Proc. of ED-MEDIA 2017*, pp. 1317–1326, AACE, 2017.

[21] M. Herczeg, A. Ohlei, T. Reins, and T. Schumacher, "Ambient Learning Spaces: Constructing Timelines through Distributed Collaborative Learning," in *Proc. of iCERi 2021*, pp. 3972–3981, IATED, 2021.

[22] T. Winkler, M. Ide, and M Herczeg, "The Use of Hypervideo in Teacher Education," in *Proc. of AUCEi Intl. Conf. 2013,* Florida, USA, AUCEi, 2013.

[23] M. Herczeg, A. Ohlei, and T. Schumacher, "VideoEdit: An easy-to-use web-based Video Creation Tool for the Classroom," in *Proc. of INTED 2021*, IATED, pp. 6076–6084, 2021.

[24] D. Bouck-Standen, A. Ohlei, S. Höffler, V. Daibert, T. Winkler, and M. Herczeg, "Reconstruction and Web-based Editing of 3D Objects from Photo and Video Footage for Ambient Learning Spaces," in *Intl. J. on Advances in Intelligent Systems*, vol. 11, no. 1/2, pp. 94–108, 2018.

[25] D. Bouck-Standen, C. Eggert, A. Ohlei, and M. Herczeg, "A User Rights Concept for Semantic Media in Ambient Learning Spaces," in *Proc. of CENTRIC 2018*, pp. 24–25, IARIA, 2018.