# Creating Augmented Realities
# in the Context of Lessons in Secondary Schools

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**Abstract:** This contribution describes the use of augmented reality in teaching contexts for secondary schools. As part of the project, Ambient Learning Spaces (ALS) a cloud-based learning system is used in combination with the mobile InfoGrid learning application. Together with other frontend applications, the software enables students at school to create complex narrative augmented reality tours that automatically adapt to the users. The InfoGrid app for mobile devices allows the execution of these tours by means of image recognition of photographic visual markers. Using a concrete teaching project as an example, we describe how InfoGrid and other applications of the learning system support learning in an art class. We also present the results of a usability study of InfoGrid.

## Introduction

The Institute for Multimedia and Interactive Systems (IMIS) at the University of Lübeck works for more than 10 years on digitally networked learning systems. We call them *Ambient Learning Spaces (ALS)* (Winkler, Scharf, et al., 2011). In research projects and research transfer projects, we developed digitally enriched body- and space-oriented learning environments for schools and museums. In contrast to other learning environments enriched with digital educational applications at school, students in these ambient learning spaces create and work in a lifelike manner with the teaching content related to the respective subjects. They interact with multiple interconnected display devices in physical space to learn cooperatively. In the context of ALS, body- and space-oriented human-computer interaction build a conceptual foundation. Technologically, a special framework, the *Network Environment for Multimedia Objects* (*NEMO)*, makes this possible. *NEMO* contains a multitude of additional functions in addition to the back ends and middleware of all ALS applications. Inside *NEMO*, all media created are stored in a context-specific semantic model, which supports the use by ALS applications. Along with *NEMO*, we developed a suite of learning applications as frontend applications for ALS.

One of these educational applications is *InfoGrid*. With this application augmented reality (AR) tours are created and executed. *InfoGrid* has two interfaces: The first interface is part of the *ALS Portal*, a central, web-based platform for controlling various educational applications as well as applications for the additional input of media, data editing, and user-specific data output. Teachers create projects that enable students to create AR tours with *InfoGrid* and other applications that support projects. The second interface is the *InfoGrid* mobile app, which serves to execute a previously created AR tour. Users can run the *InfoGrid* mobile app on their smartphones and use it to interact with personalized and contextualized digital content superimposed over physical objects using AR technology.

The second chapter describes related work. The third chapter describes a teaching scenario that shows how *InfoGrid*, along with some other ALS applications, is used by a teacher and students. In the third chapter, we describe the technological structure of *InfoGrid* embedded in the web-based learning system, we developed. In the fourth chapter, we present a first study of students evaluating the usability of the educational application *InfoGrid* along with the *ALS Portal*. In the conclusion, we will summarize the results and suggest further work.

**Related Work**

AR in an educational context is a field of intensive research. A large part of the research focuses on prebuild systems that school students can use, either in the classroom or at home, to consume AR content that supports learning. These prebuild systems are used in several areas. Work can be found about AR books that can be used to virtually illustrate content in a new way for the learner (Billinghurst, Poupyrev, 2001). Other work concentrates on AR games, which are used to support learning outside of the classroom (Liu, Tan, Chu, 2009). Some research focuses on how AR simulators support the discovery-based learning process (Ibanez, Di-Serio, Villaran-Molina, Delgado-Kloos, 2015). However little research has been done about school students producing AR content themselves.

**The Teaching Scenario**

Marion Ingarden[1] teaches art in the 7th grade at a grammar school. The school is located in the Hanseatic city of Lübeck in Northern Germany. She is planning a teaching unit in the field of "Designed Environment", which will focus on two thematic areas: "Architecture" and "Communication Design". With regard to the field of architecture, an examination of the buildings in the historic city of Lübeck is planned, which represent different architectural styles. In the field of communication design, the aim is to design an augmented reality tour for smartphones to the locations, where the buildings stand or once stood.

As part of her class preparation, Marion addresses the members of the Geographical Society in Lübeck and inspires some of them to support her planned teaching project. Then she creates a project in the *ALS Portal* for *InfoGrid*, which she annotates appropriately. In addition, she also creates a project of the same name in the *ALS Portal* for *Mobile Learning Exploration System* (*MoLES*), which she also annotates accordingly.

For Hatice, Max, Lena, Olli, and Alex, as well as for the other 20 pupils of the school class, who learn together in a so-called "table group", small groups of five, the lesson begins with the presentation of the teaching project by Marion. In the context of an in-depth discussion on the already started topic "Designed Environment-Architecture", Marion describes her concept and plan of the creation of an augmented reality tour using *InfoGrid*. This tour will include information about a large number of existing or formerly existing buildings from all periods of Lübeck's long history. Marion also makes it clear to the students that they can count on the support of some members of the Geographical Society of Lübeck, which she was able to win

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1 The persons and names that appear in the scenario are fictitious.

over as extracurricular experts for the project. She then reports that the *InfoGrid mobile app* can play back self-made videos in the form of augmented reality if the mobile device's camera recognizes something previously photographed (in the sense of a marker). She further explains that the students will also create digital 3D objects on a photographic basis and that these will also be included in the planned tour in the form of AR.

