

buildingSMART International (2022)

435-TECHNOLOGY Technology Solution using openBIM

AR-supported Teaching



yQbwkMgw

Entrant details

Role or Job Title on the Project | Projectlead

Employer

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Employer Role | Academic or Research Institution

Are you or your employer a member of buildingSMART? | Yes - Chapter Member

Entry details

Entry Details

By checking this box I understand and acknowledge that this awards program is to assess information about openBIM, and that openBIM is not only about the use of solutions. |

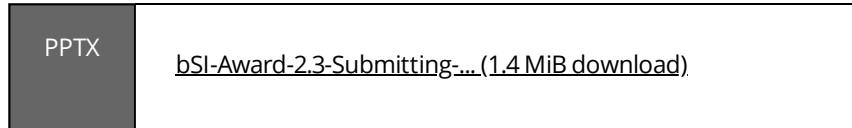
openBIM is about setting up an environment where every party in a team can work in the optimal way ("how they prefer") without putting limitations on others.

It is about freedom to take control over your data and workflows, while keeping that freedom for others as well. Full use of open standards is not mandatory for this mission.

Website | <https://arserver.bilab.tuwien.ac.at/projects>

Location

Submitting Party and Stakeholder Logos (compiled into one .ppt/pptx file for upload)



Entry Description

The networking of digital solutions in the AEC sector has become increasingly important in recent years. The focus here is on Building Information Modelling (BIM) and the associated Industry Foundation Classes (IFC). BIM forms the basis for further technical developments. The technologies that serve the functional expansion of BIM are labelled under the term "Construction 4.0". These include Augmented Reality (AR), Virtual Reality (VR), robotics, drones, 3D printing, etc.

AR is the extension of the real environment with additional virtual content [1]. AR-capable mobile devices such as smartphones or tablets are used for this purpose. The mobile augmented reality (mAR) thus achieved contrasts with the head-mounted displays (HMDs), which are not yet widespread. Numerous studies have already proved the added value of BIM with AR [2–8]. BIM and AR complement each other in their application, so BIM enables the use of AR already in training. Not only is the learning effect increased, but the students also learn the handling of BIM and this "Construction 4.0" technology.

At first glance, teachers who want to implement AR in their lessons have a wide choice of software solutions. But a closer look reveals that most of them are not suitable. On the one hand, most AR software manufacturers demand financial compensation. BIM authoring software sometimes provides solutions free of charge. However, this can lead to a dependency on software manufacturers through proprietary formats. In addition, longer workflows or programming skills are often required. This leads to a high barrier to entry and use.

In the AR-supported Teaching project, an AR platform of the same name was developed that enables teaching scenes to be created without programming knowledge and based on open standards (IFC). The aim is to lower the hurdles mentioned and make it possible to implement AR in the classroom. For this purpose, the team created three applications (AR editor=Create; AR viewer=View; Website=Manage) functionally separate but interconnected.

With the help of the AR editor, teachers can create AR teaching scenes. Teachers use IFC files, which they import into the AR editor. The teaching scene can then be adapted or extended with annotations, animations, layers and buttons while the IFC remains intact. The AR editor saves the contents of a teaching scene in a database, which improves data access and data up-to-dateness.

The end-user views the created teaching scenes with the AR viewer. Buttons enable self-directed, exploratory learning. The speed is freely selectable, which prevents cognitive overload. The "Live Session" function makes a live connection between AR editor and AR viewer. This allows communication between learners and teachers across spatial barriers. The user of the AR editor can set markers in the live session and expand it with media files (images, videos). An integrated voice and message chat also supports communication.

A web application is used to administer users. This mainly involves defining user roles and assigning groups. Roles regulate which AR-supported Teaching applications a user can use. Teaching scenes are not user-specific but always refer to groups. These are tree-like and can also be created in the web application. It is possible to publish scenes to promote the user base. These appear on the website, can be presented there and can be downloaded by anyone in the AR viewer.

Why does AR-supported Teaching rely on openBIM and other open formats?

