AMBIENT LEARNING SPACES: CONSTRUCTING TIMELINES THROUGH DISTRIBUTED COLLABORATIVE LEARNING

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Abstract

With the Ambient Learning Spaces (ALS) environment, we developed a didactic infrastructure as an integrated environment for self-directed and distributed learning inside and outside school. The environment combines and interlinks mobile, stationary and immersive learning applications on a variety of interaction devices. The artificial division between the classroom and the world outside vanishes through the pervasive cloud-based backend repository NEMO (Network Environment for Multimedia Objects) connecting a growing number of interactive learning applications with a central semantic media storage. This contribution emphasizes on the ALS learning application TimeLine used for teaching history and chronological correlation of events in an interactive environment. ALS with learning applications like the TimeLine module has been used in schools before and during the COVID-19 pandemic for successful distributed distance learning.

Keywords: Ambient Learning Spaces, Semantic Modeling, Timelines, Collaborative Learning, Distance Learning, COVID-19.

1 INTRODUCTION

While computer-supported teaching and learning during the early years of computing has been focusing on the use of digital media and networking, we meanwhile can find a growing number of learning applications, which enrich the pure digital media by *didactic and domain-related metadata* like annotations, tags, thesauri, ontologies, derivation rules, and semantic networks. In a simple form, like tagging, semantic models help with searching and collecting, while in a more sophisticated manner they are a foundation for *knowledge media* [1], sometimes called *semantic media*.

As there are many applications of *knowledge media* in general, their creation and usage in teaching and learning will be emphasized in this contribution. We will discuss and describe the implementation of a teaching and learning environment with the following properties:

- Interactive learning systems (hardware and software) that are *stationary* (like digital boards), *mobile* (like augmented reality apps), or *immersive* (like virtual realities or 360° images);
- *Central media repository* for reusable media for all connected learning applications;
- *Cloud-based architecture* allowing ubiquitous and pervasive access for teachers and learners;
- *Modeling layer* enriching the media by *semantic metadata* to create *knowledge media*;
- *Content management portal* that can be used by teachers and students to create media and construct the meta layer;
- *Cascading architecture* that allows linking knowledge-media repositories of schools, museums, archives, and other sources.

These properties describe a system, which can be used as a learning environment fitting to different contexts of space, time and social structures in schools like classrooms, foyers, team spaces, school gardens, school theatres or digital domes. This learning environment will also adapt to out of school contexts like urban spaces, museums, biotopes, and industrial environments through mobile devices. Because of its ubiquitous, pervasive, and embedding nature, we called it *Ambient Learning Spaces (ALS)* ([2], [3], [4]).

With the basic ALS ideas corresponding to the properties listed above in mind, we developed a didactic infrastructure as an integrated environment for self-directed and distributed learning inside and outside schools. The environment combines and interlinks stationary, mobile and immersive learning applications on a variety of interaction devices like wearables, mobiles, PCs, boards, theatres, and full-dome environments [5]. The artificial division between the classroom and the world outside vanishes through the pervasive cloud-based backend repository NEMO (Network Environment for Multimedia Objects) connecting the interactive learning applications with a central semantic media storage.

With ALS applications, students are able to collect media such as text, sketches, images, 3D models, audio or video footage out of school with the task-oriented *MoLES* mobile app ([6], [7]) and other media capturing applications. Already collected digital media can be uploaded into ALS. All media will be stored in NEMO and may later be discussed, tagged, edited, combined, and presented in the interaction devices as described above. Media can later be reused, e.g. in the discovery-oriented augmented reality app *InfoGrid* ([7], [8]). With ALS, teachers can decide to publish selected media productions in social spaces inside school or on the schools' website for public presentation through the *InteractiveWall (IW)* ([9], [10], [11]) or the *InteractiveDome (ID)* [5].

ALS applications search, create, connect and utilize semantic media using tagging and ontologies. The students discuss, transform and combine media from basic media into complex interactive knowledge media by enriching them with semantic information. The resulting semantic media can be reused in other teaching contexts, creating topical links between the curriculum and the semantic media constructed by the students or their teachers.

