AMBIENT LEARNING SPACES: DISCOVER, EXPLORE AND UNDERSTAND SEMANTIC CORRELATIONS

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Abstract

There is a worldwide discussion about digitization in school education. This discussion is mostly technology-centered, leaving a lack of solutions for daily schooling or focuses on isolated educational applications. With the Ambient Learning Spaces (ALS) platform, we developed a didactic infrastructure as an integrated environment that supports self-directed learning inside and outside school. The platform interlinks mobile and stationary learning applications. The artificial division between the classroom and the world outside vanishes through the pervasive cloud-based backend system NEMO (Network Environment for Multimedia Objects) connecting students' mobile applications with central semantic media storage. This paper emphasizes on the two learning applications for general semantic correlations (SemCor) and chronological correlations (TimeLine). SemCor is a learning application within ALS that supports interactive exploration of semantic relationships between knowledge entities and graphically visualizes a semantic web. With SemCor students may use any knowledge entity as a starting point to search for related entities. SemCor can use any semantically annotated ALS media object, any notion, or Wikipedia entity as a seed leading to related entities through attributes, tags (e.g. Wikipedia weblinks) or abstractions (e.g. DBpedia categories). Other knowledge spaces can be defined and available ones can be connected to SemCor leading to learning by discovery in more predefined topical domains. SemCor implements the principle of serendipity through a dynamic graphical representation of structure and content of knowledge. The learning application TimeLine is specialized in showing chronological correlations of events in the world. It allows setting up multidimensional timelines to display knowledge entities represented by annotated media like text, image, audio, or video in the ALS storage NEMO, visualizing distances between events and their entities. It enables students to set up their own timelines and attach media related to selected events and entities. TimeLine entities can be used as seeds for SemCor leading to further semantical explorations of the time structures already found.

Keywords: Ambient Learning Spaces, Semantic Modeling, Semantic Web, Timelines, Multimedia Learning.

1 INTRODUCTION

The worldwide ongoing discourse about digitization in school education is often highly technology-centered, leaving a lack of solutions for daily schooling or focuses on isolated educational applications. Neither Wi-Fi at school nor desktop-PCs, tablets, or smartphones will be the answer. However, they can be a key for a solution, if there is a didactic infrastructure that connects and integrates these devices into methods of self-directed forms of solving tasks and discovering teaching content. This idea follows, among others, the conceptualizations of Weiser [1], where there will be a range of different sizes and form-factors to enable people accessing personalized knowledge sources any place at any time.

With the *Ambient Learning Spaces (ALS)* platform ([2], [3]) we developed a didactic infrastructure as an integrated and pervasive environment that supports self-directed learning inside and outside school [4]. The platform connects mobile and stationary learning applications. The artificial division between the classroom and the world outside vanishes through a pervasive cloud-based backend system called *NEMO (Network Environment for Multimedia Objects)* connecting students' mobile applications with a central semantic media storage. This paper emphasizes on the two learning applications for general semantic correlations *(SemCor)* and chronological correlations *(TimeLine).* In another paper in the same proceedings, we described the mobile learning application *MoLES* and *InfoGrid* [5].

Semantic relationships play a key role in building up knowledge about the world. *SemCor* is a learning application within ALS that supports the interactive exploration of semantic correlations between knowledge entities. It graphically as well as dynamically visualizes a semantic web. With SemCor, students may use any knowledge entity as a starting point (the seed) to search for related entities.

SemCor can use any semantically annotated media object of ALS, notion, or Wikipedia entity as a seed leading to related entities through attributes and tags (e.g. Wikipedia weblinks) or through abstractions (e.g. DBpedia categories). Other knowledge spaces can be defined and already available ones connected to SemCor leading to learning by discovery in predefined topical domains of different authorship and authenticity, which is an interesting topic of itself. SemCor implements the principle of *serendipity* through a dynamic graphical representation of the structure and content of world knowledge. Other than just following links in the World Wide Web, SemCor keeps and visualizes the current context of learning together with its complexity and offers new semantic relationships dynamically.