- AR-supported Teaching should be freely available to all educational institutions. However, free refers not only to costs (software costs, training costs) but also to a free choice of software. Therefore, the open format IFC is used. This allows the free selection of the BIM authoring software in educational institutions. openBIM file formats also ensure the longevity of data. On the one hand, the BIM models needed for the teaching scene can also be used in the future. On the other hand, this means that ongoing adaptation of the import process in the AR editor is not necessary.
- The file formats used in AR-supported Teaching (IFC, JSON) are also human-readable. Hence, advanced users can develop their own applications that can be used to create more complex teaching scenes. The usage of, e.g., the software Blender can simplify the creation of complex animation sequences. Animation and object are linked using BlenderBIM via GUIDs. The animation data exported from Blender can then be included in the JSON file.
- Modelling for the teaching scene is done in native software. The model information comes exclusively from the IFC. Therefore, modelling for the teaching scene can take place in any buildingSMART-certified software (IFC 2x3, IFC 4). This brings openBIM into the classroom and is a clear, visually easy to view introduction for young, interested pupils/students.

Project team:

- Alexander Gerger
- Konstantin Höbart
- Gabriel Pelikan
- Christian Schranz
- Harald Urban

What stage of completion is the entry content representing? | Testing Stage, Feature Extension

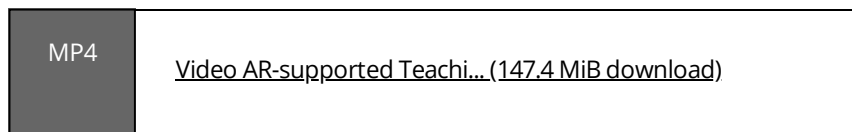
Stakeholder Statements

University assistant: AR offers two major benefits in teaching. On the one hand, AR enables a clear representation of complicated structures, e.g., reinforcement cages in highly loaded areas. On the other hand, different teaching contents can be displayed and linked centrally in one model.

Student: As a civil engineer, I see the great advantage in the fact that complicated geometries, such as complex reinforcement, are easier to understand. Especially as a first-year student, when you haven't had much experience with spatial thinking, this can be very helpful. I can also imagine that complex detailed connections, such as for a parapet or the connection of a window with all its sealing levels, could be very well represented with AR. Many such things are difficult to grasp as a student if you have never seen them in reality in 3D. I think that can help enormously.

BIM Operations Manager: AR simplifies the perception of spatial dimensions. By placing them in the environment, the viewer has real reference objects and can thus better perceive sizes. This is only possible to a limited extent through the use of VR or 3D models in conventional viewers. AR also makes it possible to display scenes that would otherwise be too small, too large or take too long. This includes, for example, the microscopic structure of materials or a construction process simulation.

Upload a 2 minute video to show the scope of the entry.



Technology Solution Description

Teachers who want to create AR teaching scenes for their students face problems. The available choice of applications is large, but most drop out after the first viewing: To ensure high-quality AR models, providers demand monetary consideration in the form of subscriptions or one-off payments. However, educational institutions often have a tight budget, so applications with paywalls are ruled out. While an extensive collection of high-quality AR models is available to the paying user, custom creation is often impossible. Free methods that allow individual creation are often only individual, software-specific solutions. A cumbersome workflow often characterises these solutions, and most require programming skills. In addition, out-of-the-box functions are limited and would have to be integrated independently.

AR-supported Teaching is an AR platform geared toward teaching in the AEC sector. It enables teachers to create individual AR teaching scenes without programming knowledge. The basis for this is a BIM model as IFC, which can be expanded with additional content. This content includes annotations, animations, buttons and layers.

The following objectives were pursued during the development:

- Open Standards:
 - Use of the openBIM standard IFC as data exchange format to ensure a software-independent environment. An additional advantage is the extension of the AR teaching scenes to include alphanumeric data. The aim is not to develop a BIM authoring software but to read and further use the alphanumeric and geometric information contained in an IFC file. Thus, IFC serves as an import format, allowing the teaching scene creator to choose between the available BIM authoring software freely. In conjunction with the open, also standardised JavaScript Object Notation (JSON) format, advanced users can automate repetitive or more complex activities through their extensions. For example, Blender can be used with the BlenderBIM add-on to create animation sequences.
- Simple usability:
 - Development of an environment with simple usability, enabling people without in-depth programming knowledge to create AR teaching scenes and fill them with annotations and animations.

- Open Content:
Development of a web application for project management and teaching scene presentation. Users can manage AR teaching scenes (versioning), share them and have them commented on and further developed by other users. This will increase the number of freely available AR models in the construction industry.
- Cross-platform:
The applications developed should be as platform-independent as possible. This refers to the creation of the AR teaching scenes and their viewing. As a first step, it should only be possible to experience the AR models on mobile devices (smartphones and tablets).