One of these semantic media applications connecting media into higher knowledge concepts is *TimeLine* [12]. This learning application is designed to construct and interact with chronological correlations of historical events. It allows defining multidimensional timelines to display knowledge entities represented by semantically annotated media like text, image, 3D, audio, and video. Up to five dimensions representing semantic categories can be displayed simultaneously as parallel zoomable sub-timelines on an IW, visualizing the chronological correlations of events. *TimeLine* has been used for natural sciences (e.g. paleontological excavations) and history (e.g. political, economic, technological development in certain contexts and historical periods). Teachers can define the dimensions as timeline categories for sub-timelines chosen for a certain topic. Students fill these sub-timelines by researching and defining entities of events and by attaching media like text, image, audio or video content to these events. *TimeLine* entities can also be used as seeds for the SemCor semantic internet discovery system based on DBpedia and Wikipedia or custom knowledge spaces leading to further semantical explorations of the knowledge structures and media already found and represented [12].

During the COVID-19 pandemic, ALS with the TimeLine application has been used for *distributed collaborative distance learning.* Teachers and students used the ALS web-based platform over the course of several weeks to create different timelines. Groups of three to five students worked on disjunctive chronological intervals assigned by the teacher, while the ALS system managed and displayed the complete timeline. We studied how timelines have been constructed by groups of students in a school, one of them creating a timeline for the history of the European Union and one for the historical development of China. Both timelines are available in the school and can be used for further teaching and extension. Similar timelines have been constructed in other schools and museums for different topics. The process of timeline construction has been accompanied by scientists observing the teaching process and using questionnaires about the teaching and ALS TimeLine system usage. The findings have been helpful for further improvements of the TimeLine learning application and its integration into the ALS environment.

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.

Since the advent of interactive computer systems, there have been many discussions about the usage of computer hardware, networks and computer applications in the classroom. Most of the applications have been dealing with generic skills like writing, math or about domains like geography, politics or economy. While pedagogy is focusing on higher concepts than just plain facts, learning software rarely addresses the conceptual knowledge layers [13].

Contemporary didactic approaches assume that learning is an active construction process, where a learner creates an individual mental representation of the world. Learning therefore 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 [14] and Leont'ev [15] and further differentiated in *Critical Psychology for Self-Determined Learning* by Holzkamp, as discussed by Engeström [16]. 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 define a system of mediating artifacts relating the subjects with the objects of the world surrounding them [17]. 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."* [18]. In this sense, the design of digital systems supporting learning shall be fostering the individual construction of sustainable knowledge in a social or cultural context, 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 collaborative learning in school and creates a relevant relationship to life physically, mentally, and digitally. 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 (subjects, objects, events) and classes (taxonomies, categories, schemas, concepts) in layers of abstractions,
- Creation and usage of consistent vocabularies (tag lists, thesauri),
- Roles and differences of tagging and classification,
- Process of knowledge construction in general, and
- History as a construction of chronologically ordered and referenced entities and events.

A technological multimedia platform for teaching and learning needs to support a variety of media types like text, audio, image, video, 3D objects, and interactive scenes to support the content in different domains in generally available digital formats. The media created need to be enriched by informally or formally predefined annotations referring as a simple form of semantic markup in the application contexts. Additionally, media and their connected entities shall have and show relations to higher level concepts, like taxonomies and ontologies. These relationships, as well as tags, will fortify media into semantic media related to the real world and to real live. 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.

3 TIMELINE – A SEMANTIC ALS APPLICATION

In the following, we will outline the semantic learning application *TimeLine* modeling and displaying time-based knowledge structures within the ALS environment. Embedded in the *InteractiveWall (IW)*, students can use this learning application to structure, arrange and explore information in *chronological and semantic relationships*. TimeLine visualizes *events* as knowledge entities, their content in different media types, and their semantic interrelations along a visualized timeline consisting of several parallel sub-timelines (representing knowledge categories or perspectives) (Fig.1).

Figure 1. Screenshot of a TimeLine ("History of the EU") with 3 sub-timelines ("People, Historical Context, Contracts") displaying text, images, and videos of an event ("Conference in Geneva"). It has been created by students collaboratively during a distributed COVID-19 school project.

