AMBIENT LEARNING SPACES: CHANCES AND CHALLENGES OF INTERACTIVE KNOWLEDGE MEDIA PLATFORMS FOR SCHOOLS AND MUSEUMS

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Abstract

With the *Ambient Learning Spaces (ALS)* environment we developed a digital infrastructure as an integrated environment for self-directed and distributed learning inside and outside school. The cloud-based environment combines and interlinks mobile and stationary learning applications for a large variety of interaction devices. It plays the role of a ubiquitous and pervasive knowledge media machine. This contribution emphasizes on the need and the values of knowledge media for various teaching and learning contexts inside and outside school, especially for schools, museums, and their interoperation. The paper describes theoretical foundations, the integrated system architecture together with scenarios and examples of its application.

Keywords: Ambient Learning Spaces, Knowledge Media, Teaching and Learning Contexts, Digital Technologies for Learning, Interactive Learning Devices, Educational Media Platforms, Post-Constructivism.

1 INTRODUCTION

Today, we can find teaching and learning applications for nearly any type and format of digital interactive device. These can be used in *different contexts like schools, museums, urban or natural environments*. They have in common that they shall support constructing, modeling, and acquiring knowledge through the use of interactive digital media.

The basic conceptualization followed is building a learning environment for ubiquitous and pervasive interaction based on *knowledge media,* i.e. *media with semantic markups.* This kind of media shall fit various contexts of learning in space, time, and format and thus serve for in-school settings like classrooms, foyers, team spaces, school gardens, school theatres, or immersive domes as well as out of school contexts like urban spaces, museums, biotopes, or industrial environments. Applications for a variety of mobile and stationary interactive devices are needed to give access to a *common backend storage system* managing and providing the content together with media formats that fit to the application's frontend systems. The knowledge media themselves shall be reusable and manageable through *integrated authoring systems* considering context and cognitive and physical abilities of their users. Import and export functions shall allow reusing available media resources.

With the *Ambient Learning Spaces (ALS)* environment and platform we conceptualized and implemented such a system for schools and museums. We will discuss the use of ALS in these environments. Detailed descriptions of the ALS system can be found in ([1], [2], [3], [4], [5], [6], [7]).

2 METHODOLOGY

The basic approach we have been following is a *post-constructivist model of learning and teaching* ([1], [8], [9]). Learners need to be situated in authentic environments searching, designing, and acting in the world of applicable human knowledge. This implies identifying entities of knowledge, combining and interrelating as well as externalizing them through interactive media to present, discuss, change, and enrich these chunks and structures of historical and current knowledge within social settings. Knowledge emerges through individual and social construction with the help of *knowledge tools,* in this case *interactive media*. This approach of coupling knowledge with interactive media has been called *knowledge media* or *knowledge media design,* when seen as process [10]. Knowledge media play an important role in the post-constructivist approach to identify, communicate, elaborate, discuss, and question knowledge. Depending on the knowledge modeling mechanisms we will transform pure media collections, like image or video collections, into connected and cultural knowledge media.

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To collect and connect knowledge media in interlinked contexts we can make use of a spectrum of ubiquitous and pervasive *devices and frontends* for the knowledge tools. Their ubiquitous and pervasive nature has been denoted by Weiser as *Boards, Pads* and *Tabs* [11]. Earlier, McLuhan called them *Extensions of Man* [12] referencing a variety of tools humans make use of when interacting with their environments. Similar constructions from Vygotsky and Leont'ev have been discussed in ([7], [8], [9]). The frontend devices, the knowledge tools, need to be connected through a common persistent storage backend, which serves as a repository for knowledge entities and structures as well as for media elements to externalize these entities for learner interaction.

With ALS we developed, applied, and evaluated such a knowledge media environment in the field. It consists of the common repository *NEMO (Network Environment for Multimedia Objects)* and a variety of interaction devices of different form factors for different learning contexts. The same ALS system has been used in schools and museums with connectivity between them. The following chapters will elaborate the methodology, the implementation, and the observations in some more depth.

3 KNOWLEDGE MEDIA IN USE WITH A KNOWLEDGE MEDIA MACHINE

The term *knowledge media* has been used before in the history of interactive media. The meaning depends heavily on the scientific and application fields [10]. It has been introduced to clarify that media are not independent of *grounding and human reason*. Media can be *mediators* between humans or between humans and things and be understood as *externalizations of knowledge*. Media therefore is able to represent knowledge entities, their attributions as well as their relations to other entities. With this in mind, it needs a kind of *knowledge media machine* as an externalization mechanism for knowledge access and display and at the same time as an internalization mechanism for knowledge creation and change, making it a vital conceptual foundation for teaching and learning.

