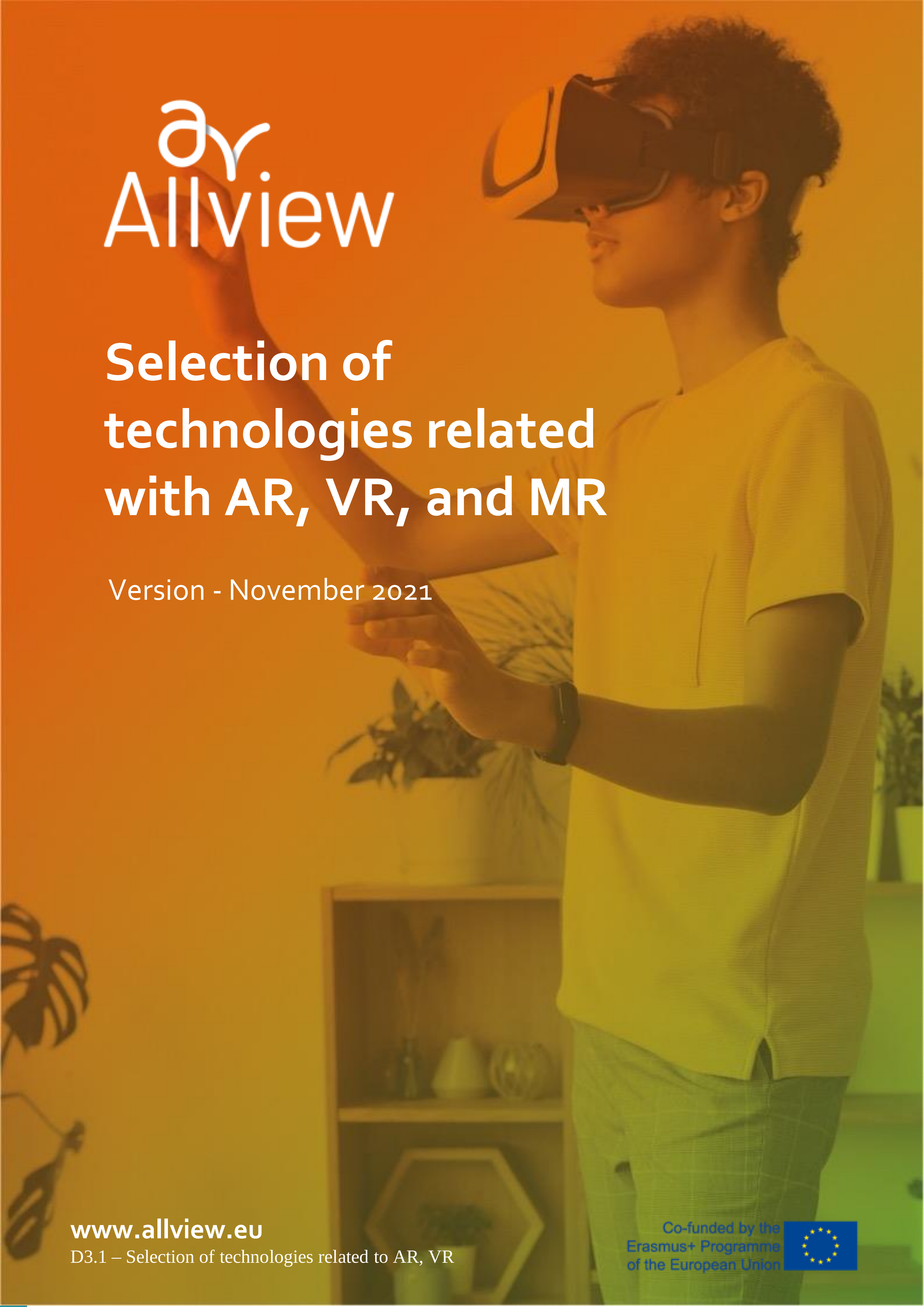

Allview

# Selection of technologies related with AR, VR, and MR

Version - November 2021



Co-funded by the Erasmus+ Programme of the European Union

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*The ALLVIEW project is a new transnational cooperation platform that connects Centres of Vocational Excellence (CoVEs) within the wood and furniture sector. ALLVIEW has operational objectives on a regional, national, and European level which aim at an innovative approach to modernising vocational education and training.*