Another learning application of ALS, named *TimeLine*, is specialized in showing chronological correlations. It allows setting up multidimensional timelines to display knowledge entities represented by annotated media like text, image, audio, or video in the ALS storage. Several topical dimensions can be displayed as parallel timelines visualizing chronological correlations of events seen from different perspectives. TimeLine has been used for natural sciences (e.g. paleontological excavations) and history (e.g. political, economic, and technological development in certain contexts and periods). It enables students to set up their own timelines and attach media connected to selected events and entities. TimeLine entities can be used as seeds for SemCor leading to further semantically guided explorations of the chronological event structures already found and represented.

Both applications make use of large multi-touch screens *(InteractiveWall, IW)* or multi-touch tables *(InteractiveTable, IT)* located in school. These large displays can be placed in classrooms, project spaces or in social settings like in school foyers.

Teachers and learners are enabled to use the different modular teaching applications of ALS as a modeling environment as well as learning applications. An overview of the whole system can be found in [3]. ALS installations are currently in experimental daily use in several schools and museums.

2 METHODOLOGY

Ambient Learning Spaces (ALS) and the concepts of semantic modeling are based on several methodological foundations. In this section we will refer to some of the more important pedagogical theories, especially about knowledge construction, and outline the resulting systemic model of ALS.

2.1 Pedagogical Foundations

In our digital age, there are many discussions about the usage of computers, networks and computer applications in the classroom. Most of the applications are dealing with generic skills like writing, math or about abstractions of the world like geography, politics or economy. Contemporary didactic approaches assume that learning is an active construction process, where a learner creates an individual mental representation of the world. Learning depends strongly on individual prior knowledge and the social, natural and technical environment in which learning takes place.

An important constructivist foundation for our approach is the theory of *Expansive Learning* in the sense of Engeström. His pedagogical concepts follow the so-called cultural-historical theory of activity, founded in the 1920s by researchers such as Vygotskij [6] and Leont'ev [7] and further differentiated in *Critical Psychology* for *Self-Determined Learning* by Holzkamp, as discussed by Engeström [8]. According to Critical Psychology, learning in general means the appropriation of an object meaning by a learning subject and not the achievement of a normative educational ideal. In addition to concrete things, this also includes abstract and symbolic references. Thus, learning addresses individual or collective learning processes with the goal of extending action possibilities, competencies, and self-determination. Cole and Engeström [9] define a system of mediating artifacts relating the subjects with the objects of the world surrounding them (Fig. 1). They outline in respect to knowledge construction: *"When moving toward the mastery of any academic subject, schoolchildren, with the teacher's help, analyze the content of the curricular material and identify the primary general relationship in it, at the same time making the discovery that this relationship is manifest in many other particular relationships found in the given material."* [10]. In this sense, the design of digital systems supporting learning shall be enabling and supporting the individual construction of sustainable knowledge, i.e. knowledge that is interrelated and finds a relevance of use in the reality of daily life. Learning software, which uses such capabilities of the new interfaces, has a high potential to support learning in school contexts, also collaboratively, and, above all, a relevant relationship to life physically, mentally, and digitally.

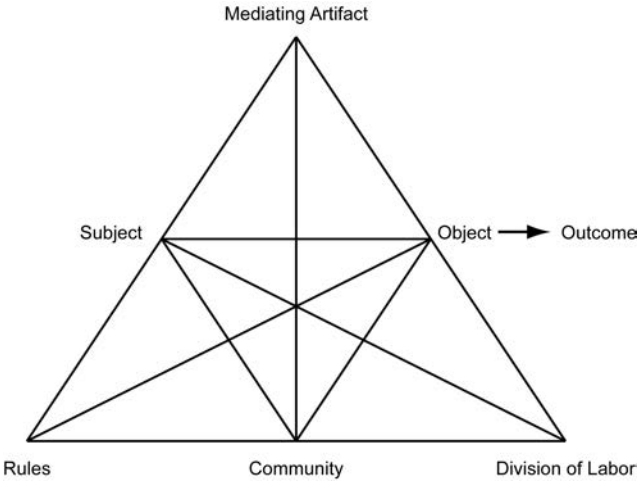

Figure 1. Activity Analysis (cf. Cole & Engeström 1993).