3.1 Connecting Knowledge and Media

We usually will not teach or learn from scratch. We already keep a universe of knowledge entities with a variety of media forms that can be attached to knowledge entities and vice versa. To make this available for a knowledge media machine, we need a system of *semantic representations* that can be connected to media. Typical *representations for knowledge* are in ascending complexity and strength

- Common *tags* as attributes,
- *Thesauri* as a collection of domain terms, relating to other synonym, antonym, generic and subordinate terms,
- *Ontologies* and *semantic networks* for formal classification, structure and reference,
- *Contexts* and *schemas* for meaningful and stereotypical situations and activities.

All of these common methods, besides others, can be used for modeling in a knowledge media machine for teaching and learning. We have to keep in mind that in the process of digitization of learning, i.e. the media and mechanisms used for knowledge media, are implemented through media devices of different type and size allowing to interact with the models. The knowledge entities accessed need to be digital representations of knowledge structures as listed above. As we have methods and technologies for digital media and knowledge representations, the digital knowledge media machine can be implemented stepwise with growing complexity and strength of representation.

3.2 Knowledge Media in Schools

What kind of knowledge media can we construct and use in schools? Typical teaching will introduce knowledge entities and provide text, images, or other media to depict and reference the chunks of knowledge. This is usually done through boards, maps, books, lab equipment, and many other medializations of knowledge. This semantic layer is usually enriched by pragmatics giving examples of meaning and use. It will be a constructive process of identifying knowledge entities, making them "visible" and referable and bringing them into higher structures of knowledge by generalizing them through their attributes and relationships to other entities. Identifying, creating, changing, collecting, describing, and interacting with knowledge media is the basic compound of individual learning about the world. Co-creating, sharing, discussing, criticizing, and relating entities of knowledge are driving the process of social and cultural learning. *Internalizing (representing and memorizing)* and *externalizing (medializing, communicating) knowledge entities and structures* is the basic constructivist process of learning. Teaching is nothing more or less then initializing, structuring, observing, documenting, guiding, mediating, and energizing this process. A digital knowledge media machine as described can serve as enrichment and partial replacement for the old media and tools used for teaching in school so far. However, a replacement often means embedding old into new media [12].

3.3 Knowledge Media in Museums

The potentials for learning in museums and archives are different to schools. They provide large collections and well-defined structures of knowledge in certain domains. The knowledge can be medialized by physical objects (artifacts) in an exhibit or by more virtual media like posters and digital media with certain content selected by curators. One basic mission of a museum or archive is to trigger learning processes with the visitors to change or enrich the knowledge they already internalized. The main challenge is to motivate and energize this constructivist and, through its authenticity, even post-constructivist process of extending and translating the knowledge already present through the authentic collections of a museum or archive.

It is interesting that today nearly all museums use digital media applications to externalize their collections, bringing them with the help of time-based and interactive media to some kind of life and relevance to catch the attention of the visitors. Sometimes the mission fails completely, when the visitors use the museum and the installations just for entertainment or killing time. It can succeed when the museum triggers a constructivist process transforming curiosity and questions into new or changed individual knowledge. This typically happens in a social context like with families, school classes, or other visitor groups. Whether the museum is succeeding or failing in this sense is often seen as the quality of the way the museum medialized its content to attract especially young visitors by making them curious to explore the information bound to the artifacts of the collection.

3.4 Linking and Using Knowledge Media of Schools and Museums

As we have discussed, knowledge media in schools and museums have different roles. However, they fit perfectly together if connected in the right way [1]. The authentic museum and archive can serve as a valuable reference and anchor for teaching and learning processes. To play this role more easily, systematically, and traceable, the digital media machines of the school and the museum should be compatible and connected. The collections of museums and archives shall be accessible through the learning and teaching in and outside school. Outside school can mean that the learners are visiting the museum itself bringing their own learning devices with them. BYOD (Bring Your Own Device) gets a much deeper meaning when seen as the connection of these two worlds of knowledge media [5]. Through the visit the learners will bring their own externalized knowledge constructions with them, change and enrich them in the museum using the *common media machine*.