3.1 Learning with Chronological Correlations

TimeLine is a web application embedded in the ALS IW. It displays an interactive graph visualizing knowledge entities with chronological information and dependencies. The knowledge entities represent *events* at a point or period of time. These events can be annotated with multiple *tags* and can be assigned to a *category (sub-timeline)*. Depending on the zoom level, events will be grouped and combined by their semantic tags. When zooming in, the groups dissolve and the individual events become visible (cf. Fig. 1 and Fig. 2). This way, many events can be displayed on the timeline at the same time creating a chronological visualization without clutter. Events can be described by different types of media like text, image, audio, and video from the central ALS storage NEMO (see Section 4).

Figure 2. Screenshot of TimeLine when zooming in (cf. Fig. 1).

Inside the TimeLine application, users can navigate with a mouse or by multitouch interaction deliberately through the chronological graph and explore knowledge entities with their annotated content. When selecting an event, the related media will be offered for larger display. Zooming in and out in time will be done by a pinch gesture.

A TimeLine display 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”, “Legal Contracts” shown in the EU Timeline; cf. Fig. 1 and Fig. 2). This structural element allows multiple perspectives on history and helps to identify, question and explain causalities and other dependencies between the events. The number of simultaneously visible sub-timelines has been limited to a maximum of five because of screen space. Users can hide and display sub-timelines and can thus adapt the whole visualization to their own interests.

A TimeLine can be created in the ALS-Portal and can be configured in various aspects (Fig. 3 left). Using the NEMO user authentication, teachers and students can collaborate to create or edit timelines. Users with sufficient permissions can specify the categories to be assigned to the events. This is particularly useful in a school context, where teachers can define a set of categories that students can then use to research and categorize the events.

Events can be assigned and annotated in the ALS-Portal with a variety of information (Fig. 3 right). Users can add a title and a description to the event. The title is directly visible on the timeline, all other information is only visible when selecting an event in the timeline (Fig. 4). An event can have one or two dates. Events with one date are shown on the timeline as a single point in time and events with two dates are shown as an interval of time.

TimeLine also offers a link to *SemCor*, another semantic ALS application. TimeLine events can be used to trigger a SemCor search in semantic databases and thus lead to further semantical explorations of the time structures represented [12].