The cultural artifacts or tools like applications discussed by Vygotskij and followers foster self-determination by building up interrelated knowledge in social relationships within a cultural context.

To support constructivist pedagogical concepts, including the world of current digital media, we need a systemic technological concept for a digital media and computing platform that is connected to real world information repositories for the purpose of teaching and learning. This platform has to serve as a technological substrate for didactic methods. It shall store and provide media that can be semantically marked-up and enriched to reach the level of externalized symbols or knowledge entities. Interaction with such semantic media can support, among other things, a better understanding of the culture of knowledge and artifacts, like

- networked complexity of the world,
- relationships between artifacts and the physical world,
- differences between instances and classes in layers of abstractions,
- creation and usage of consistent vocabularies,
- roles of tagging and classification,
- process of knowledge construction in general, and as well
- history as a construction of chronologically ordered and referenced entities and events.

Media created or provided need to be accessible through a variety of interactive frontend applications by the learners for stationary and mobile usage and have to be reusable in different teaching and learning contexts. Access to the media is done through user interfaces that permit different interaction forms, like image and video editors and viewers, interactive form definition and data entry, dynamic image graphs as well as augmented and virtual realities.

A technological multimedia platform for teaching and learning needs to support a variety of media types like text, sound, image, video, 3D objects and interactive scenes. Media shall be constructible from interlinked basic media for different input and output devices. The platform needs to be able to dynamically generate end user device dependent variations of source media like images, videos or 3D objects with specific formats or resolutions as needed. For example, mobile smartphones will be served with lower resolution images than large public screens. The conversion of media shall be performed in automatic processes invisible for users, since for human knowledge construction there is no relevant meaning in this process, expecting that media always can be efficiently and comfortably perceived by human senses. The platform shall provide flexible personal, group and public ownerships for media objects or media collections referencing the social relationships.

The media created need to be enriched by informally or formally predefined annotations referring as simple form of semantic markup in the application contexts. Additionally media and the entities behind them shall have relations to higher level concepts like taxonomies referencing to the global DBpedia or self-constructed taxonomies of knowledge. These relationships as well as tags will transform the media into semantic media related to real world and real usage.

The media need to be hosted and organized in a cloud-based distributed media database to be accessible anytime and anyplace for contextualized learning and teaching.

2.2 Ambient Learning Spaces

The two semantic applications *SemCor* and *TimeLine,* which will be described in more detail, are modules of a larger integrated and embedded system we call *Ambient Learning Spaces (ALS)*. ALS connects these *frontend learning applications* with a *semantic backend repository* storing and semantically modeling and annotating the media for these frontend applications. As an interactive integrating frontend application, we developed the *InteractiveWall (IW),* often placed in school foyers and other public school spaces or in the classrooms. The IW is a large multi-touch interactive screen with a capability of up to 50 simultaneous touch events allowing several students interacting with the content at the same time. The IW comes in a variation as an *InteractiveTable (IT)* with the additional capability of recognizing not only touch events, but also tangible objects (fiducials) placed on the surface. These tangibles are haptical and graspable symbols representing meaning and can therefore be used to connect to the semantics of the media in the repository itself to annotate or filter the media.

ALS is a kind of didactic infrastructure providing modularized frontend applications on mobile and stationary interactive computer systems connected to a semantically modeled multimedia backend store called *Network Environment for Multimedia Objects (NEMO)*. As an open system, ALS can be enriched by new media applications. ALS is a digital teaching and learning environment that is used to support contextualized learning in real-world contexts.