Allview

# 1

## Overview

# 1. Overview

This document reports the results performed in task **"T3.1: Identification of technologies (AR, VR, MR)" in the framework of the WP3 "KET kit for training in the F&W sector".**

The aim of this task, led by KIT, is to carry out an in-depth research on Augmented Reality, Virtual Reality, and Mixed Reality technologies, in order to identify which of them are most appropriate, useful, and beneficial for use in education and teaching, more specifically in the furniture and wood sector. In addition, reference is also made to those software and hardware tools currently available, and those that are necessary for the correct development and use of the technologies previously identified as optimal for education in the sector under study.

The steps followed for the development of this report are as follows:

- Introduction to the different technologies: definition, main characteristics, operation, and examples.
- Research on the hardware and software tools currently available for the development and deployment of the technologies under study.
- Benefits of the use of these technologies in education in the wood and furniture sector.
- State of the Art:
  - Analysis of 112 surveys carried out by students and teachers from different European countries who have worked or are currently working with these technologies.
  - Case studies in the field of education.
- Selection of the most appropriate technology/s for use in education.
- Presentation of the conclusions aligned with the objectives of the task and laying the foundations for the following WP3 tasks.

The structure of the document has been designed to provide the reader with a progressive immersion in the technologies on a theoretical and technical level, and then, with this understanding, to see the potential they have in education and specifically in the furniture and wood sector. This is followed by an analysis of the data from the teacher and student surveys prepared for this report. All this information from the first sections of the document is the basis that has been used to choose the technologies and development paths that are best suited to education, the main objective of the report. Finally, conclusions are drawn, which lay the foundations for further work on the following tasks of the work package.

Allview

# 2

# Introduction to AR, VR, and MR

# 2. Introduction to AR, VR, and MR

Virtual, mixed, and augmented reality (VR/MR/AR) are immersive media that take digitalisation in business and society to the next level. These media enable new forms of use, simplify communication and production processes, and thus the way we will learn, communicate, and work in the future. This creates new challenges for companies and society. Numerous applications are currently being developed for the immersive media AR, MR, and VR in areas such as education, marketing, health, and product manufacturing. However, uniform technical and legal standards, as well as methods for workflows to develop content and products, are still missing for mass-market maturity. Distribution channels through which larger user groups can use these media are also only just emerging. In short, AR, MR, and VR are media innovations that are in an early stage of development. These media are at the beginning to enter the mass market [1].

One of the biggest differences between AR/MR and VR (at the current time) is that AR or MR is more of an individual experience, whereas in VR you can now easily communicate and collaborate with other avatars, and not just in multiplayer video games. However, according to recent reports [2] [3] [4], AR will also soon move towards collaboration [5].

Nevertheless, AR, MR, and VR should not be seen as competing products, as the three technologies have individual potential uses with advantages and disadvantages. For example, while people only want information to be displayed when they are travelling, in other application scenarios they want to be completely immersed in another world. In the field of education, both technologies have great potential [5].

This educational potential of stereoscopic images was recognised as early as 1901 and depicted in a stereographic image entitled "The stereograph as an educator" [6].

Although AR and VR do not necessarily fit into traditional didactic concepts, once you leave the established paths and leave the ideas behind, you quickly find modern didactic models such as the SAMR model or the 4K model of learning. But the use of AR and VR also does justice to older approaches that did not make it into the mainstream: for example. the action and problem orientation that Dewey[1] was convinced of, or the idea of experiential learning according to Kolb[2]. Almost all of these approaches are about placing the learner at the center and encouraging him or her to actively take charge of its own learning. One learns far more through experiences and emotions than through memorizing. Albert Einstein already said "Learning is experience. Everything else is simply information" [6].