AR-supported Teaching consists of 3 interlinked applications:

- The AR editor is needed to create and edit AR teaching scenes. The starting point for this is an IFC 2x3 file whose geometric but also alphanumeric information is imported and displayed. A more detailed description of this process can be found in the next chapter. The AR editor now offers various tools for creating a teaching scene. Fundamental to this are buttons that allow a step-by-step, self-directed experience of the AR scene (e.g., for the step-by-step representation of construction processes). These can either show or hide layers or start animations in the AR viewer. The assignment takes place at the component level, whereby an IFC hierarchy view is used to support the creator in component selection. Two options are available for creating animations: On the one hand, the choice of a predefined explosion animation or, on the other hand, an individual creation using keyframes. Annotations allow explanations in the form of text, images or videos to be attached to components. To save the teaching scene, export to the server is necessary. In addition to saving, it is also possible to view the model in the AR viewer. If the teaching scene needs to be edited or adapted, it can be downloaded from the server to any device and edited.
- The AR viewer is used to view the scenes created in the AR editor. mAR is used. Hence, only a mobile device (tablet or smartphone) with an Android operating system (version 8+), AR core support, and an internet connection are required to download the desired scenes. The mobile device saves the downloaded scenes locally on the device, so no network connection is required for pure viewing. Buttons in the form of buttons control the display allowing layers to be shown or hidden and animations to be played. Flags represent the added annotations in the AR viewer. Tapping on them displays the stored information text or attached media files. The BIM data can be displayed by selecting a component.
- The web application is the link between AR editor and AR viewer. The website allows the administration of already created teaching scenes and the assignment of user roles or groups. The latter two serve to separate the entire AR platform functionally. On the one hand, a new user must be assigned to one of three roles. A distinction is made here between a user (viewing teaching scenes), an editor (creating teaching scenes) and a group admin (managing teaching scenes, roles, and groups). Depending on the role of the user, the application used also varies. For example, a user can and should only use the AR viewer, an editor also uses the AR editor, and a group admin has access to the web application. On the other hand, each user must be assigned to at least one tree-like group. Teaching scenes always refer to groups and not to creators. This makes it possible for an editor to create AR scenes for two groups simultaneously, but the viewers of a group can only view the scenes intended for them in the AR viewer. If the editor wants his teaching scenes to be visible to all groups, this is possible by publishing the scene. Public projects are visible on the website and can be presented with the help of images and descriptions.

What underlying technology are you using for your solution?

AR-supported Teaching is the continuation of a diploma thesis [9] and comprises three applications:

- AR editor
- AR viewer
- web application

The Unity Engine based AR editor allows the creation and customisation of AR teaching scenes. It has an IFC importer as well as a project export function. The import of an IFC file is divided into two pipelines, as Unity does not natively support IFC file import:

- Model generation is done with the Unity extension TriLib. This extension allows 3D models to be loaded during the software runtime. TriLib supports numerous data formats, including IFC 2x3, which means that conversion to other file formats is unnecessary.
- The import of non-geometric information is done with IfcOpenShell or the IfcConvert command-line program based on IfcOpenShell. This software is used to create a more retrievable XML file from an IFC file. Although the geometric information is lost, it is already covered by the TriLib import process.

The two import pipelines are linked together at the end of the import process. This is necessary to assign the corresponding alphanumeric data to each geometrically interpreted component. The Globally Unique Identifier (GUID) is used for this purpose, which is attached to each object as a suffix during the TriLib import and is also contained in the XML file. After the import, editing and

extension are done in the AR editor. The added data is not integrated into the IFC file but stored separately in a JSON file. The export of the project is needed for backup and consists of the IFC files used in the teaching scene and the JSON file, which contains a list of all IFC elements, annotations, animations, layers and buttons. The media files used are also included. The files are then combined in a folder and transferred to a database (PostgreSQL) using File Transport Protocol over Transport Layer Security (FTPS) and are available to the AR viewer.

The AR viewer makes the teaching scene previously exported on the server available to the user. The IFC files and the JSON file must be downloaded to open a model. As in the AR editor, TriLib is used to create the 3D model. The AR viewer then links the alphanumeric data in the JSON file with the generated model.