The museum or archive can provide a subcollection of knowledge media for certain school classes, grades, and curricula. These will be accessible through the school's knowledge media machine, discussed and prepared for the visit of the museum, where the media concepts might be enriched by the physical presence of objects (artifacts) and through the social interaction with domain experts, museum educators, and curators, sometimes even artists, i.e. creators themselves.

4 AMBIENT LEARNING SPACES (ALS)

Ambient Learning Spaces (ALS) is the name of an infrastructure, a *digital media machine* in the previously described sense, providing *frontend applications (ALS Modules)* for mobile, stationary, and immersive interactive computer systems. Each of these application modules is connected to a common *backend system (ALS Repository)*. ALS and its modules have been developed, used, and improved over years in schools and museums.

4.1 The Integrated Backend Platform NEMO

To create the pervasive experience of integrated seamless media, ALS is based on a central cloud-based backend storage system, the *Network Environment for Multimedia Objects (NEMO)* (Fig. 1) ([4], [13], [14]). The applications are loosely coupled with the backend by web-services. Most of the frontend applications and authoring systems are web-based for a maximum flexibility within standard network structures. The NEMO can be installed and operated inside or outside schools or museums, only depending on internet web access and sufficient bandwidth, depending mostly on the volume of digital media used. The ALS-Portal combines a content management system with functionality to annotate, edit and link media to the corresponding ALS Modules to create knowledge media.

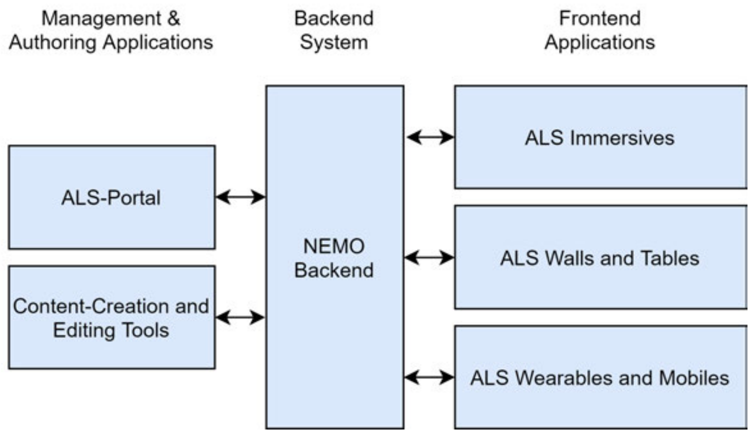

Figure 1. ALS system architecture

4.2 ALS Wearables and Mobiles

Authentic education through social activities in context is a post-constructivist approach to build individual knowledge within cultural settings. Learners leave school and enter live spaces like urban, industrial, and natural environments or places of collections like museums or archives. With networked mobile applications on smartphones, tablets or wearables [3], the computing devices and the digital media machine can be with the learners in the sense of BYOD [5]. This enables the learners to carry the scaffold of teaching in form of learning applications with them, study in context, and collect data and media to be brought or automatically transmitted back to their school repository.

4.3 ALS Walls and Tables

After searching, discussing, and collecting media in the physical context, the students need to select and arrange their findings to answer questions or create abstractions of what they found. This can be done in a social process that will typically take place in school with larger devices in group spaces or classrooms. To visualize the findings, the students can use large multitouch screens on the wall called in ALS the *InteractiveWall (IW)* ([15], [16], [17]). Alternatively to the IW there is the *InteractiveTable (IT)* that supports certain spatial working setups in school. Additionally to an IW, an IT allows the use of *tangibles (fiducials),* i.e. physical objects that can be placed on the IT to interact with the applications, like wooden figures for tagging or filtering.

4.4 ALS Immersives

Special media effects emerge with immersive media [3]. They are more a result of human perception than of a certain kind of technology. Sherman and Craig [18] distinguish *physical and mental immersion* besides *immersion* in general. We will refer to both, physical and mental immersion, when we discuss immersive media in the context of ALS. The more physically immersive applications will be available, the more we will create *Mixed Reality Learning Environments* [19].

5 KNOWLEDGE MEDIA USED IN SCHOOLS AND MUSEUMS

In this section we will describe ALS Modules that have been used in both schools and museums and can be seen as blueprints or implemented starting points for the interchange and common use of knowledge media between the two types of institutions for learning.