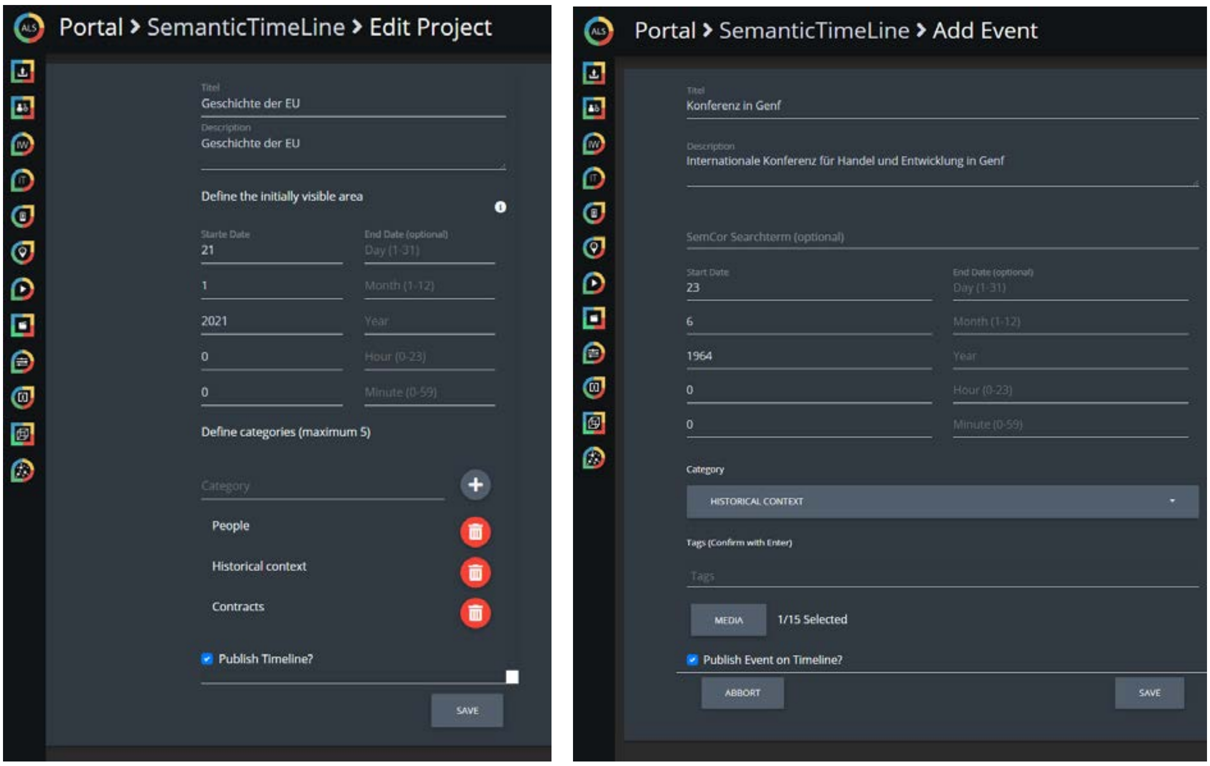

Figure 3. ALS-Portal dialogs to create and edit TimeLine entities.
Left: Dialog to add a new TimeLine: details like a title, a description or a timescale can be set.
Right: Dialog to create and edit a TimeLine event and assign corresponding media files.

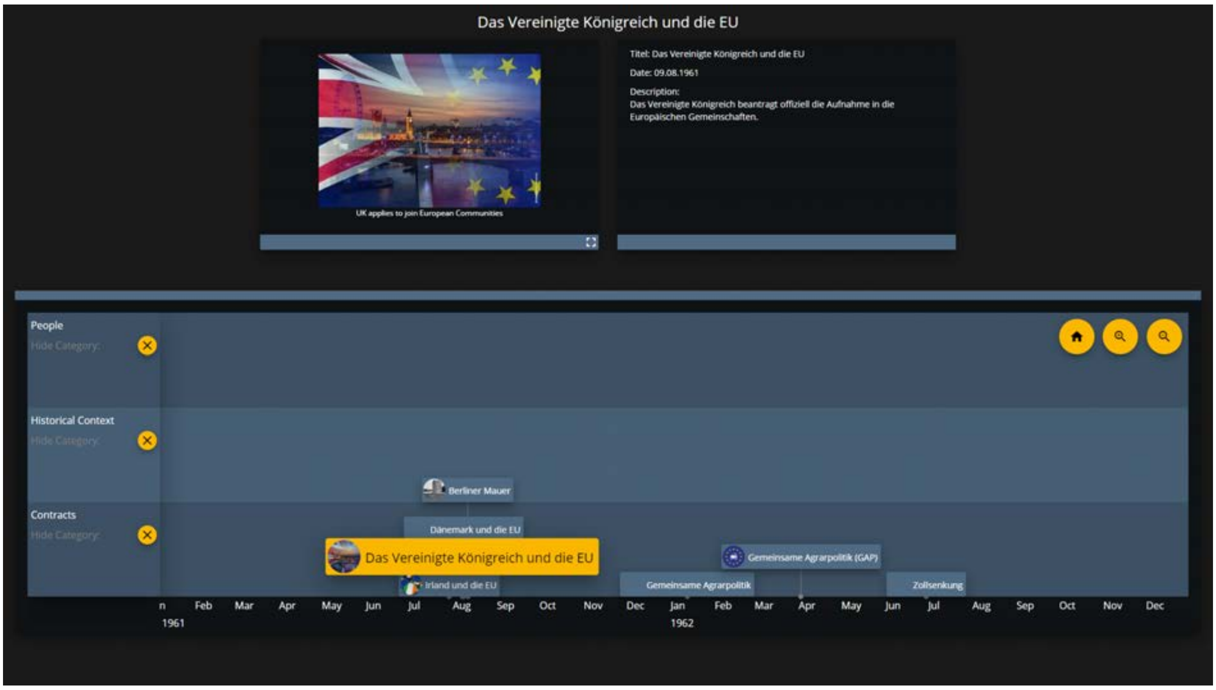

Figure 4. Screenshot of a new event created and integrated into the TimeLine through the ALS-Portal. Selected events get highlighted and the content is displayed in the upper section of the screen. Activating the media leads to a larger display of the content itself (e.g. a photo or video).