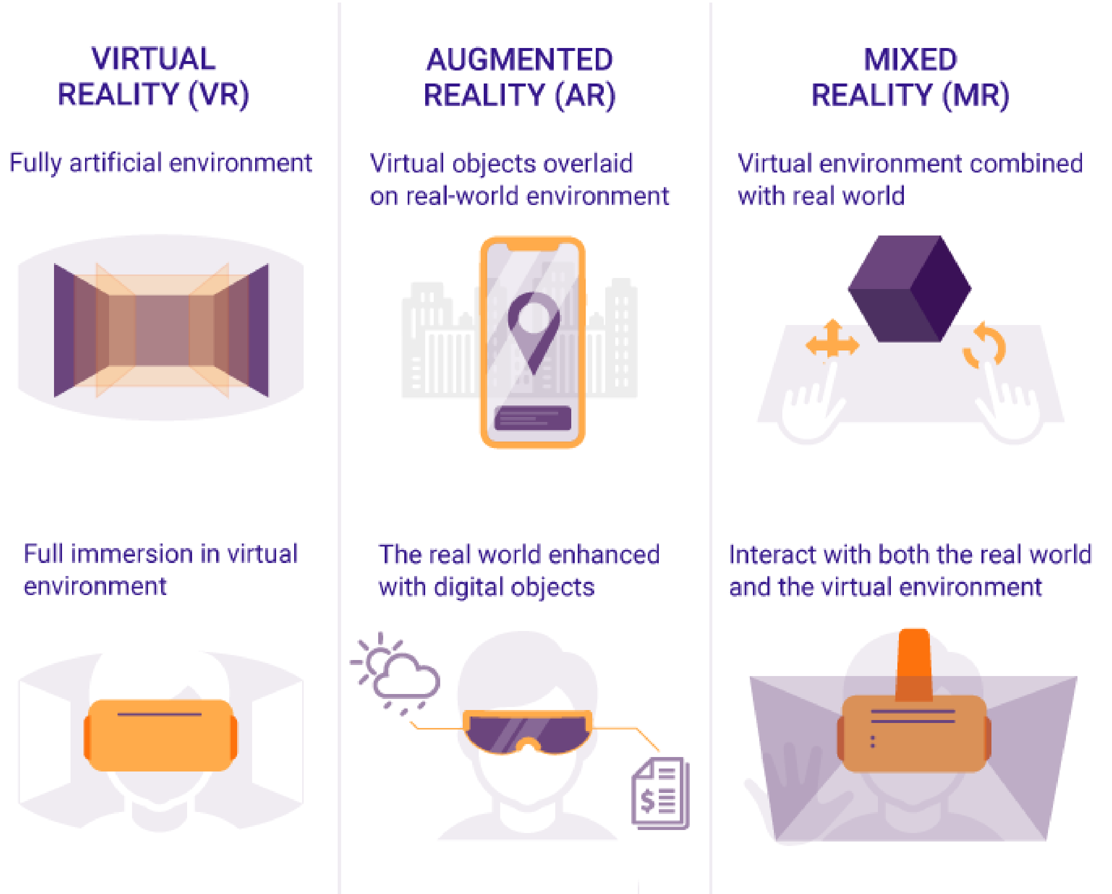



Figure 1: *Differentiation of VR, AR, and MR*

1 *John Dewey. https://en.wikipedia.org/wiki/John_Dewey*
2 *David Kobl. Theory of Experimental Learning. https://en.wikipedia.org/wiki/Kolb%27s_experiential_learning*

## 2.1. Virtual Reality (VR)

VR is not uniformly defined today. One can approach the term from a technology-centered perspective and understand it as computer systems that create immersive and interactive environments through appropriate hardware such as stereo displays. However, VR can also be described as a methodology for giving users the experience of inclusion in an illusory reality. The goal is not necessarily to achieve a perfect virtual reality in which virtuality and reality can no longer be distinguished. Peculiarities of human perception such as the "Suspension of Disbelief"[3] can be used to create effective virtual environments for people and to give them the feeling of being present in VR. This can serve different purposes: research (e.g., human perception), education, entertainment, supporting communication, visualising simulation results, or economic goals (e.g., prototyping to increase efficiency or save costs). In principle, the purpose of VR is to create an innovative interface between humans and computers [7].