Now Marion also has to explain to the students how to create the media that will be fed into *InfoGrid*. She introduces the *Mobile Learning Exploration System* (*MoLES*). She describes how the students first enter the tasks in *MoLES* in the *ALS Portal*, which they then complete outside the school by creating media using the *MoLES mobile app*. She also explains that the *MoLES mobile app* saves the media created by the students in such a way that they are available for them in the *ALS Portal*. Furthermore, Marion explains to the students how the videos for the AR tour are composed from photos, sound recordings and short videos, which were mainly created using the *MoLES mobile app*, using the video editing application *VideoEdit* in the *ALS Portal*. Finally, Marion explains how the students can use the *Narrator* in the *ALS Portal*, with which they can make a tour created in the *InfoGrid* more exciting in many respects and individualize it for the future users of the *InfoGrid* mobile app.

For Hatice, Max, Lena, Olli, and Alex the following lesson begins with a concrete discussion of the tasks, which the students have to take care of. In terms of subject-related content, this is about compiling background information on architecture. These consist of archive materials, for example, plans or original photographs of historical facades before their destruction in the Second World War, usage contexts of buildings, age-dependent aesthetics, and much more. From a technological point of view, the aim is to process this information and media for presentation in the form of AR by means of the *InfoGrid mobile app*.

In the course of several lessons, in which some members of the Geographical Society of Lübeck also participate in an informative and advisory function, Hatice, Max, Lena, Olli, and Alex as well as the other students in their small groups, determine the buildings to which an *InfoGrid* tour will lead. Then the students create their concrete tasks in detail. These deal with the AR annotations in the form of different media like spoken text, photos, videos, and virtual 3D objects. In this phase of the project, the focus of the learning process is on the special nature of the planned tour to Lübeck's architecture. As Marion explains to the students, the planning envisages that the later users of the tour will not be homogeneous. They will be of different ages and different expertise. There will also be users who are not proficient in the German language. For this reason, media must be produced slightly differently for each group regarding the locations. After the tasks were distributed in the plenum of the whole school class, Hatice, Max, Lena, Olli, and Alex write their tasks into the application *MoLES*, annotate them, also by entering the locations in a digital city map.

As part of their homework, Hatice, Max, Lena, Olli, and Alex go to the city archive of the Hanseatic city to obtain historical photographs of buildings that no longer exist. Another group of students photographs existing, detailed 3D models of the Lübeck city gates, which no longer exist today, from different directions, so that they can be automatically rendered by the ALS system to 3D objects. The other three groups of students take pictures of existing architecture from a specific perspective, in order to be able to use these images later as markers, so that the

virtual objects can be placed appropriately in the real-physical space as augmented reality. And finally, all students record spoken text, which is also needed for implementing the AR tour.

After working out all aspects of the content in the form of different media, the students begin the following lesson with the post-production of the AR content. Hatice and Max open an image editor to adapt some of the historical images of the city archive for an overlay. Lena, Olli, and Alex open the application *VideoEdit* to produce the short videos, which usually consist of an image, which is later displayed in the *InfoGrid mobile app* as an overlay over a camera image, and a spoken text (see figure 1). In order to free the automatically generated 3D objects from small artifacts and to place them upright, students of another "table group" use the application *3DEdit* in the *ALS Portal*.
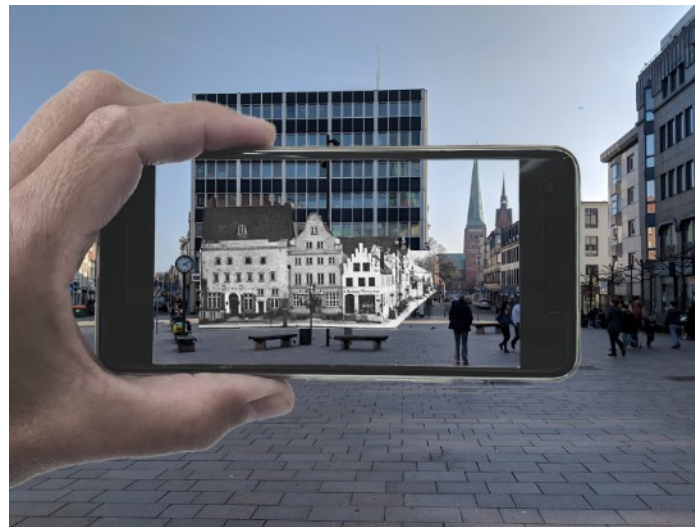


Figure 1: The *InfoGrid* mobile app shows an overlay of several historical
buildings from the year 1900 on top of the current real-physical building. An
audio recording of an interview with an expert from the Geographical Society is
played simultaneously.

In the last lesson of the teaching project, the student, and so Hatice, Max, Lena, Olli and Alex, first log into *InfoGrid* in the *ALS Portal*. Here they upload the marker and the media they have created and annotate them further in consultation with Marion. These annotations make it easier for them to work with the *Narrator*. They now open in the *ALS Portal* the *Narrator* to place different media for each location. Lena and Olli use the Narrator to enter videos rendered in simple language for a tour for children or people with special needs. Hatice, Max, and Alex create a tour that follows the time of the construction of the buildings. It is set in a way that a user is not taken to a location until he or she has seen the buildings that were constructed earlier. Other students from another group put together a tour that follows a little story in which a curious cat discovers the city. Another small group translates finished tours into English.

Figure 2: Left: The building serves InfoGrid as a marker. Right: When the building is recognized, a 3D sculpture is displayed on the camera image of the smartphone on the ground in front of the building, viewable from all sides.