3.2 TimeLine used in Collaboration during COVID-19

During the COVID-19 pandemic, an ALS installation with the TimeLine application has been used for distributed collaborative distance learning in a school of business, economics and administration in Germany. Teachers and students used the ALS web-based platform over the course of several weeks to create different timelines, one for the history of the formation of the European Union and one for the historical development of China.

Groups of three to five students worked together by collecting information and media files on important events in a timeframe assigned by the teacher. The research was carried out by the students at home, and they made virtual meetings to discuss their findings. The different groups worked on disjunctive time intervals, which in summary create the whole timeline. In the *“EU Timeline”* project, the students used the collected information to create events and assigned them to the three categories *“People”, “Historical Context”,* and *“Contracts”.* These categories had been provided by the teacher.

The events were entered into the ALS-Portal along with the upload of the corresponding media files. Students were instructed how to use the ALS-Portal and how to enter the information by a virtual presentation by the research team. The students also had access to tutorials in a PDF format to learn the functions for the timeline creation process. The students informed the teacher when they finished their tasks. The teacher then verified the timeline and gave feedback to the students by email and during the regular scheduled lessons.

Finally, the finished timelines were approved by the teacher and published on the schools’ internal IWs. This allows other students to explore these timelines. Furthermore, the teacher can use the timelines in future classes and let the students explore the timelines as part of the lesson. If necessary, the existing timelines can be edited or extended in other classes as well.

The process of the timeline creation has been accompanied by scientists observing the teaching process and using questionnaires about the teaching and usage of the ALS and TimeLine system (see Section 5). The findings have been used for further improvements of the TimeLine learning application and the embedding ALS environment.

4 THE ARCHITECTURE OF ALS

ALS is based on a central cloud-based backend system, the *Network Environment for Multimedia Objects (NEMO)* ([4], [13], [19], [20]). The platform needs to be able to dynamically generate end user device dependant 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 screens. The conversion of media is performed in automated processes invisible for the users, since for the human knowledge construction there is no relevant meaning in this technical 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.

4.1 System Structure of ALS

The basic system structure of ALS is shown in Figure 5. The applications are decoupled from the backend by web-services. Most of the frontend applications and authoring systems are web-based for maximum flexibility. As web-based applications, the stationary ALS learning apps like *TimeLine* are embedded in an *InteractiveWall* (a presentation-like board view), *InteractiveTable* (for groups standing around an interactive table) and will also be available in the *InteractiveDome* (for an immersive experience being inside a complex semantic structure) [5]. The backend system *NEMO* can be installed and operated at any place inside or outside school, providing internet web access and sufficient bandwidth, depending mainly on the volume of digital media transmitted and displayed.

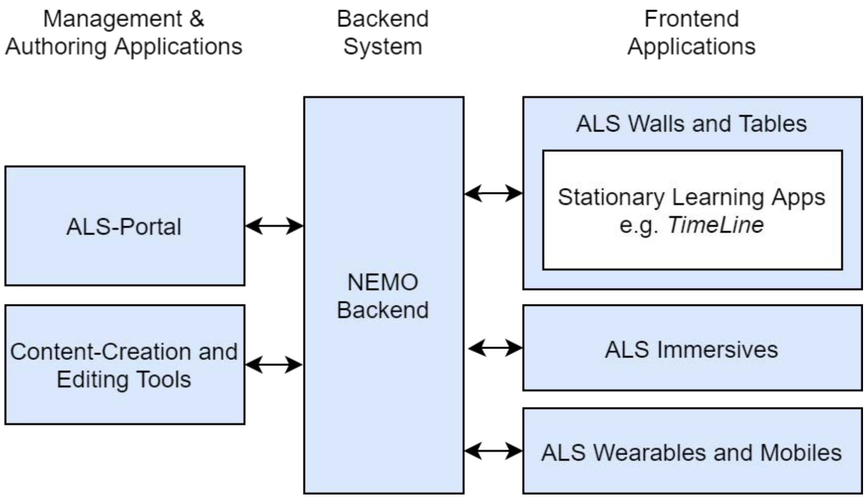

Figure 5. ALS system architecture showing the connections of the ALS Management & Authoring Applications with the NEMO Backend System and ALS Frontend Applications like the TimeLine

4.2 The Service-Based Architecture of NEMO

The API and Application Model Layer of NEMO represent the information structures needed by the frontend applications. It is implemented as an object-oriented class structure that provides the interfaces for the applications. For example, the TimeLine event-based application will store its information in this model. NEMO has been implemented as a flexible and modular service-based architecture (Fig. 6).