5.1 MediaGalleries – Static and Dynamic Knowledge Media Collections

In ALS, an *InteractiveWall (IW)* (Fig. 2) or *Interactive Table (IT)* can provide *MediaGalleries* to display collections of raw as well as selected, grouped, tagged, and categorized media bound semantically to objects of the learning domain. Using MediaGalleries, the learners can create documents, presentations, and higher media under the supervision and guidance of teachers and curators.

A MediaGallery may be constructed as a simple manually selected fixed collection of media. Alternatively it can be the dynamic result of a semantically tagged collection of media, automatically filtered and constructed from the repository.

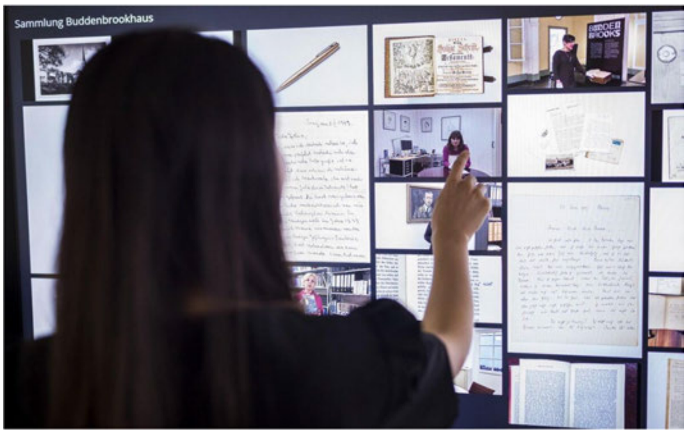

Figure 2. Using an ALS MediaGallery on an InteractiveWall with images, videos, music, and 3D objects in the museum Buddenbrookhaus (Heinrich-und-Thomas-Mann-Zentrum) in Lübeck, Germany in preparation to be used by schools through their own ALS installations.

5.2 TimeLines – Chronological Structures creating History

The ALS *TimeLine* module is embedded in IWs and ITs ([6], [20]). It displays an interactive graph visualizing knowledge entities with chronological information and dependencies (Fig. 3). These entities represent *events* at a point or period of time. Events can be annotated with *multiple semantic tags* and be assigned to a *category (sub-timeline)*. Depending on the zoom level, events will be grouped and combined through their tags. When zooming in, the groups dissolve and the individual events become visible. Events can be presented by different types of media like text, image, audio, and video.

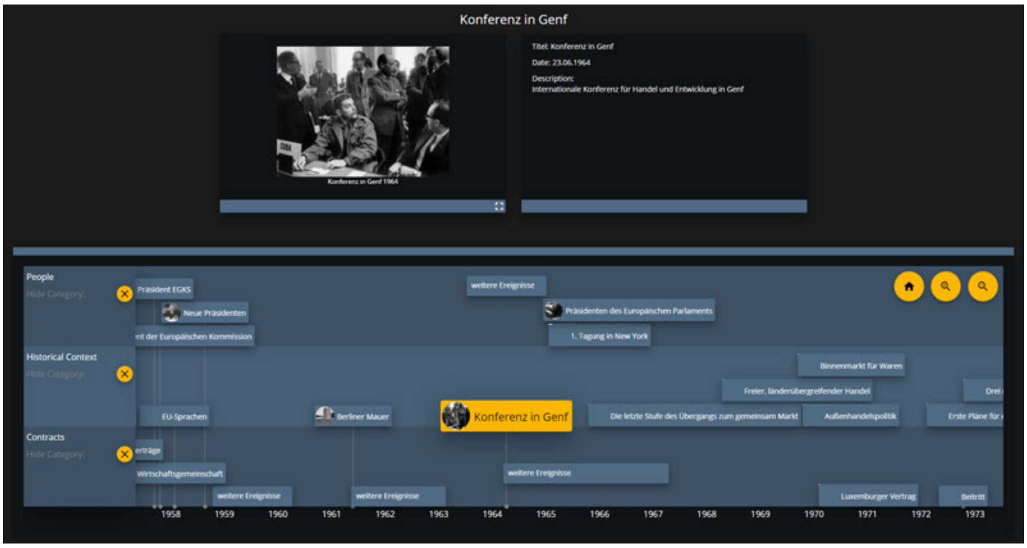

Figure 3. Screenshot of TimeLine about the development of the European Union prepared by a school class of the Hanseatic School of Business, Economics and Administration in Lübeck developed in a distributed project during the COVID-19 pandemic.