Finally, the *InfoGrid* tour is finished (an example with a 3D object, see figure 2). Now it is important that as many people as possible learn about the existence of the *InfoGrid* tour. But first Marion has to make this AR city tour available to the public in its possible variants in *InfoGrid* through the *ALS Portal*. Then she makes sure that the information about the existence of the tour also reaches the public. The first step is very simple. It reaches everyone at her school. In the *ALS Portal,* she opens *InteractiveWall* and enters a small text under *Announcements*. This now appears in the "Announcements" section on the four large multitouch screens of the hypermedia platform in the lobby of her school (Winkler, Bouck-Standen, Ide, Ohlei, Herczeg, 2017). Then she asks for an appearance of the announcement on the KiMM (Kids in Media and Motion) website. KiMM is an initiative that promotes the transfer of scientifically proven and evaluated teaching models using the latest digital learning media to schools in the greater Lübeck area.[2] But most important is their third step. It is the announcement in the Lübeck tourist office, where an advertisement shows the possibility to download and use the *InfoGrid* mobile app to experience a special Augmented Reality City Tour designed by students. The announcements state that the free tour can be run with the *InfoGrid* app. The *InfoGrid* can be downloaded free of charge from the Play Store for Android devices and from the App Store for Apple iOS devices. It also states that the tour can be user-specific and that the AR information is only available as a highly compressed stream when it is called upon site.

**InfoGrid in Context of ALS**

As Ambient Learning Spaces (ALS) we understand digitally enriched body- and space-related learning environments, especially for children and adolescents (Winkler, Scharf, et al., 2011). In these learners use a variety of annotateable multimedia objects (e.g. image, video, sound, 3D models), mainly created by the learners themselves. These multimedia objects can be used for mobile learning and site-specific learning with a variety of different interfaces. Our research started 18 years ago and relies on a pedagogical background known as critical constructivism. The development of our body- and space-related media is based on innovative scenarios and was

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2 https://www.kimm.uni-luebeck.de

done within a participative design process with real users. The research on innovative learning environments is founded on Design-Based Research. According to this approach theory and real-world usage are conjoined and of equal importance. Thus theory and applications evolve simultaneously during the design process. Technically, this is made possible by a framework for the central storage of the logic of ALS learning programs and of program modules used in them, the common semantic data storage as well as various modules for the conversion of data and user authentication.

**NEMO**

The *Network Environment for Multimedia Objects (NEMO)* is the backend platform for all ALS applications. *NEMO* stores all media created by learners in a specific semantic model, which supports the use by ALS applications and reflects the respective application's context. The ALS applications run on stationary or mobile devices and access *NEMO* as a contextualized repository. Media created in *NEMO* can be interrelated inside *NEMO* and will be presented via *InfoGrid* to all users as augmentations of the physical space on different interconnected digital devices like smartphones or tablets.

Ten years after the first *NEMO* was developed (Feldner, Günther, Schmitt, Winkler, Herczeg, 2009) (Lob, Cassens, Herczeg, Stoddart, 2010), we enhanced and re-engineered *NEMO* in 2016. The *NEMO* framework now offers an environment for the creation and interaction with contextualized and personalized media. The media is created by a learner, stored as binary data, and simultaneously enriched with a dynamic set of semantic annotations. In addition, the learner's manual annotations complete the set of semantic annotations. These enriched media managed by *NEMO* consist of pictures (mainly photos), texts, animations, video, audio, and 3D objects of an object captured with digital properties represented by semantic annotations. *NEMO* distributes enriched media inside the learner's environment through a digital overlay morphing with physical daily objects. This way, learners interact with enriched media device-independently. *NEMO* provides the basis for constructing, structuring and cross-linking knowledge. Apart from that, we use *NEMO* to store location-specific settings and data. Due to its modular structure (see figure 3), we are able to implement customized extensions for our learning applications. *NEMO* provides features through web services, thus enabling both rapid application development and utmost flexibility for any developer and the deployment.
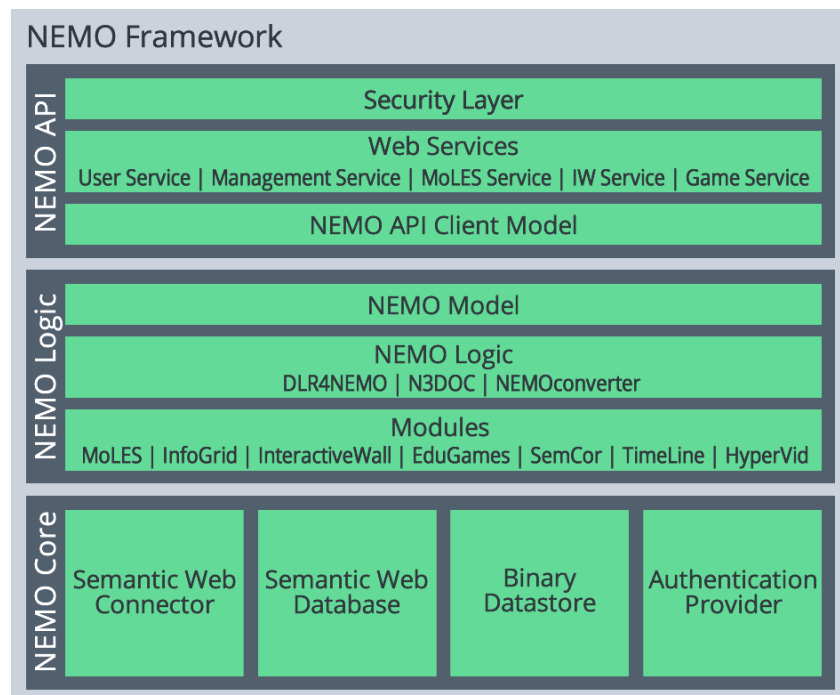
**NEMO Framework**