Figure 2: *Virtual Reality*

*3 Suspend disbelief: Temporarily allow oneself to believe something that is not true, especially in order to enjoy a work of fiction. (Oxford Dictionary)*

Virtual reality experiences can have different levels of immersion, immersion being understood as the capacity of a system to generate an environment that emulates our experience of presence in the real world.

Depending on the degree of immersion, the following systems are differentiated:

**Non-immersive systems:** These systems show the virtual world through a combination of three-dimensional images on screen, sounds, and a high degree of interaction with the simulated virtual world. The hardware used is low cost and easy to install. A clear example is the desktop personal computer and 3D video games. Although they are not immersive systems per se, they are capable of generating a high degree of attraction of the user's attention, producing strong emotional responses.

**Semi-immersive systems:** These generally comprise a projection system that displays the virtual environment on the walls and floor of a room. They also have a system that tracks the user's head movements in order to adjust the simulation accordingly, and in most cases, they incorporate a handheld device to interact with the virtual world. This type of system has a multi-user capability, where several people can enjoy the virtual experience, which makes them very interesting in collaborative work environments. These systems require a large space for their installation and their cost is high.

**Immersive systems:** They offer the highest degree of immersion, making the user's perception of the virtual world as close as possible to the human relationship with the real world, blurring the line between the physical world and the digital or simulated world. These systems are generally comprised of a helmet with a stereoscopic vision system that allows the user to visually perceive the three-dimensional virtual world in a way that is identical to how the real world is perceived. The helmet also incorporates position and movement sensors that synchronise the user's position and perspective with the virtual world in real time, as well as headphones that reproduce a surround sound environment and various input devices, such as joysticks or gloves, that allow interaction with the virtual world. The cost of these systems varies from medium to high, depending on the system chosen and its peripherals.

### 2.1.1. VR: Devices and current development

When we speak of VR, we mean that the viewer is completely immersed in another world. This immersive experience can completely isolate the viewer from the outside world by using VR goggles with headphones to make him virtually forget the real world and control his avatar with gestures, controllers, or a special suit via motion tracking. He can also immerse himself only visually in this world, as is the case, for example, when playing Minecraft or visiting a virtual world such as Second Life by means of a computer screen [5].

If elements of the real world are integrated into the virtual world, for example, a door intercom that is switched to the VR headset's headphones, or even objects that can be used in the virtual world, we speak of AR. HTC in particular is currently experimenting here with the Vive Tracker [5].

Figure 4: *VR glasses*


Figure 3: *Cybershoes*

Figure 5: *HTC Vive Tracker*

Figure 6: *VR Traking*

## 2.2. Augmented Reality (AR)

Augmented Reality can be defined as a set of tools that offer a user experience in which the real world that the user perceives is enriched by additional information. This information is usually generated by a computer. Therefore, AR can be understood as an integration of the virtual world into the real world.

It is worth mentioning here that the real world can be augmented by one or several senses, therefore, we can find visual, sound, tactile, and even olfactory AR experiences, as well as different combinations of all of them. Also, and more specifically, in the field of visual augmented experiences, we can find two types that may or may not complement each other, two-dimensional or three-dimensional content.

Focusing on AR experiences with a visual component, these can also be classified according to their levels of immersion, with the following degrees or levels:

**Non-immersive systems:** These systems monitor the user's orientation by means of sensors and capture the real world through a camera, which in turn is shown to the user through a screen. It is in this interface where the integration of the real world with the virtual elements takes place, which are oriented according to the data received by the sensor system. Many of the developments in this technology have used the different mobile devices currently on the market, such as smartphones and tablets, as a tool for capturing, processing, and projecting the augmented experience. This allows wide dissemination of these experiences, at a reduced cost, since the user has the hardware that supports the experience beforehand.

**Immersive systems:** These are the same immersive systems used in VR experiences, but with the addition of a set of cameras that capture the real world, transferring it to the helmet's vision system. The experience reproduced has a strong immersion, by combining its stereoscopic vision system, together with the advanced sensor system and controls for interaction with the virtual elements.