A TimeLine consists of one or more *sub-timelines*, i.e. semantic dimensions over the same period of time. For example, political events can be seen from different perspectives (e.g. “People”, “Historical Context”, and “Legal Contracts” like in Fig. 3). This allows multiple perspectives of history and helps to identify, question, and explain causalities and other dependencies between the events. Learners can hide and display sub-timelines and can thus adapt the whole visualization to their own interests. TimeLines show how history can be constructed seen from different perspectives. Inside the TimeLine application, users can navigate with a mouse or by natural multitouch interactions (gestures) deliberately through the chronological graph and explore knowledge entities with annotated and categorized content. When selecting an event, the related media (documents, images, audio, video, 3D objects) will be displayed. Zooming in and out in time can be done by pinch gestures.

Using the NEMO user authentication, curators, teachers, and students can collaborate physically or virtually to create, edit, and enrich timelines. Users with sufficient permissions may specify the tags and categories to be assigned to the events. This is particularly useful in school or museum contexts, where teachers or curators define a set of categories that shall be used by students to research, annotate, and categorize events in a certain sense.

5.3 SemCor – Semantic Networks and Serendipity

SemCor is an ALS learning application for active search and knowledge discovery [6]. It supports interactive exploration of semantic correlations between knowledge media entities to inspect interrelated visual representations of information in a *semantic web* (Fig. 4). Students, teachers, or curators can provide starting seeds (knowledge entities) to explore semantic correlations from there.

Figure 4. A SemCor graph visualizing semantic correlations for a seed entity displayed as the center of a dynamic force-directed graph. Nodes of the graph represent related entities, whereas edges between nodes represent relations. This screenshots shows a semantic network in the Buddenbrookhaus (Heinrich-und-Thomas-Mann-Zentrum) created from DBpedia and Wikipedia.

SemCor connects to a predefined semantic repository (e.g. DBpedia with Wikipedia) to search for related entities. Once entities are found, they are grouped into categories and visualized dynamically in a force-directed graph. Entities can be selected to further expand the visualized knowledge space. Selecting a knowledge entity, more detailed content (e.g. the corresponding Wikipedia article) will be displayed to be explored further. SemCor will search and dynamically deliver new knowledge entities in the graph that can be selected by the learners. These entities are automatically searched and selected through certain search algorithms and filters. SemCor visualizes the mesh and complexity of world knowledge and motivates explorations through the *serendipity* phenomenon.

The knowledge repositories for SemCor can be self-created or chosen from available ones. The standard system works with DBpedia and Wikipedia. Other external repositories with well defined knowledge domains, like the Europeana for cultural heritage, have been connected as well.

5.4 HyperVid – Rhizomes of Knowledge for Storytelling

HyperVid is a web-based *hypermedia system* in ALS that enables linking images and video fragments into a hypervideo (Fig. 5). The finished hypervideo can be presented on the IW. It can also be integrated in webpages, e.g. the homepage of a school or a museum. HyperVid promotes networked thinking and storytelling. It supports joint learning with narrative time-based multimedia [21].

Additionally to standard image and video formats, HyperVid has been enabled using 360° images and videos as well. The connectors will be jumping points in a panoramic scene to switch to other visual locations. Through this, a virtual 3D space will be created, which can be discovered.