2.3 The Integrated ALS Backend Platform NEMO

The Network Environment for Multimedia Objects (NEMO) ([3], [11], [12]) is a service-based architecture (cf. Fig. 2) that provides:

- User Authentication (accounts and profiles for users and groups)
- Usage Tracking (anonymous tracking for user research)
- Media Conversion (automatic data conversion for 2D, 3D, and video footage)
- Cognitive Services (automatic tagging and classification)
- Central Logic (store and retrieve media content considering ownership and context)
- Semantic Database (tagged object- and RDF-based storage)

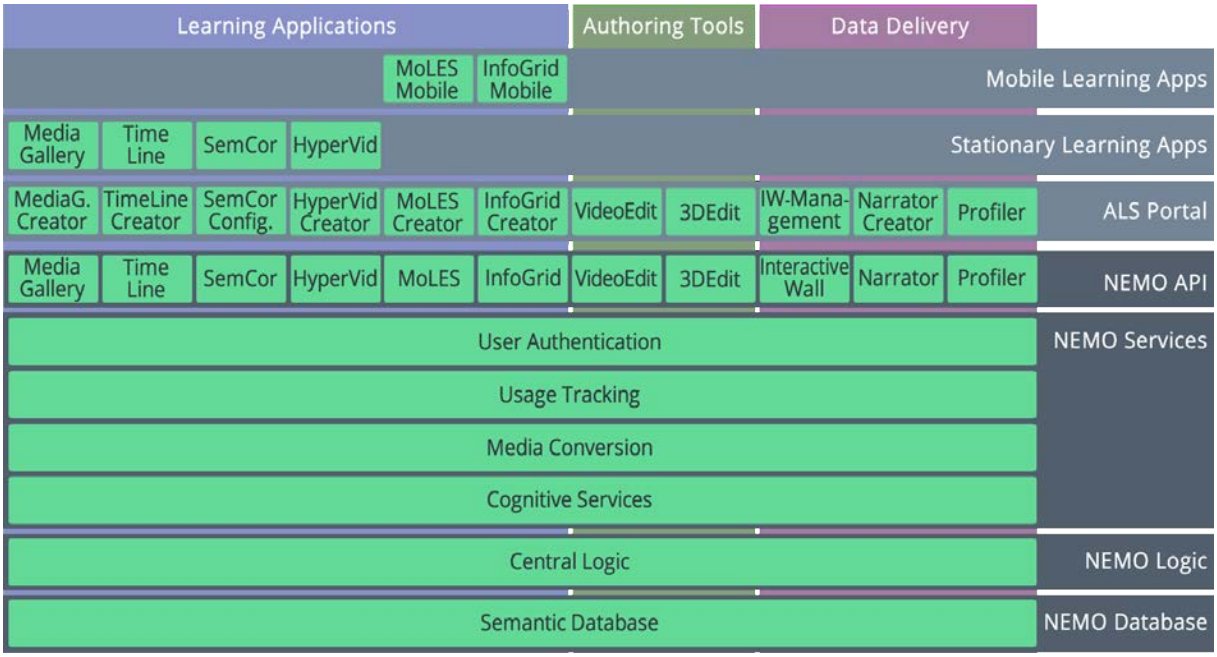

Figure 2. ALS System Architecture [3].

Media created and bound to objects representing the entities of the world are building up a semantic web of artifacts. Several media in different formats for different devices may represent a certain entity. NEMO enables the learners to reuse media created or collected through one frontend application in other frontend applications for related, but different learning contexts. This is important to create a growing semantic repository of media that can be abstracted and enriched to symbols and entities through annotations, classifications and relations between them.

2.4 The Mobiles of ALS

Authentic education through authentic social activities in context is a constructivist approach to build individual knowledge within a cultural setting. Learners have to leave the synthetic space of school and enter mainly physical cultural contexts like urban space, biotopes, industrial environments, or cultural collections and archives like museums and libraries. Through the use of networked mobile applications on smartphones, tablets, or wearables, the computing devices - the knowledge tools - can be taken with the learners to keep the scaffold of teaching with them and enable them studying in context and collecting data and media to be brought back to school.

The mobiles of ALS, as well as their roles in teaching, are described in more detail in a paper in the same proceedings [4]. Further work of semantic modeling in mobile applications can be found in ([13], [14]).

2.5 The Stationeries of ALS

After having been searching, discussing and collecting in the real context, the students need to select and order their findings to answer questions or create abstractions of what they found. This again shall be a social process that will typically happen in schools with larger devices in a larger group or class context. To visualize the findings they can make use of large screens (typically 55-65") on the wall called the *InteractiveWall (IW)* ([15], [16], [17]) (Fig. 3). The IW provides so-called *MediaGalleries* that show collections from the field or collections of selected, grouped, tagged and classified media bound to objects of the learning domain. From these, the students can create presentations or documents under supervision and guidance of their teachers or parents at home.