The idea of keeping users present in reality, but extending it with parts from a virtual world, leads to AR. On one hand, the realisation of corresponding virtual or augmented environments requires a virtual world, e.g., the content to be shown in the environment (e.g., description of the geometry, appearance, behaviour of the virtual objects present in it). On the other hand, a VR/AR system, e.g., a computer system that incorporates the essential components of determining information about the user and its interactions (e.g., by tracking), generating stimuli for the user (e.g., images and sounds) and simulating the virtual world [8].

Despite its existence for over 50 years, VR/AR is still a young science whose development can be divided into four generations that can be characterised by the hardware used (HMD and data glove, stereo projection and optical tracking, high-resolution displays and low-cost tracking without the use of artificial markers, consumer HMD incl. tracking and controllers, and AR on smartphones and tablets) [8].

Figure 7: *Augmented Reality*

### 2.2.1. AR: Devices and current development

Augmented reality is generally spoken of when information or elements are superimposed on the real world. It can be considered a form of mixed reality. This can be done with the help of glasses equipped with a camera (such as Google Glass or slightly futuristic-looking glasses like Microsoft's HoloLens, which also make it possible to superimpose virtual elements in the real world [5].

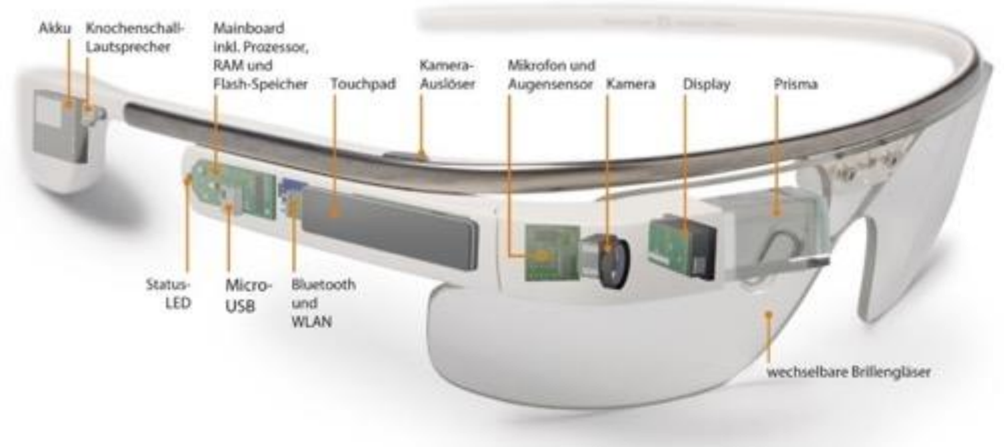



Figure 8: *Google Glass*

*Figure 9:* Virtuality in the real world

It is possible to set up a new flat on a trial basis or play Minecraft directly in your living room instead of in a virtual world. However, it is equally possible to use the smartphone camera and, via an app such as Aumentaty, superimpose content on the smartphone screen over the images that come from the camera. For example, information about interesting monuments with historical significance can be superimposed on a journey. It is also possible, for example, to superimpose vocabulary from the word field "kitchen" in a foreign language over a picture of a kitchen. Probably the best-known example of augmented reality to date is the smartphone game Pokémon GO, in which Pokémon are superimposed on the user's current surroundings [1].

Figure 10: *Pokémon GO*


Figure 11: Aumentaty

## 2.3. Mixed Reality (MR)

Mixed Reality systems also belong to the continuous spectrum of virtuality, integrating the virtual world with the real world, but in this case, MR technology goes one step further, allowing the physical elements of the user's environment to be components of interaction with the virtual elements, This allows the creation and modification of virtual objects through data obtained from the real world and a better integration of the virtual elements in the real world, by being able to calculate how they are affected by the real physical environment in which they are incorporated, being able, for example, to adapt their shadows and reflections to the physical environment, modify the lighting of the object depending on the luminosity of the scene, limit their movements to the real environment, etc.