ARCore [10] and the AR Foundation package [11] are used to position the AR teaching scenes. These frameworks enable the placement of virtual models in the real environment using motion tracking and environmental understanding. Currently, the AR viewer is optimised for Android tablets and smartphones.

Additionally, the AR-supported Teaching platform allows live interaction between the AR viewer and AR editor. This feature allows teachers to communicate directly with learners across spatial barriers using an integrated text and voice chat function. Furthermore, teachers can place additional markers during a live session and link them to images and videos.

openBIM methods used

- ✓ IFC 2x3
- ✓ IFC 4
- ✓ ifcXML

Were there other open data standards used other than those listed above?

In addition to IFC, JSON (JavaScript Object Notation) is used to store the additional content created during the work in the AR editor, like animation keyframes, annotations, transformations, buttons and layers. Of course, it would be optimal to store this information in an IFC file, but this is not possible at present.

Similar or Comparable Solutions on the market today

Numerous software products make it easy to create AR models. An example is ARki, developed by Darf Design [12]. This software provides similar features to those developed in the course of AR-supported Teaching. These features include the import of 3D models and the extension of these with animations, annotations and layers. However, there are two problems. On the one hand, only FBX files (Filmbox) are currently supported, but these only contain animation-related data. This data includes geometries, materials and animation paths. Unfortunately, ARki does not use BIM files (like IFC) and misses out on the advantages of having alphanumeric data alongside geometric data. With a BIM file, a student can grasp, e.g., the material parameters of a wall and whether it is a load-bearing element. Hence, the learners can better understand a teaching scene using BIM files as a basis. The only use of FBX files eliminates this added value of BIM files. On the other hand, a monthly subscription is necessary to create multiple projects. The subscription costs are a significant hurdle in teaching because financial resources are often limited.

But there are already solutions for creating AR models in the context of teaching. ARTutor [13] allows the insertion of virtual 3D models in non-fiction books using mobile devices. The models can be adjusted by gestures or voice commands, and users can ask questions using the software. The software searches the text for an answer and outputs it.

Another successful use of AR in education is shown by the project mARble [14], although not in the AEC sector. The project focuses on the implementation of AR in the education of students in the field of forensic medicine. This AR application uses paper markers to project wounds onto learners' bodies. An extension with images, audio, videos and questions and answers is possible. A comparative study between mARble and conventional textbooks found an increased learning effect of the AR application [15].

Companies have also discovered the added value of this immersive technology in training. One of them is the formwork manufacturer Doka. This company created an AR application [16] for displaying Doka formwork systems projected onto associated two-dimensional plans. This model improves spatial awareness. Another advantage is central data management, which makes it possible to adapt the language, for example, without much extra effort. The application only allows the viewing of predefined scenarios and cannot be extended with user-created models.

Some of the existing AR solutions were developed specifically for teaching. An increased learning effect through the use of AR could be determined. If we look at the AEC sector, the possibility of using AR already exists there as well. However, no application allows the simple creation of AR teaching scenes based on openBIM models.

What added value does your solution give?

Teaching currently relies almost exclusively on two-dimensional representations of mostly three-dimensional problems. This makes interaction with the learning material difficult in some cases. Teachers try to compensate for this in face-to-face teaching with supplementary auditory explanations. If anything is unclear, students can ask questions. However, this component has become more complex since the beginning of the COVID-19 pandemic and the resulting switch to distance learning. Therefore, even greater importance is attached to the clear presentation of illustrations.

Nevertheless, especially first-year students have problems interpreting the two-dimensional representation spatially. However, this interpretation is a core competence of engineers (cf. [17,18]). A plastic imagination is necessary, for example, to understand building details and construction plans. AR can provide support here when used in a targeted manner. AR enables three-dimensional teaching scenes to be projected into the environment and experienced. AR-supported Teaching attempts to combine the advantages of AR in teaching with those of openBIM. This innovative step should support the end-user (student, pupil) didactically and teach them how to deal with openBIM and "Construction 4.0". The authors hope to increase acceptance and further dissemination through early contact with these technologies.