**NEMO API**

Security Layer

Web Services
User Service | Management Service | MoLES Service | IW Service | Game Service

NEMO API Client Model

**NEMO Logic**

NEMO Model

NEMO Logic
DLR4NEMO | N3DOC | NEMOconverter

Modules
MoLES | InfoGrid | InteractiveWall | EduGames | SemCor | TimeLine | HyperVid

**NEMO Core**

Semantic Web Connector

Semantic Web Database

Binary Datastore

Authentication Provider

Figure 3: *NEMO* layered structure. Top: ALS applications connect to the NEMO API to exchange data with *NEMO*. Center: The NEMO Logic contains the application logic for the ALS applications. Bottom: The NEMO Core is a semantic data repository which stores data, media files, and authentication information.

The following describes how, after the tour has been theoretically worked out in class, the students enter the tasks (to be completed by the students outside the school building) into the *MoLES* application using the *ALS Portal*. This makes it possible that these tasks can later be performed with the mobile *MoLES App*. This is done by recording information and creating media. The locations here are first of all the city archives and the building construction office. Furthermore, photos of the places (predominant in the historical center of the city) are to be taken. These photos function as markers for the retrieval of media to experiencing AR while using the *InfoGrid* mobile app is planned.

Furthermore, the subsidiary applications *VideoEdit*, *3DEdit,* as well as *Narrator* are described, with which the media are edited and, regarding *Narrator*, annotated for a special way of provision via *InfoGrid*. The application *InfoGrid*, which is centrally described in this paper, will then be presented in detail, as well as in the processing sequence in the school project (see figure 4).
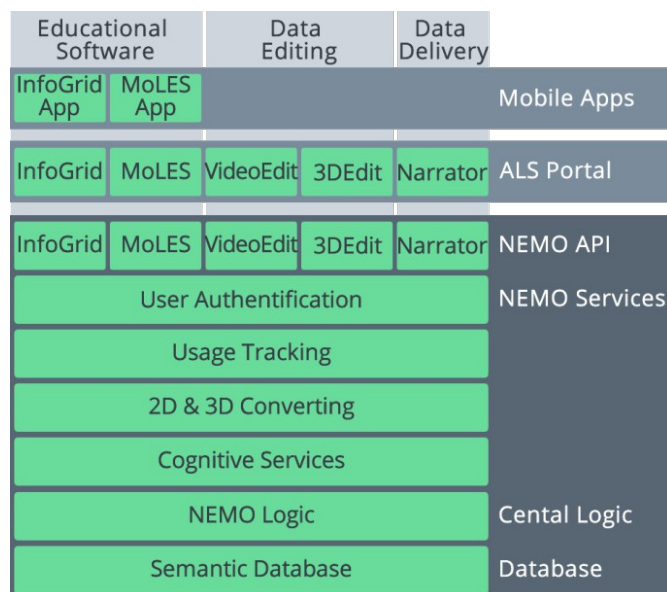
| | Educational Software | | Data Editing | | Data Delivery | |
|---|---|---|---|---|---|---|
| | InfoGrid App | MoLES App | | | | Mobile Apps |
| | InfoGrid | MoLES | VideoEdit | 3DEdit | Narrator | ALS Portal |
| | InfoGrid | MoLES | VideoEdit | 3DEdit | Narrator | NEMO API |
| | User Authentification | | | | | NEMO Services |
| | Usage Tracking | | | | | |
| | 2D & 3D Converting | | | | | |
| | Cognitive Services | | | | | |
| | NEMO Logic | | | | | Cental Logic |
| | Semantic Database | | | | | Database |

Figure 4: Overview of the five ALS applications (InfoGrid, MoLES, VideoEdit, 3DEdit, Narrator) described in the scenario in this paper. At the top the two mobile and the five static front-ends. First the two mobile apps *InfoGrid* and *MoLES*. Below, as part of the *ALS Portal*, on the left the frontends in which the two learning applications *InfoGrid* and *MoLES* are managed, to the right the two frontends for the applications *VideoEdit* and *3DEdit,* used for data preparation, and rightmost in the line the frontend of the application *Narrator*, with which individual tours can be provided with user-specifically media. In the backend, at the top as part of the NEMO API, the main components of the server-based five applications are shown. Below the NEMO API are the NEMO services, consisting of user authentication, the element for converting 2D to 3D and the cognitive services. Below the NEMO services is the central NEMO logic and below it the semantic database.

**MoLES**

The *Mobile Learning Exploration System (MoLES)* has been developed to link learning at extracurricular learning locations with learning in the classroom (Winkler, Herczeg, 2013). In the *ALS Portal*, educators or students create tasks that are solved by creating media on excursions using the mobile MoLES app (see figure 5). For this purpose, two frontends were developed. One frontend for PC and larger tablets, in which the tasks to be completed are entered in the *ALS Portal* in relation to specific locations, and a mobile frontend for mobiles, with which the tasks are handled by creating media outside the school building. The media created by the school students can consist of text, images, audio recordings or videos.
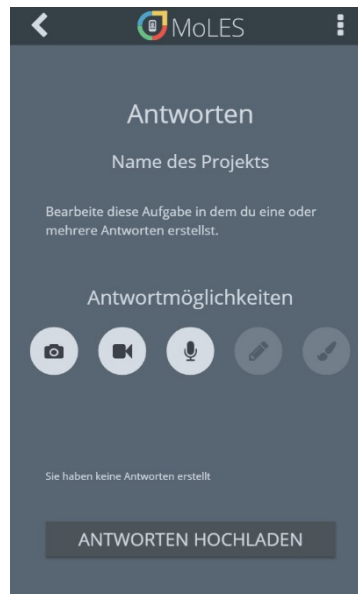
Figure 5: The mobile *MoLES App*. It displays tasks that are prepared via the
*ALS Portal* and can be used to carry out the tasks.