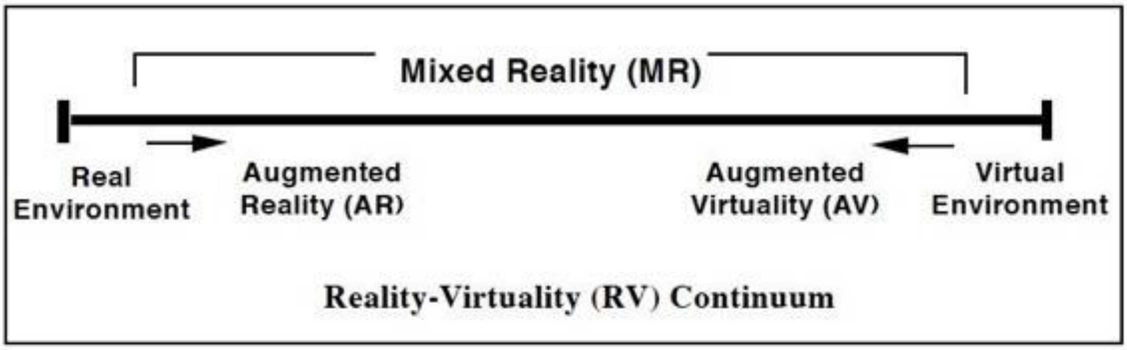



Figure 12: *Reality-Virtuality (RV Continuum)*

This technology is currently in the development phase and requires a boost in research at both software and hardware level, making it necessary to explore improvements in the algorithms for interpreting the real world and perfecting the capabilities of components and systems for immersive technologies.

MR systems can be classified analogously to AR systems: non-immersive systems and immersive systems, as AR systems were taken as the basis for further research and development in MR technologies. [1].

We can conclude that VR is the one that immerses us in a completely artificial digital environment. While AR is the one that superimposes virtual objects and/or elements on the physical world. MR, on the other hand, anchors and superimposes virtual objects on the real world to create an interaction between these elements and people; the latter is the one that is currently the least developed and the one that requires the most resources, both financial and in terms of time, for its implementation.

# 3

# Research on available hardware and software

# 3. Research on available hardware and software

## 3.1. Software

Designing for VR, AR and MR is akin to creating new realities. This new paradigm of immersive and multidimensional content creation demands new rules and considerations. Designing for AR/VR/MR leverages existing skills ranging from 3D visual design, to experience design and development, among others.

The following table lists the most relevant programming and development tools on the market for these technologies. These technological routes are used to implement the algorithms in charge of sensor management, digitisation of the physical world, interaction between the physical world and the real world, etc. These programming environments allow the management of the different actors involved in this type of applications, such as: 3D geometry, textures, sound, visualisation devices, user interface, sound management, interactions, and interactivity, etc.

| SOFTWARE | TARGET PLATFORMS | ENABLED TECHNOLOGIES | | |
|---|---|---|---|---|
| | | VR | AR | MR |
| Unity | Web<br>PC<br>Mobil Devices<br>Smart TV<br>Game consoles.<br>Virtual/Extended Reality Devices. | X | X | X |
| Unreal | Web<br>PC<br>Smart TV<br>Game consoles.<br>Virtual/Extended Reality Devices. | X | X | X |
| WebXR | Web | X | X | |
| Native | Depends on the platform | X | X | X |

Table 1: Different technological routes.

In the following subsections we will see the types of software necessary for the development of these technologies as well as their main characteristics.

### 3.1.1. Virtual Reality

Several steps are necessary to create an ideal VR user experience. The virtual world is created by software developers and then rendered so that users can interact with the objects created by the developers. The headsets, help to provide users with the illusion of being fully immersed in the 3D environment. These 3D objects tend to respond to changes in the user's movement, and the interactions simulate those of the real world. Additional hardware components, such as gloves or other accessories in the room, can also simulate other senses, such as touch [9].

This technology can provide a variety of benefits to users in countless fields, such as education, as VR can take hands-on learning to the next level. Instead of observing a teacher performing a task, a student or learner can visualise themselves performing it.