The central backend storage is implemented by a Media Storage and Database Layer to provide persistent semantic storage of the media used. Media created and bound to objects representing the learning discourses are representing a semantic web. Several media in different formats for different devices can represent an object of the world. 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 repository of media that can be abstracted and enriched through media, annotations and classifications.

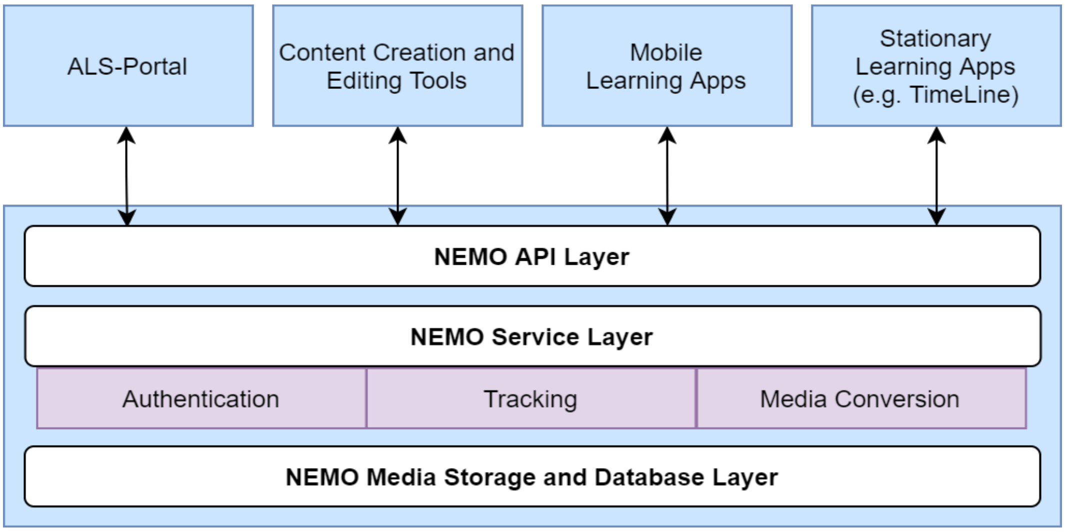

Figure 6. Layered Architecture of NEMO

5 EVALUATION STUDIES AND RESULTS

We can report a first user study on the TimeLine that was carried out in a school of business, economics and administration in Germany. Combined with the feedback from trials in the lab, with other schools and with museums we continuously improve the application and its features.

5.1 Usability and User Experience

We conducted a usability study based on the standardized ISONORM 9241/110-S Usability Questionnaire [21]. The questionnaire is related to the *dialogue principles* defined in the ISO standard 9241-110. A questionnaire template can be found in https://docplayer.org/20439300-Isonorm-9241-110-fragebogen.html.

For the study, in cooperation with a teacher, students were asked to create a timeline about the formation of the European Union. The students collected the information in groups of three students and entered the information into the ALS-Portal mostly at home. After finishing the project, the students were asked to fill out the ISONORM usability questionnaire and answer the questions regarding the usage of TimeLine and other ALS applications related to TimeLine.

5.2 Results and Discussion

The ISONORM usability questionnaire was filled out by 9 students (1 male, 8 female) of the mean age of 25 years (SD = 7.14, min = 21, max = 44) who took part in the class. The combined results of the questionnaire are shown in Figure 7. The students filled out the web-based questionnaire using LimeSurvey. Fields of the questionnaire that were left empty by the students were rated as neutral.