Figure 3. Several InteractiveWalls in a school foyer [16].

Besides the InteractiveWall, there is an *InteractiveTable (IT)* that provides support for certain working or spatial contexts in school. Other than an IW, an IT will allow the use of tangibles, i.e. objects that can be placed on the table and interact with the collections for example as instruments for tagging or filtering. IWs or ITs have been placed in social places within school buildings like the school foyer or

open museum spaces that allow social interaction with the results, like with media collections or presentations of contextualized projects as described above.

SemCor and *TimeLine* are two applications that foster an understanding of knowledge construction to act in an authentic environment (e.g. the real WWW or a real collection of artifacts), discuss with experts (e.g. museum curators) and learn by discovery. They are examples of *Experience Design* within cultural learning environments [18].

3 THE SEMANTIC APPLICATIONS TIMELINE AND SEMCOR OF ALS

This paper emphasizes on the two learning applications, *SemCor* and *TimeLine* for general semantic and for chronological correlations. Integrated in the IW, students can use these learning applications to structure, arrange and explore information in chronological and semantic relationships. TimeLine and SemCor visualize the knowledge entities and interconnections in dynamic explorable graphs.

3.1 TimeLine – Learning with Chronological Correlations

TimeLine is a web application embedded in the IW. It displays a chronological graph visualizing knowledge entity with chronological meaning and dependencies. The knowledge entities are therefore called *events*. They represent a point or a period of time on the chronological graph. Events can be annotated with a topic. They can also be associated with media like text, image, audio, or video from the cloud-based ALS storage NEMO. In TimeLine users can navigate through touch interaction freely through the chronological graph and explore knowledge entities and the annotated content (Fig. 4).

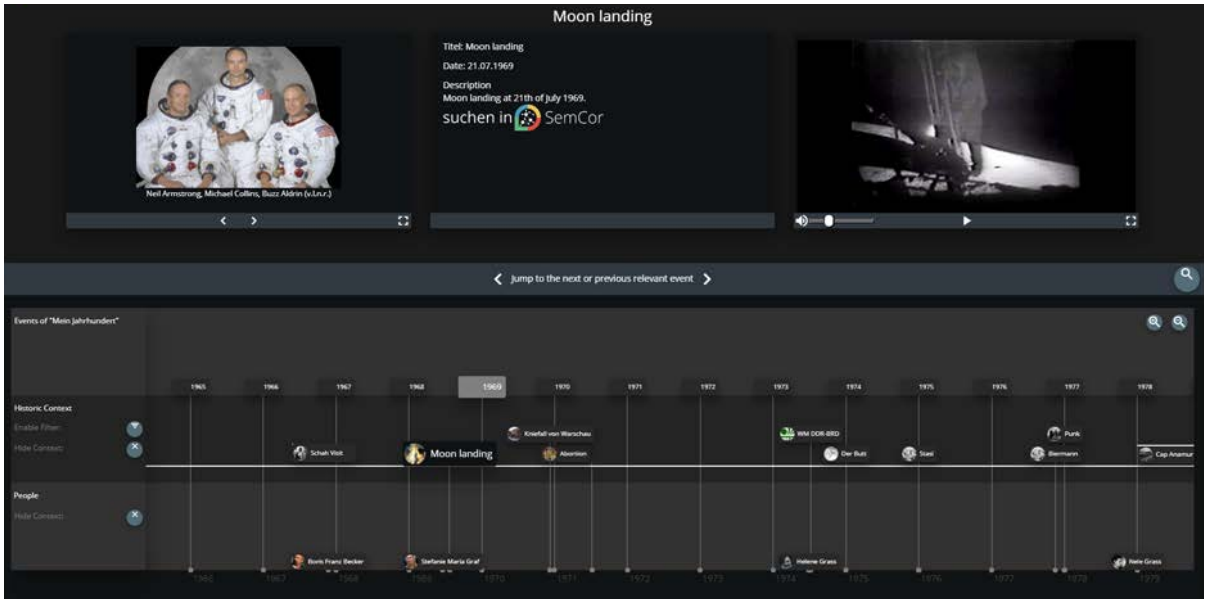

Figure 4. Screenshot of TimeLine showing details, graphics and a video of the selected event Moon Landing of the TimeLine of the book "Mein Jahrhundert".