The *MoLES* mobile app can also be used to collect images of physical objects from all sides. If enough images have been created, the students can use *NEMO Converter 3D* (Bouck-Standen, Ohlei, et al., 2017) to convert them into a virtual 3D object. The *NEMO Converter 3D* aligns the photos automatically and uses photometry methods to generate the 3D model of the objects visible on the photo. The time required for the process depends on the amount and quality of the pictures the student has taken. Another factor influencing the amount of time needed for the 3D processing is the speed of the server that runs the *NEMO Converter 3D*. The quality of the 3D model also depends on the amount and quality of photos. From the quality side more photos in a high-resolution result in a better quality of the rendered 3D model (Bouck-Standen, Ohlei, Höffler, Daibert, Winkler, Herczeg, 2018). When the object processing is finished, the resulting 3D file can be edited with our tool called *3DEdit*.

**3DEdit**

When the conversion process of the *NEMO Converter 3D* finishes, the resulting 3D objects typically contain artifacts that do not belong to the object. With *3DEdit* we provide a system that can be used through the *ALS Portal* to correct this kind of errors. With *3DEdit* it is also possible to correct the orientation of the model so it is displayed in an upright position (see figure 6). When the user finished the manual editing of the 3D object, it is available for all ALS-Applications such as *InfoGrid*.
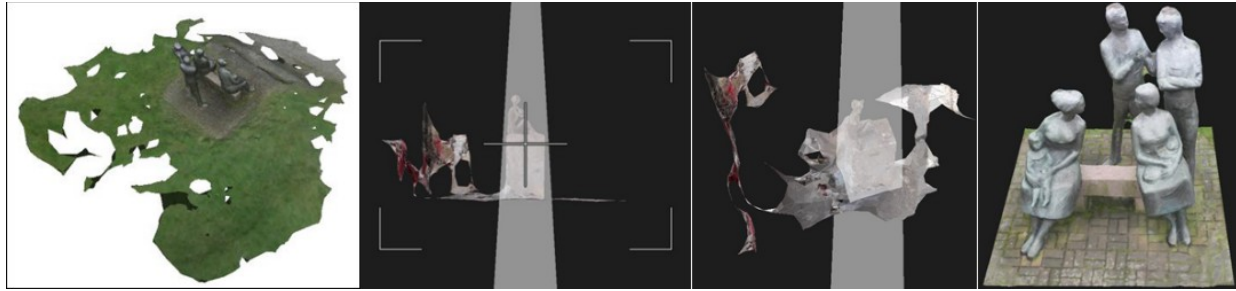
Figure 6: Correcting the orientation of a sculpture and freeing it from artifacts with *3DEdit*.
A) Original 3D Object with wrong orientation and artifacts around it. B) Camera view of *3DEdit*
that allows setting the orientation of the 3D Object. C) Selection of the cutout of the object
by means of an in size adjustable transparent white cone. D) The resulting 3D object.

**VideoEdit**

*VideoEdit* is a tool we developed to enable the students to easily edit the videos they recorded. It
is available through the *ALS Portal* and has a series of functions that were selected and evaluated
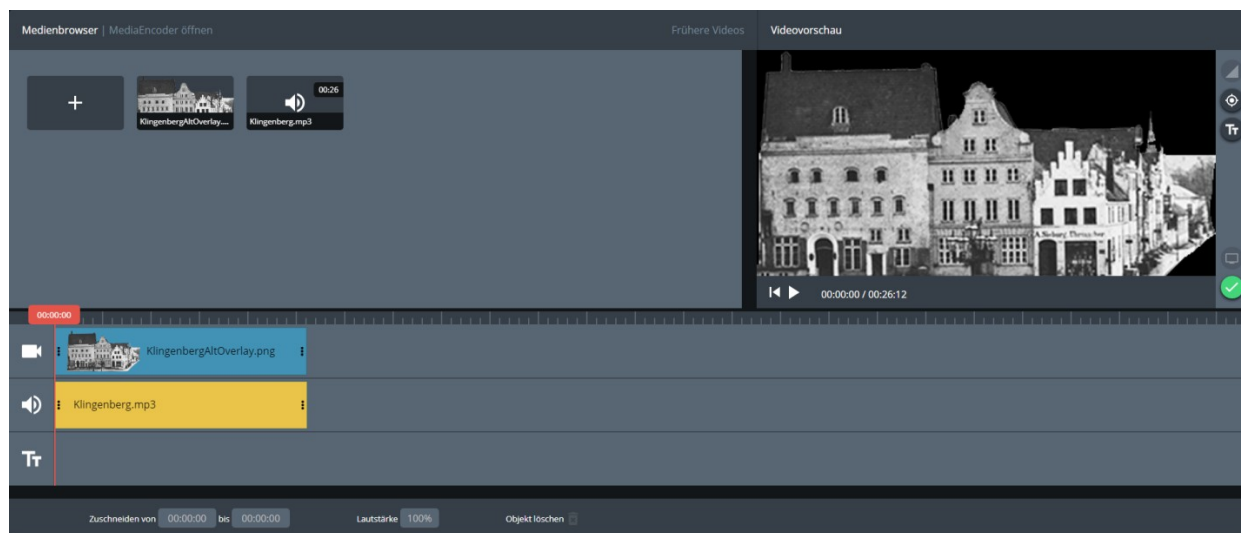in a user-centered design process.