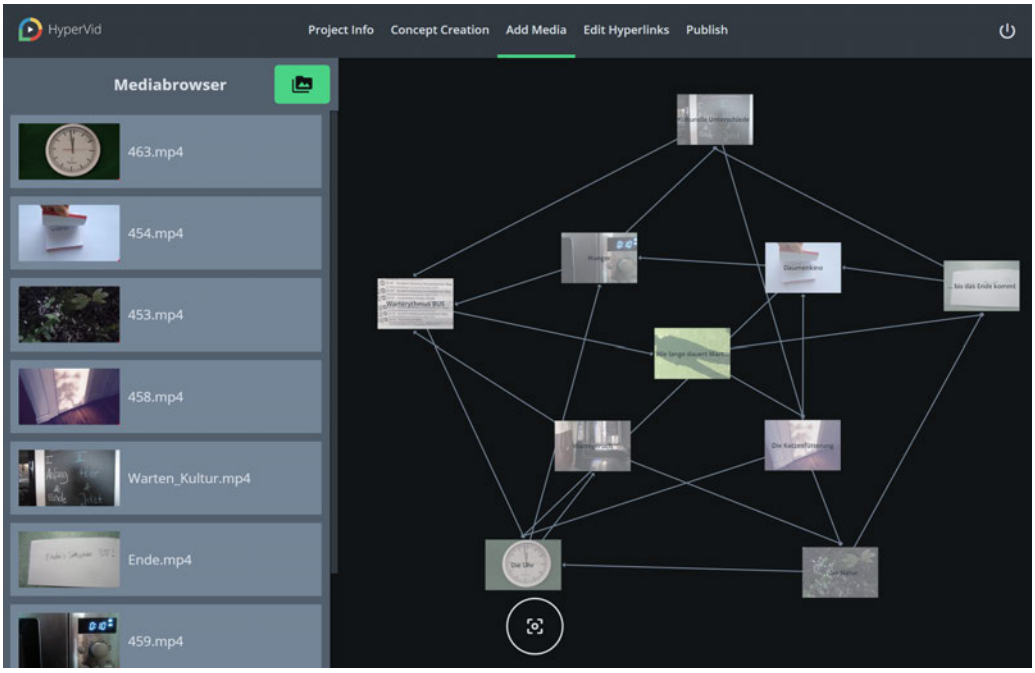

Figure 5. HyperVid editor showing the production of a hypervideo consisting of multiple interlinked video fragments. This screenshot is an art production built in a teacher workshop with some elements reused from the work of an art class to represent aspects of "Waiting".

5.5 InfoGrid – Information Layers through Augmented Reality

InfoGrid is an *Augmented Reality (AR) app* that allows studying an environment by searching for active objects (targets) providing digital visual or auditory informational overlays of images, audio or video clips, static or animated 3D models. The learners can visit certain places and point their smartphone camera towards scenes like displays and artifacts in a museum (Fig. 6) ([5], [22], [23]). InfoGrid streams audio and video data from the connected NEMO repository. Additionally it can display a map or a floor plan to support orientation or guide through an environment.

Figure 6. InfoGrid displays a virtual 3D whale skeleton and animated body augmented over exhibited paleontological whale bones inside the Museum for Nature and Environment in Lübeck, Germany.

For the production of 3D objects from image and video footage, a converter has been developed that can be used by teachers, students, and curators themselves to create their own AR tours. For this purpose photos or videos of physical 3D objects will be taken. A special module of the NEMO media conversion layer as well as the 3DEdit authoring system will be used to create these 3D objects [23].

5.6 MoLES – Going for Challenges and Search

The *MoLES (Mobile Learning Exploration System)* provides a task-based teaching framework to guide through a series of tasks and challenges along a topical and geographical learning path ([5], [24]).

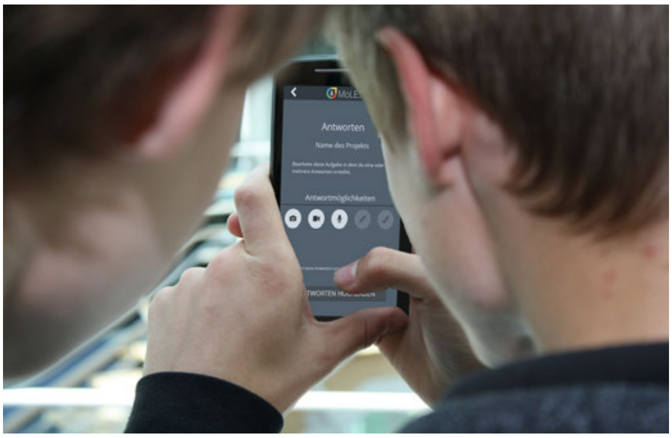

Figure 7. Students solve tasks while following a tour. The data, images, or videos collected will be uploaded to NEMO to be selected, tagged, and used for presentations when back in school.

A task may be to take pictures of certain plants or buildings or capture videos of industrial processes. Students have to answer questions, research, and store data about the objects and contexts and follow the next task until the whole tour has been completed. Typically, the students will go out in small groups of 2 to 4 with fewer devices than group members to be forced to discuss and decide together what shall be noted and collected (Fig. 7). The ALS MoLES app will transmit data and media automatically as soon as possible via internet connectivity to the NEMO repository. These will then be available for presentations or other purposes during lessons or used in projects.