A TimeLine display consists of one or more timelines, i.e. semantic dimensions over the same period of time. For example, political events can be shown in parallel to economic or technological developments. This allows multiple perspectives on history and helps to identify, question and explain causalities and other dependencies.

A TimeLine can be created in the ALS-Portal. Using the NEMO user authentication, teachers and students can collaborate to create new TimeLines. Events can be assigned a category (e.g. person, artwork, place). Furthermore, events may be tagged (Fig. 5). All information entered into the ALS-Portal are saved in the NEMO backend system. Therefore, events can even be reused for multiple TimeLines. TimeLine events can also be transferred as seeds to *SemCor* leading to further semantical explorations of the time structures represented.

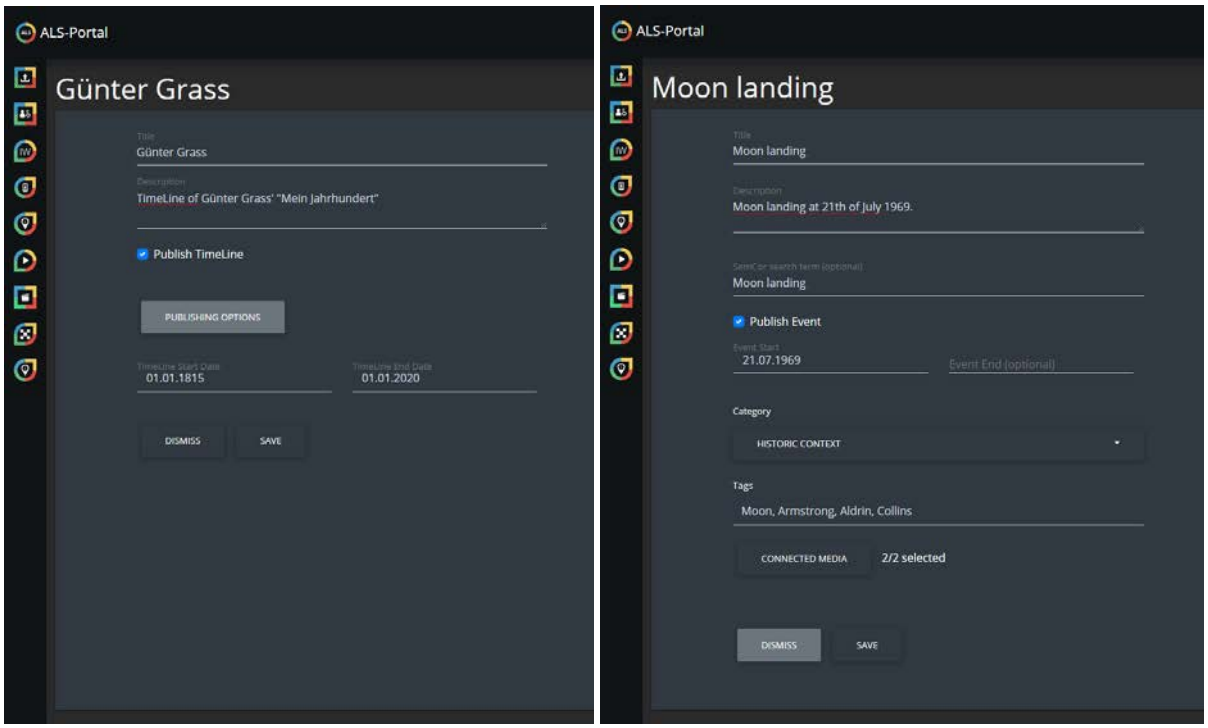

Figure 5. Screenshots of the ALS-Portal dialogues to create and edit TimeLine entities. Left: Dialog to add a new TimeLine. Details like a title, a description or a timescale to display the TimeLine can be set. Right: ALS-Portal view showing the dialog to create and edit a TimeLine event and assign corresponding media files.