The team currently investigates how AR-supported Teaching can be used in the classroom. The simplest way of use would be the creation of AR teaching scenes by teachers and subsequent viewing by learners. AR-supported Teaching can also be used outside the AEC sector. The prerequisite is the need for 3D images, such as vectors in mathematics. However, it is necessary that the model is available in the form of an IFC file or is convertible into it. A more diversified use already involves students/pupils creating teaching scenes and IFC models. This can be done in the course of project work or, in the case of larger scenes, in group work. After completion, the AR models are presented to fellow students, and other students use good models as learning materials in the following years (=peer-to-peer system). In the future, a collection of AEC AR models could develop from this, which would be available to educational institutions free of charge. But other use cases of AR-supported Teaching have also emerged outside of education. A more detailed description of these can be found below.

Results In Practice

As a technology, the Actual System Use of the AR-supported Teaching Platform can be assessed according to the Technology Acceptance Model (TAM). [19] can be assessed. TAM enables a statement of whether a technology is being used. This is done based on two input parameters: perceived usefulness and perceived ease of use. The latter has already been surveyed in the course of courses at the TU Wien. Two standardised questionnaires were used: the System Usability Scale (SUS) for the AR editor and the Handheld. [20] for the AR editor and the Handheld Augmented Reality Usability Scale (HARUS) [21] for the AR viewer. Both allow usability to be assessed on a scale of 0 to 100, with a score of 70 or higher indicating acceptable usability. In the case of the SUS, ten standardised questions on a five-point Likert scale (1 = "Strongly agree" to 5 = "Strongly disagree") are to be answered by the test person. The HARUS consists of 16 standardised questions and a seven-point Likert scale (1 = "Strongly agree" to 7 = "Strongly disagree"). The questions in both scales are alternately scored (positive/negative) to prevent a response bias. It was also possible to provide feedback in the form of free text. Twelve people were interviewed about the AR editor and 15 about the AR viewer. With an average of 78.33 points, the AR editor scored slightly better than the AR viewer with 71.88 points.

The test persons rated the steep learning curve and the fact that hardly any prior knowledge is required to use the AR editor as positive. There is room for improvement in the implementation of functions, which leads to some inconsistencies.

The main problem with the AR viewer was the handling. Not the physical effort involved but the operation of the mobile device while viewing the educational scenes. When using a tablet, both hands are needed to hold the device securely. This results in awkward grip positions when selecting annotations or buttons. To solve this, a hardware-based [9] a hardware-based solution (hand strap for tablet) is preferable to a software-based one. When viewing with smartphones, the size of the screen was more of a problem. The font size of some texts can be adjusted, but the buttons were found to be too small. An adjustment of the Graphical User Interface (GUI) could remedy this. The tests were carried out with an earlier UI version. A corresponding adjustment could increase user-friendliness.

The standardised questions (SUS and HARUS) and the average points achieved per question can be found in the appendix. The Distance to Optimum (DtO) was also calculated for better comprehensibility, reflecting the difference between the maximum achievable score and the score achieved.

The survey of perceived usefulness is to follow soon. The aim is to determine whether learning performance can be increased through the use of AR-supported Teaching.

Example Use

PDF

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What is the accessibility of your solution?

The development of AR-supported Teaching focused on functions for educational institutions and is also available to them free of charge. These mainly include educational institutions in the AEC sector, such as universities and schools for higher technical education. The access threshold was kept low by paying attention to the available infrastructure, for example, through the use of mAR, where no costs are incurred through the use of smartphones or tablets. However, accessibility is not always financially limited but can also depend on other factors. Different educational institutions use different BIM authoring software. This results in a dependency on a proprietary file format. Movement within a vendor-specific software ecosystem is thus necessary. By using openBIM (IFC) and other open standards (JSON), AR-supported Teaching can break this software vendor dependency.

What are next steps and future developments of your solution?

To increase the scalability of AR-supported Teaching, the implementation of other open file formats such as OBJ and FBX is being considered. Although the advantage of alphanumeric data is lost, these formats are more common in other disciplines.

The Unity extension TriLib, used for importing geometric data, was replaced by TriLib 2, and further development stopped. However, the new version no longer supports IFC. A changeover is, therefore, necessary to implement IFC 4. This is necessary to achieve OS independence of the AR editor. The development of an AR editor web application is thus currently taking place. The open-source project "ifc.js" is being used for this.

The dissemination of the AR viewer is to be increased soon by implementing it on other mobile operating systems (e.g., iOS)

The feedback collected during the usability tests will be incorporated into the new versions of the AR viewer and AR editor. Further usability tests will ensure that the new versions are easy to use.