Figure 7: User Interface of *VideoEdit*. In the top left, users can add photo, video
and audio files. These files can then be dragged into the corresponding timeline.
Once a video is prepared a preview window on the top right shows the resulting
video.

*VideoEdit* can be used to cut and join movie files, edit or change the audio tracks of the
movie files or to create movies from still images to which scaling effects can be applied. When
the editing process is finished the movies are rendered in *NEMO* and available in different
resolutions to all ALS-Applications in the required format (see figure 7).

**Narrator**

The users of the architectural tour through the city center of Lübeck with its buildings of all styles since the Middle Ages are very inhomogeneous. They are of different ages, have different previous knowledge, speak insufficiently or no German at all. Therefore, the most satisfying tour for *InfoGrid mobile app* users will be those that resonate with their personal abilities. For this reason, the Narrator is used as an extension of the *InfoGrid* (Bouck-Standen, Ohlei, Winkler, Herczeg, 2018). What is special about the AR tours created additional with the Narrator is that the presented content adapts to the respective user and their path while exploring a tour.

The annotations required for an *InfoGrid* tour are entered in the user interface of the Narrator in the *ALS Portal*. Two story models are currently available. One according to the Aristotelian drama curve, in which the story model follows the course of the Aristotelian dramatic pyramid, realized by an act structure. A second postmodern structure follows the story model of a postmodern narrative structure in which a storyline is interrupted by pseudo-random elements. The tour to special places of Lübeck's architecture presented here in the scenario uses a postmodern structure. Each tour consists of several acts. Each act is then assigned as many waypoints as you like, which contain at least one narrathem. In order to be able to offer the users tours of different durations, more or fewer waypoints/narrathems are assigned to an act. The minimum for a narrator controlled tour consists of five files with at least one waypoint each. In order to create good transitions between acts, at least 12 narratives are required. An interesting narration has about 50 narratives. Each narrathem can be offered in different languages (see below).

The input screen of the narrator in the *ALS Portal* contains the following input fields:
- Name of the tour
- Description of the tour
- Language *(based on our example: German, simple language German, scientific language German, English, simple language English, scientific language English)*
- Gender – gender-neutral, female, male *(related to our example: gender-neutral)*
- Age *(in our example this is not relevant, as no content harmful to children or adolescents is used)*
- Data protection *(this is not relevant for our example since no data is used that is subject to data protection)*
- Enter waypoints: designation and geodata in the form of longitude and latitude
- Tags: tags necessary for a tour, which then appear as mandatory fields when annotating media objects *(in our example, these are the year of creation of an object/building and the building style of an object/building)*

The *Narrator* also allows you to assign the attribute "climax" to particularly spectacular waypoints, and others as possible near "predecessors" or "successors" of such a waypoint. Although the narrator offers further possibilities to create complex narratives, the above-mentioned features in the context of the school project are sufficient in this scenario to offer a shorter or longer tour in two languages and, for example, to offer a child other content than an adult not familiar with architectural history or an adult trained in the field.

Technologically seen the application *Narrator* utilizes a concept of semantically enriching media in a particular way. All media handled through *NEMO* are modeled as *NEMO Semantic Media* (NSM). NSM consists of media, such as text, still images, audio, video footage,

or 3D objects, which *NEMO* stores as binary data. In *NEMO*, they are enriched by semantic attributions. The semantic attributions consist of a basic set of annotations, which are used internally by *NEMO*, as well as an extended set of annotations, which are specific for the context the media object is dedicated to. The semantic annotations describe the content and define its place in the semantic model, see figure 8.
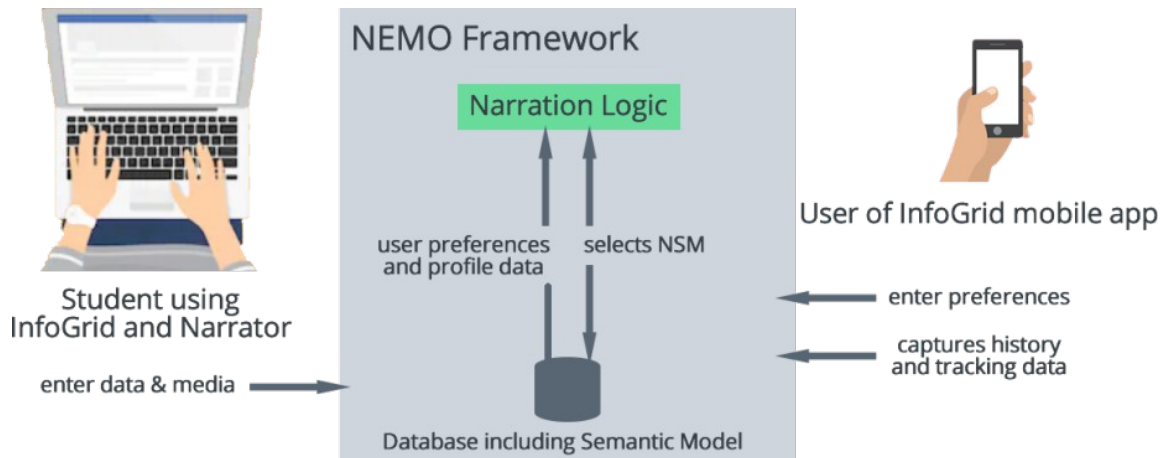


Figure 8. In the *ALS Portal*, users create Narrator-driven *InfoGrid* tours in the form of NSM. Based on visitors' preferences, history, and tracking data, the *NEMO* Framework then delivers these to the *InfoGrid mobile app*.