3.2 SemCor – Learning with Semantic Correlations

SemCor is a learning application for active search and knowledge creation within the IW. SemCor supports interactive exploration of semantic correlations between knowledge entities and allows to inspect interrelated visual representations of information in a semantic web. Students can provide a starting seed and can specify a topic (like places, species, people) to explore filtered semantic correlations (Fig. 6).

Figure 6. Screenshot of the SemCor search dialog displaying a search bar, categories to restrict the search and a search history.

SemCor connects to a semantic repository (e.g. DBpedia) to search for related entities. Once related entities are found, they are grouped into categories and are visualized in a force-directed graph (Fig. 7). Entities can be selected to expand the visualized knowledge space. Selecting a knowledge entity further detailed content (e.g. the corresponding Wikipedia article) is shown and can be explored further (Fig. 8). SemCor will deliver automatically and dynamically new knowledge entities in the graph

that can be selected by the user. They are internally searched and selected through certain search algorithms and filters. SemCor resembles and visualizes the mesh and complexity of world knowledge and motivates explorations through serendipity.

The semantic repository to which SemCor is connected can be created or chosen from available ones. The basic system works with DBpedia and Wikipedia. Other repositories for certain knowledge domains, which provide public interfaces, like the Europeana, can be connected.

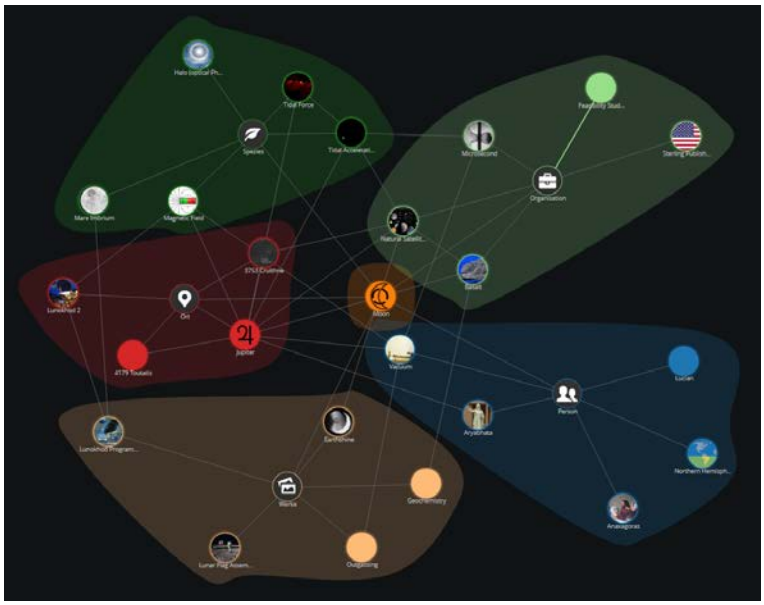

Figure 7. The SemCor graph visualizing semantic correlations for a searched entity displayed as the center of a dynamic force-directed graph. Nodes of the graph represent related entities, whereas edges between nodes represent the relations.