In addition, the second parameter of TAM is to be collected in the near future. For this purpose, a test will be conducted with two groups. The control group learns a new subject area conventionally with texts and non-fiction books, while the second group uses the applications developed in AR-supported Teaching. Subsequently, a multiple-choice test will provide information on whether an increased learning effect can be achieved through the use of AR-supported Teaching.

What is potentially possible in the future?

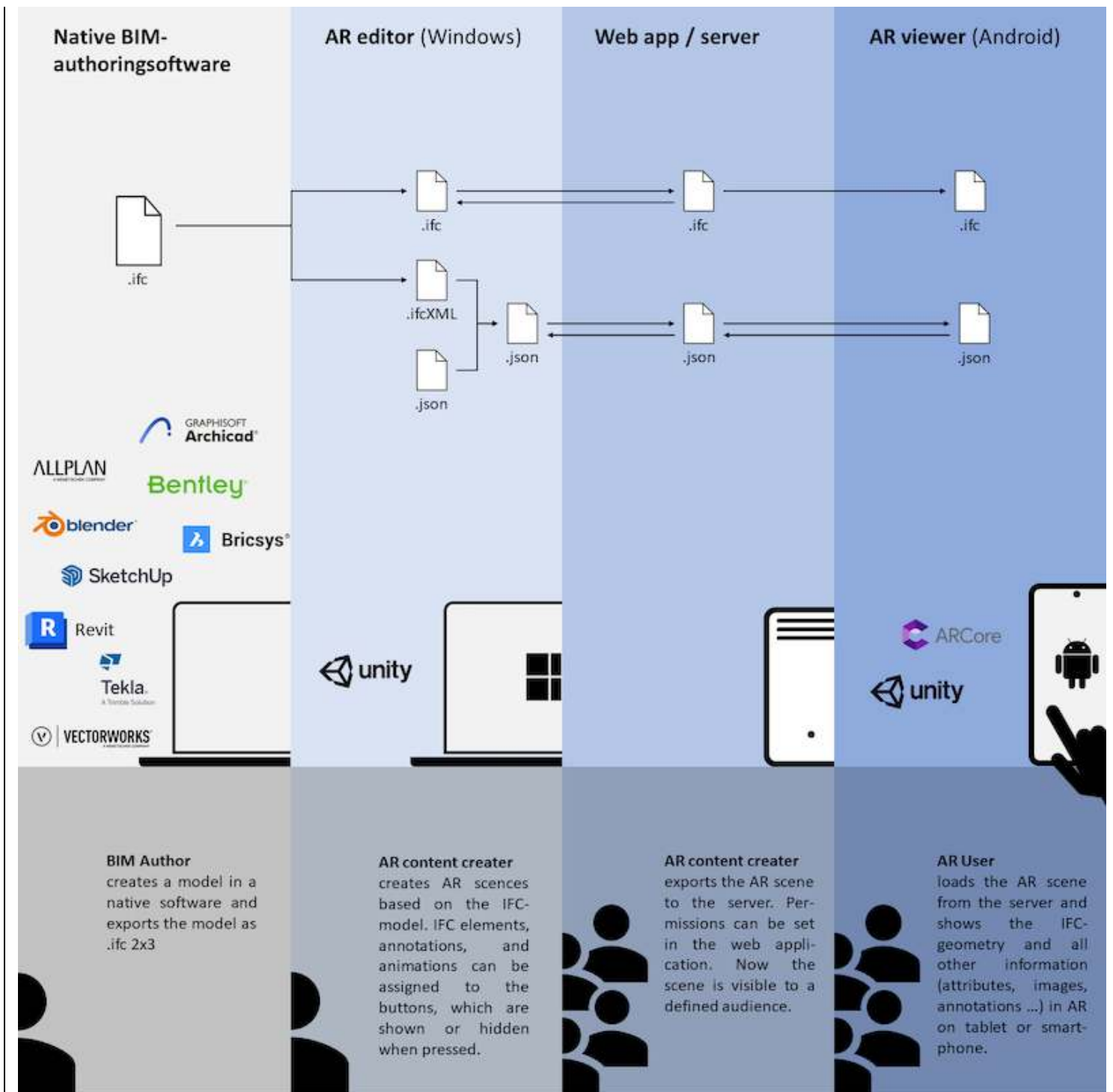
The novel bridge between openBIM, AR and AEC Education can change the way future engineers are taught. How serious this change is depends on several factors. On the one hand, the technology behind AR is constantly evolving, and its maximum potential has not yet been realised. mAR represents only one way of using it, and the mobile device's screen size limits the immersion that can be experienced. HMDs do not have this problem but are currently too expensive for use in teaching and are therefore hardly used. Further development of AR-supported Teaching on HMDs would be possible in the future.