The analysis of the results showed that the students gave lower (negative) ratings on the conformity and self-descriptiveness of TimeLine. This can be interpreted that the creation process in its current form is a demanding task for the students. The other ratings were more or less neutral, which means that the prototypical system is already usable (i.e. acceptable) in these categories, but can be improved.

According to the results of the evaluation, we improved the usability of the authoring application by adding a preview option, which can be used during the creation process to visualize the resulting timeline. Furthermore, we replaced the date pickers for the date entries with a set of form fields, as shown in Fig. 3, to simplify the data input task for the creator.

We also improved the frontend user interface of the timeline by implementing a theming model to support individualization of the application. Additionally, we refined the usability of the frontend by implementing several changes, e.g. font sizes, coloring, and the layout of interaction elements.

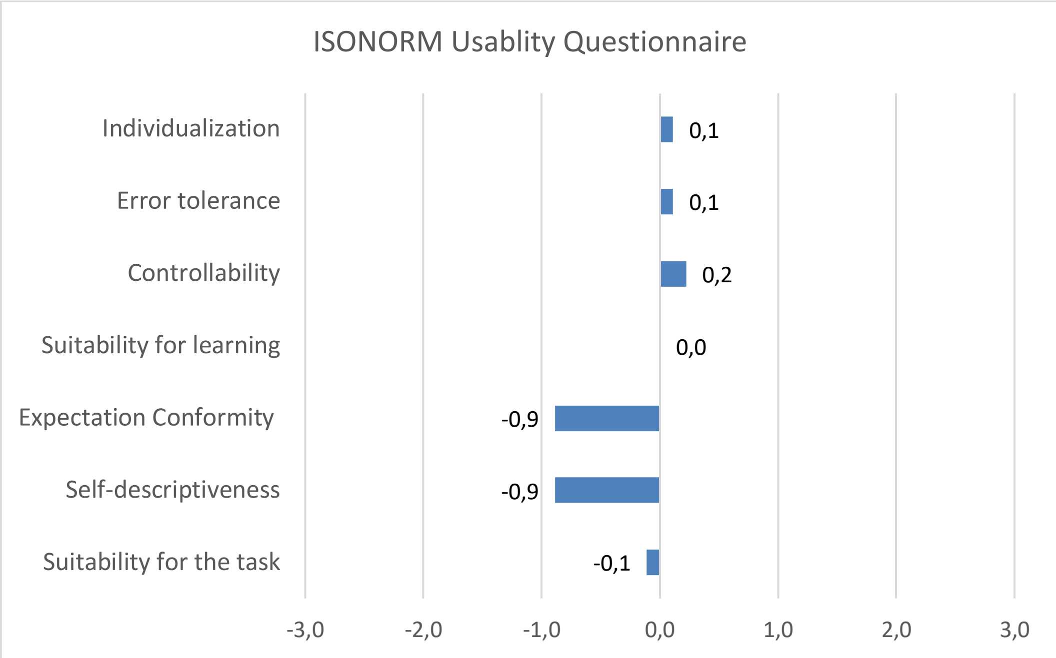

Figure 7: Results of the ISONORM Usability Questionnaire for the TimeLine application. 9 participants took part in the study. A Likert scale has been used, with 0 being a neutral point for the usability, 3 steps of negative ratings to the left, and 3 steps of positive ratings to the right.

6 SUMMARY AND CONCLUSIONS

TimeLine is a semantic teaching and learning application implemented as a module of the *Ambient Learning Spaces (ALS)* environment. It has been used for a study in a school of business, economics and administration in Germany. The results of the study show that teachers and students have been enabled, even under difficult social and spatial conditions like the COVID-19 pandemic, to use the applications together with other ALS modules in a distributed collaborative learning context. Students were able to set up a semantic chronological structure like the history of the EU as a *knowledge media* construct. TimeLine proved that it can be used successfully as a digital didactic concept and implementation that fosters thinking in complex time-based knowledge structures.

Besides the research and construction of a specific historical topic, in the sense of Constructivism and Critical Psychology, TimeLine allows teaching by the use of knowledge media, that (linear) history – and knowledge in general – are just individual, social, or cultural constructions relating to perceived, medialized, and documented realities and not realities themselves.

ALS installations including TimeLine are currently in experimental use in secondary and business schools, and as well in museums.

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