5.7 Interactive Dome – The Experience of Immersion

The media currently in use for immersive ALS applications are mainly 360° images and videos. Both can be enriched by interactive elements, like in HyperVid [21], to create non-linear 360° hypervideo structures with interactive buttons to change the location, linking to another image or video taken from the spot selected in the video.

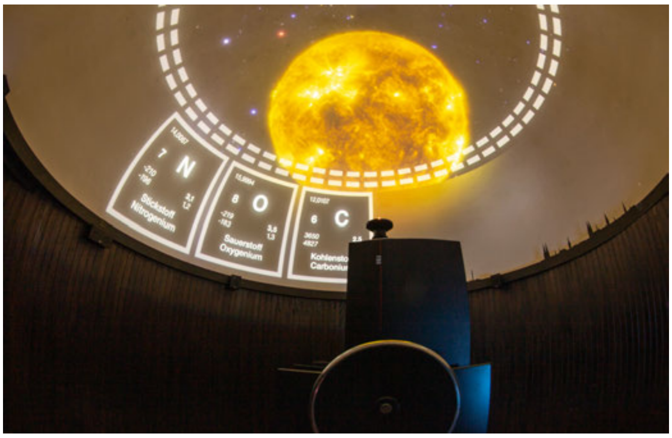

Figure 8. 360° degree productions can be brought into an interactive dome system within school. The historical planetarium "Sternkammer" of the Grund- und Gemeinschaftsschule St. Jürgen in Lübeck, Germany has been refitted with a digital projector and connected to ALS to display 360° images and videos created and used during classes (© Photo courtesy of Ralph Heinsohn).

As presentation and interaction technologies, we used VR HUD presentations like Oculus Rift and Oculus Go as well as full dome presentations. Rectangular 360° images and videos can be transformed into HUD and dome formats to create a strong immersive perception. The *InteractiveDome (ID)* system in one of the schools offers space for up to 15 students or teachers (Fig. 8) [3].

Another technology for immersive presentation and interaction are VR players for Web VR solutions that can be integrated in the IW, IT, or the ID. VR engines, like in the Unity framework, can create similar effects. The VR modes additionally support the interaction with 3D objects that can be created by students themselves through a photogrammetric pipeline from images and video footage [23].

5.8 Linking Schools, Museums, and Homes through ALS

Web-based ALS applications, as described above, can be used in schools, museums, and homes connected by the internet. This creates a common and shared knowledge media space (Fig. 9).

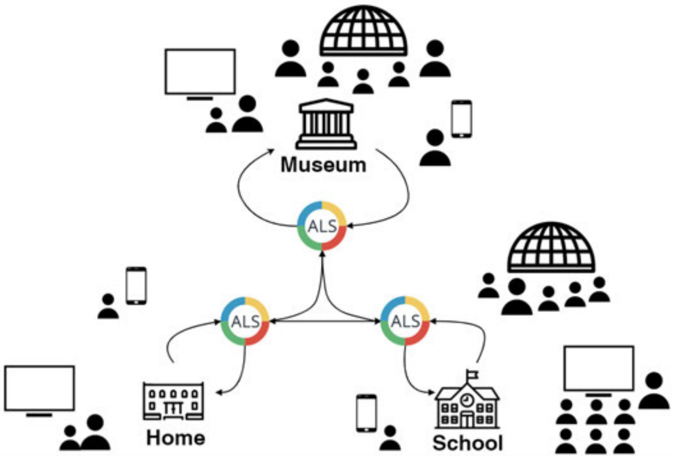

Figure 9. ALS as connected Knowledge Media Machines for Schools, Museums, and Homes

6 SUMMARY AND RESULTS

Ambient Learning Spaces (ALS) is an integrated multimedia platform for teaching and learning. Based on a central data and media storage system it allows to create, construct, and share knowledge media across a variety of interactive applications (e.g. wearables and mobiles), stationaries (e.g. interactive walls and tables), and immersives (e.g. head-mounted displays and interactive domes). These applications in different form factors and sizes empower to adapt to learning situations of practically any learning context inside and outside schools. ALS has been used as a knowledge media machine in several pilot installations in schools and museums and has been evaluated in respect to its ergonomic and didactic usability. The results show that teachers and learners were enabled to use the different modular teaching applications through regular teaching and learning in different curricular subject areas. However it showed that it is a new and powerful interactive media environment that needs tutoring and training of teachers, students, and curators for successful use.

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