Make the case for why your solution should win.

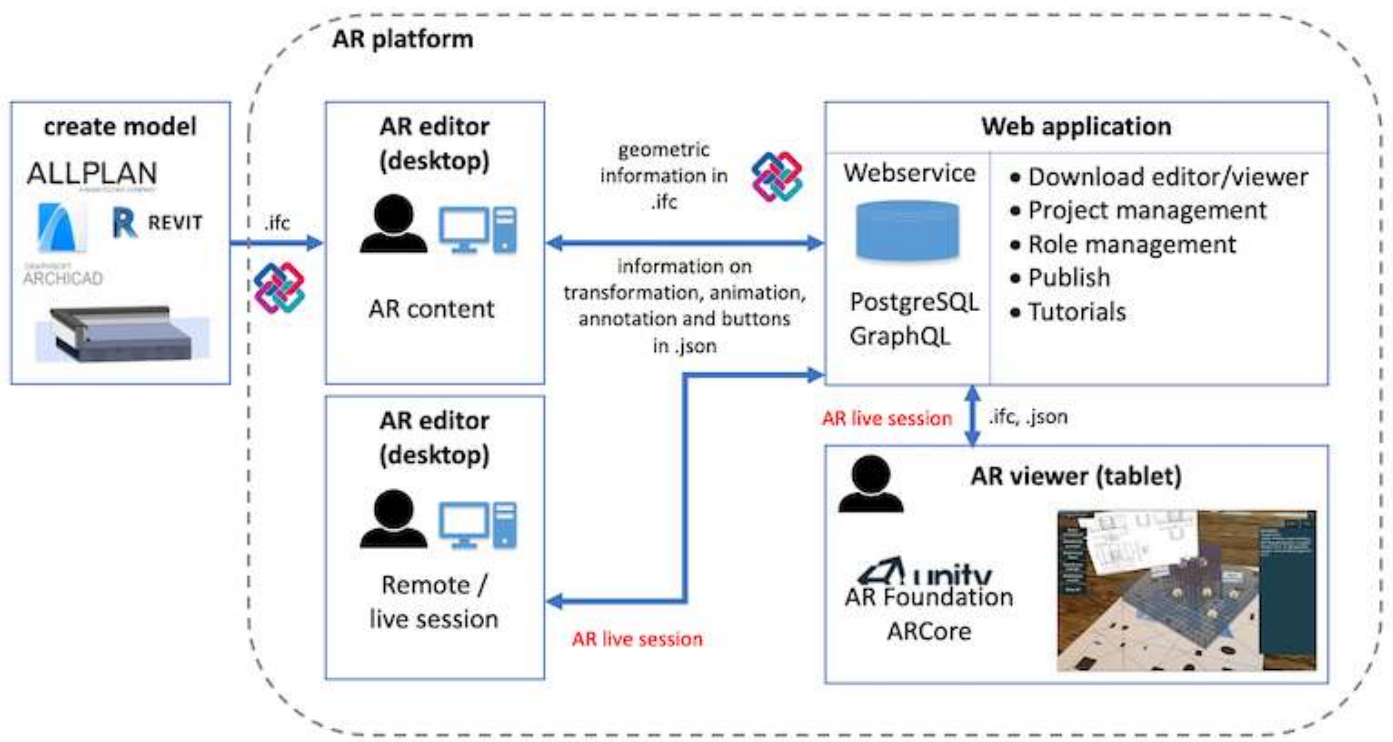
The main target group for AR-supported Teaching is not professional users of a specific discipline but students and learners. AR-supported Teaching enables the learning and handling of the "Construction 4.0" technology AR and supports the learner through simple spatial interpretation. The connection between AR and BIM in the context of teaching is a novel step. The focus here is on the intuitive usability of the applications and the resulting low entry barrier for new creators. But the barrier to use is also very low for viewers – no more than a smartphone is required for the immersive experience of interactive AR teaching scenes. The absence of strictly prescribed learning paths by the model's creator leads to a self-selectable speed at which a model is viewed. This prevents cognitive overload caused by too much information at once. By using open, standardised formats (IFC and JSON), the creation of the BIM model on which the AR teaching scene is based is software-independent. Compared to other comparable AR solutions, AR-supported Teaching chooses the path of a platform that is free of charge for educational institutions. However, other use cases for AR-supported Teaching have also emerged outside of education. A more detailed description of these can be found under "Use Cases".