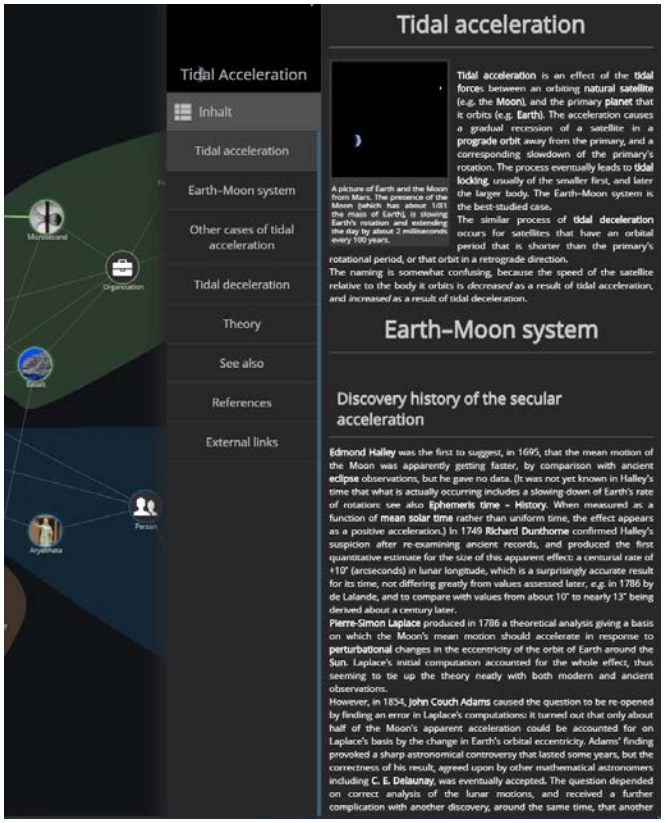

Figure 8. After selecting a knowledge node, the corresponding Wikipedia article is shown next to the hyperstructural graph.

4 RESULTS

The ALS semantic applications have been evaluated in different ways. We had to make sure that the prototype was working well in real contexts like schools and museums from a technical perspective, which means for the stationary systems that they work robust and stable with a proper functionality. Software testing and validation methods have been used to create a well working system that has been maintained regularly in the schools. Next, we had to make sure that no severe usability problems will affect the usage by the two main target groups, the teachers and their students or visitors of a museum. Besides a participatory design process, we spent effort in usability testing and evaluation for all the frontend modules with SUS [19] and ISO 9241-110 ISONORM questionnaires.

Based on a stable and usable ALS system the applications have been used in different teaching and learning contexts inside and outside school. We found that after some tutorial phases, teachers and students were capable of using the systems in school projects, sometimes across several teaching subjects with several teachers working together. We gathered promising results for the *TimeLine*. Students and teachers have been able to create and use chronological structures within their regular curricula. Students even were able to construct valuable teaching content for other students. *SemCor* representing general semantic networks is much more challenging. People like to play with it and discover relationships between entities. However, it can be difficult to identify and understand the meanings of such relationships that often are hidden in large texts or complex formal relations that have been internally found by the invisible search algorithms. More research needs to be done to incorporate SemCor in well-defined teaching contexts. However, explorations on a playful basis can be observed supporting the idea of self-driven learning processes. Examples of school projects with evaluations of TimeLine and SemCor can be found in ([15], [16]).

5 CONCLUSIONS

Ambient Learning Spaces (ALS) are a prototypical teaching and learning environment for a wide variety of learning contexts at school. The learning applications are cultural tools in the sense of activity theory bringing and keeping the learners in an active role constructing and revising their knowledge. A semantic media repository allows the focused reuse of media in different contexts with different interaction devices. A spectrum of modular learning applications for stationary as well as mobile learning has been build, applied and evaluated in real teaching contexts inside and outside school. In this paper, we emphasized on the role of stationary applications on large screens with semantic modeling. In the experiments, we found out that it is very interesting and challenging for students to do the modeling with *TimeLine*, even for other students. We found that is very challenging to provide and explain semantic webs. The construction of *SemCor* is ongoing to find out how to best start and filter search for a wide range of semantic relationships. Other than the more specialized and easy to understand chronological conceptualization of TimeLine, SemCor might be better for working with older students in more open and ethical discussions about knowledge building and trustable knowledge sources. On one side SemCor motivates for self-directed learning and on the other side it may be helpful to provide guidance and context by the teachers.

Usability and pedagogical studies show that ALS applications can be used effectively and efficiently by students and teachers. ALS support body- and space-related learning by providing a large variety of frontend systems from wearables through mobiles to room-based installations. The applications are modular and the media are reusable to enable the teachers to use and reuse the ALS system and their content according to their teaching requirements. ALS modules are ubiquitous and pervasive and do not imply or force any didactical methods. ALS is currently piloted for three schools and three museums but has been made available to a larger number of institutions, who tried out the application and authoring modules over several years. Improvements and extensions are ongoing.

ACKNOWLEDGEMENTS

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