**InfoGrid**

*InfoGrid* allows users to create AR tours using the web-based *ALS Portal* (see figure 9). Inside the *ALS Portal,* the users can create individual tours consisting of multiple images that can be recognized by the *InfoGrid* mobile app. These images are called "image markers" or simply "markers". Each marker can be assigned with a specific overlay type (3D object, video or audio) and the corresponding data file. The data files can be created with our tools, such as *NEMO 3D Converter*, *3DEdit*, *VideoEdit*.
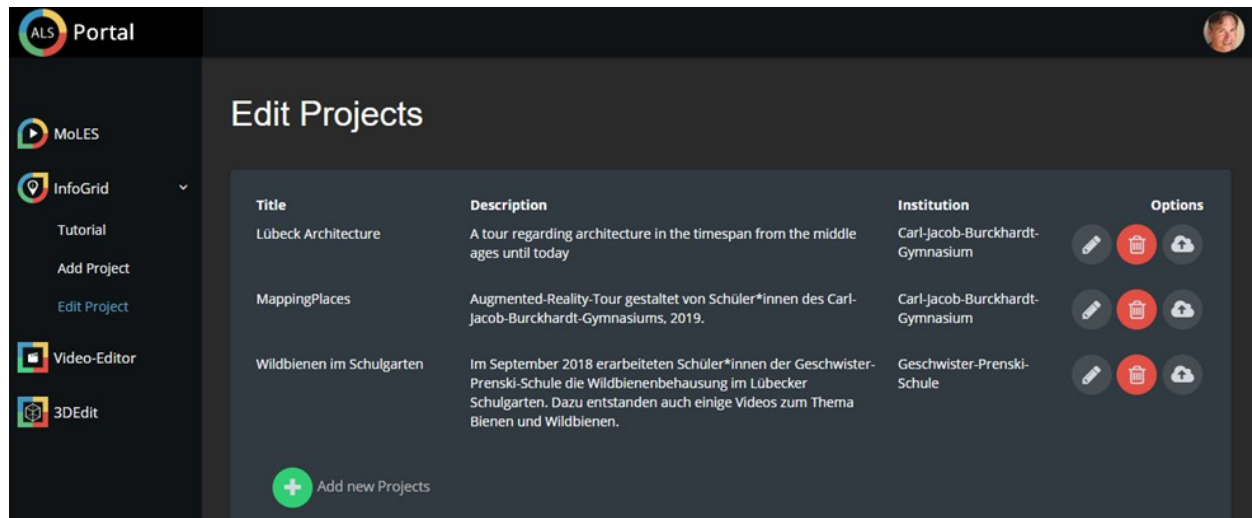
Figure 9: Administration of *InfoGrid* tours in the *ALS Portal*. In the menu on the left, the available ALS applications are listed. In the center, the edit project view of InfoGrid is displayed. It lists existing tours and provides the function to add, edit or delete tours.

After saving the information through the *ALS Portal* in our *NEMO* framework the *InfoGrid* mobile app can be used either indoor or outdoor depending on the place where the markers are located (Ohlei, Bouck-Standen, Winkler, Herczeg, 2018). *NEMO* is a distributed system that allows media files to be stored in a local *NEMO* instance in the school providing teachers and school students with high-speed access and full control over the data ownership regarding the respective files. After downloading the tour data on a smartphone, any person can use the *Info Grid* mobile app to scan the image markers and experience the selected content (see figure 10).
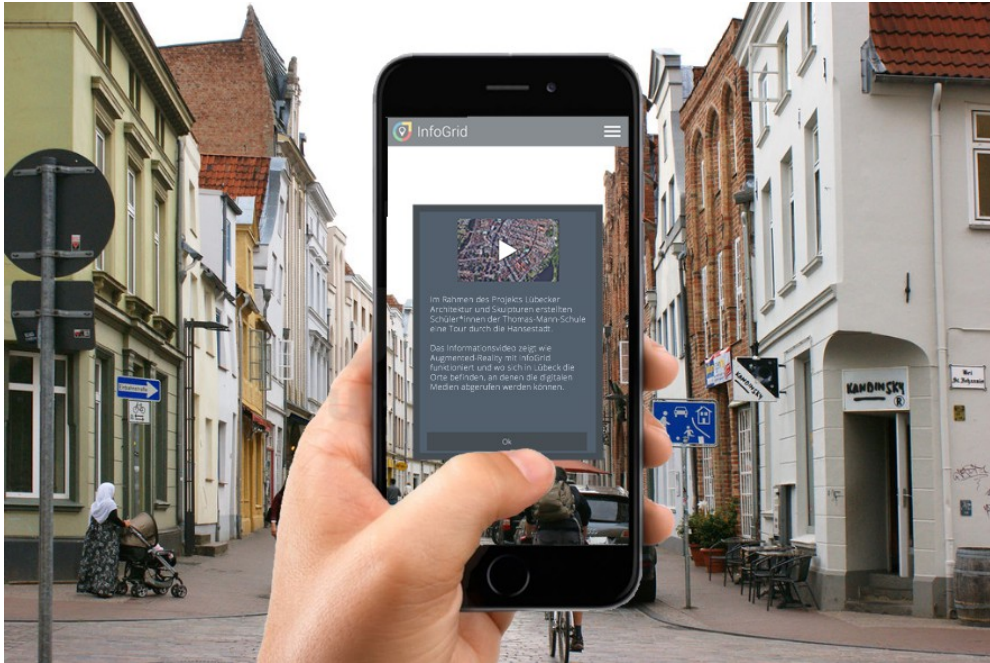
Figure 10: The mobile *InfoGrid app* for Android and iOS. After starting the mobile *InfoGrid app*, the tour can be selected and started. Besides a short text, a start video informs about the handling of the app and the location of
the places where an AR enrichment of the physical world can be found.