openBIM Evidence

Software Ecosystem Map



Process Maps



openBIM Data Metrics Summary

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Upload .ifc file(s) or other technical files to support validation of the research results.

<https://service.usbim.com/link/6298c9da8df9e612b7e5ad07>

Use Cases

BIM Uses were defined on the project | ✓

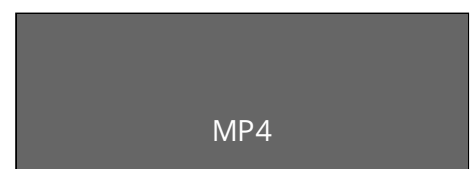
BIM Uses formed an integral part to how the project was delivered | ✓

I agree to be contacted for more information about the project BIM uses outside of this awards program. | ✓

Documentation on use case(s) as a single file upload

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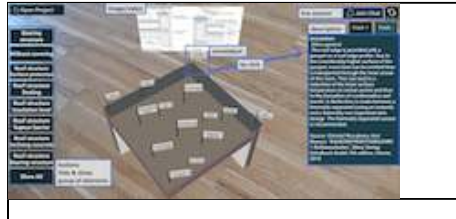


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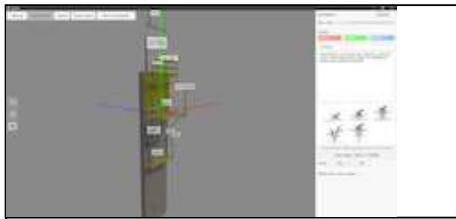
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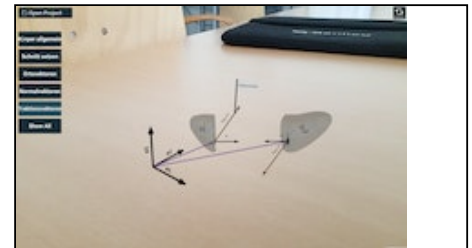

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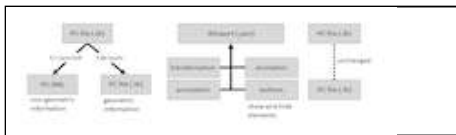

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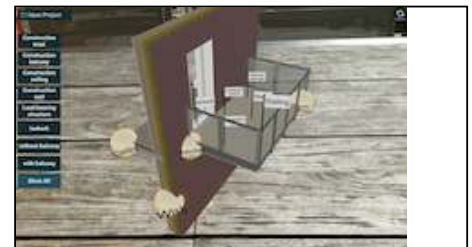

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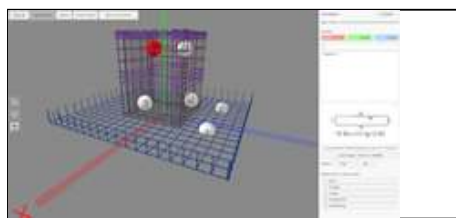

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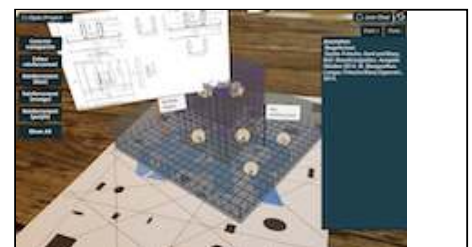

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Process Map.pdf 222 KiB

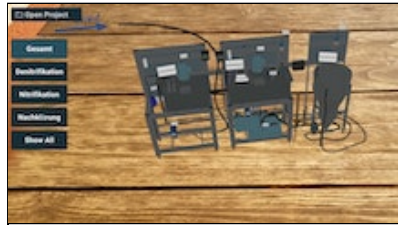

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