In this way, the public can perceive the content created by the students (see figure 11).



Figure 11: People use the mobile *InfoGrid app* in the city center of Lübeck to view a 3D model of a sculpture.

**Evaluation**

*InfoGrid* was evaluated in a usability study based on the System Usability Scale (SUS) (Brooke, 1996) among students of an art class. The evaluation was carried out on the 9th of January 2019.

**Study Participants**: 18 school students agreed to fill out the questionnaire and became part of the study. The average age of the participants was 17 years. All participants in the study came from the same school.

**Instruments**: For the evaluation, the used instruments were the *InfoGrid* app running on the students own a smartphone, and *InfoGrid* and *VideoEdit* as part of the *ALS Portal*, the questionnaire and a general Feedback towards the system.

**Study Procedure**: In an art class the *InfoGrid* project was explained to the school students. The students' tasks were to first record multiple video snippets with a city-related topic in the city of Luebeck using their own mobile phones. Next, the students could use *VideoEdit* inside the *ALS Portal* to cut and combine their recorded video files resulting in one complete final video. In the last project meeting, the students used the *ALS Portal* to connect their final video file to the selected markers and to test the completed tour on their own mobile devices. After finishing that work, the students were asked to fill out the SUS questionnaire. After filling out the questionnaire, all participating students were asked for oral feedback regarding the project.

**Results**: The results of the SUS test are shown in Table 1. The usability score of the SUS test was 68.89 (of 100; N=18) which is interpreted as an OK (Bangor, Kortum, Miller, 2009). The installation of the app on the school students' devices worked fine in all cases.

| | Statements | Total Sample N; M (SD) |
|---|---|---|
| 1 | I think that I would like to use this system frequently. | 18; 2.28 (0.75) |
| 2 | I found the system unnecessarily complex. | 18; 1.83 (1.20) |
| 3 | I thought the system was easy to use. | 18; 4.22 (1.26) |
| 4 | I think that I would need the support of a technical person to be able to use this system. | 18; 2.00 (1.28) |
| 5 | I found the various functions in this system were well integrated. | 18; 3.28 (1.18) |
| 6 | I thought there was too much inconsistency in this system. | 18; 2.61 (0.85) |
| 7 | I would imagine that most people would learn to use this system very quickly. | 18; 4.39 (0.70) |
| 8 | I found the system very cumbersome to use. | 18; 1.83 (1.29) |
| 9 | I felt very confident using the system. | 18; 3.78 |

| | | |
|---|---|---|
| | | (1.00) |
| 1 0 | I needed to learn a lot of things before I could get going with this system. | 18; 2.11 (1.13) |

**Abbreviations**: N, number of participants, M, mean; SD, standard deviation; SUS, System Usability Scale

Table *1*: Mean ± standard deviation of the SUS (statements originally provided in German). Values from 1-5 could be chosen. Statement (1,3,5,7,9): higher values are better; Statement (2,4,6,8,10): lower values are better.

**Discussion**: The first statement received the lowest values. In the last project meeting, students commented about a missing saving function in the video editor. Caused by this missing function, every time the students wanted to change something in their video, they had to start from the beginning. Several students mentioned that missing function. We assume that this was one of the reasons they have given this statement a low value. Statement 7 has received the highest value and has the lowest SD. This is an indication that the system is easy to learn for school students.

**Conclusions and Further Work**

Using the example of a teaching project in a secondary school, the creation of an augmented reality tour by school students using *InfoGrid* and several other supporting applications was presented. Due to the interconnection with various other ALS applications based on the *NEMO* framework, it is possible that *InfoGrid* offers contextualized, personalized, semantically rich, device-specific access to multimedia objects.

With *MoLES* school students can create photos, videos and 3D objects well structured. With the applications, *VideoEdit* and *3DEdit* the previously created media can be edited. With *Narrator* the school students can create dynamic descriptions of elements for an augmented reality tour.

While some applications have already been evaluated before, this study presents an evaluation of *InfoGrid* in combination with *VideoEdit*. The evaluation shows generally good usability. However, the school students commented about a missing feature which resulted in time-consuming extra work. In the meantime, this problem has been solved, which resulted in a new version of *VideoEdit.*

In further work, subsequent formative evaluations will investigate the question of the possible influence of technology on the kind of knowledge the students construct at school. We assume that similar to other ALS learning applications, we will show that the creation of medial views on a subject in a real-world context, here a specific place shaped by the architecture, invites a deeper reflection on the subject matter.

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