## Virtual Reality Software. Types:

VR is a technology that is constantly changing, so different subcategories of the technology are still emerging. The following are some of the types of software needed to work with VR.

| | |
|---|---|
| **VR VISUALIZATION** | This type of software allows users to experience aggregated data in a virtual environment. These tools enable users to see analytics in a way for them to fully understand what the data are communicating. |
| **VR CONTENT MANAGEMENT SYSTEMS** | Virtual reality software development kits (SDK) provide the necessary base to design, build, and test VR experiences. |
| **VR SDK** | VR SDKs act as the building blocks to create basically any VR experience. |
| **VR GAME ENGINE** | This software provides developers with the essential for creating a VR video game experience. |
| **VR SOCIAL PLATFORMS** | Users can collaborate in VR from remote locations using these tools. |
| **VR TRAINING SIMULATOR** | These tools can be used in almost any industry to train employees in a completely immersive environment. |

Table 2: Types of VR software *[9]*

VR software comes equipped with a multitude of features that allows users to create a complete VR experience. Some of the features available in these types of solutions include content management, where users can upload their raw 3D content and then edit it to create a VR experience or use existing content and publish it from these platforms, content editing, where users can edit the raw 3D content or existing VR experiences, and hardware integration, where any VR solution must integrate with hardware that supports VR experiences, these devices are usually headsets, but can also be mobile phones.

## Virtual Reality Development Software

### Virtual Reality SDK Software (software development kits)

Virtual Reality software development kits, or VR SDKs, provide the fundamental tools to design, create, and test VR experiences. These SDKs are the building blocks to create VR experiences such as mobile apps, marketing experiences, training simulations, and more. VR SDKs provide the tools to perform functions such as adding, cloning, and moving 3D objects. Additionally, these tools allow flexibility for non-developers, with many systems providing drag-and-drop functionality to customise experiences. These tools may sometimes be customised through the use of an API. While SDKs are typically intended for specific frameworks and hardware, some can be supported on multiple systems. In addition, while some VR SDKs also have the functionality to create AR experiences, these tools should not be confused with AR SDKs, which give developers the tools to specifically develop and test augmented reality apps [9].

For such a product to be included in the VR SDK category, it must:

- Offer the functionality to create custom VR experiences.
- Allow for the editing of existing VR experiences.
- Integrate with operating systems and hardware that can display VR.

## SOFTWARE

In the following table, a list of software that can be considered SDK platforms is provided:

| | |
|---|---|
| **CONTENTFUL** | Is the next-generation content platform to build digital experiences at scale. It enables teams to unify content in a single hub, structure it for use in any digital channel, and integrate seamlessly with hundreds of other tools through open APIs and powerful integration capabilities **[10]**. |
| **KENTICO KONTENT** | Is a headless CMS that simplifies content production for marketers so that they can focus on creating high-quality content without requiring developer involvement. This frees developers to focus on what they do best building engaging online experiences that look great in every channel [11]. |
| **CONTENTSTACK** | Renowned for earning the highest customer satisfaction in the industry, Contentstack combines the best of content management system (CMS) and digital experience (DXP) technology, enabling enterprises to manage content across all digital channels and create inimitable digital experiences [12]. |
| **EZ360** | With EZ360 Cloud, 360-degree video content can be distributed to VR devices via the cloud. Upload and manage videos in the online content management system (CMS). Easily push videos to VR devices. VR headsets automatically download new videos when they start the app. No more sideloading or transferring files one headset at the time. With EZ360 Cloud it is possible to distribute 360 videos all around the world [13]. |
| **HEADJACK** | Is an app creation and content management platform for 360 video producers. Inspired by WordPress, Headjack allows non-technical users to easily create and manage standalone VR apps which run on all the currently available VR headsets, while also giving developers the ability to tweak the source code to their liking using Headjack's Unity API [14]. |
| **IDEASPACEVR** | Free, open-source, self-hosted PHP content management platform for 3D and virtual reality web experiences for desktop PCs, mobile devices & VR headsets [15]. |
| **SMART2VR** | Is a CMS platform to publish and distribute your Virtual Reality content in your own branded VR app (iOS and Android), on your website and on the Samsung Gear VR [16]. |

| | |
|---|---|
| **TIBVR** | Is the first company in the world to provide companies or individuals with their very own virtual reality website with built in real-time content management system. It allows to create virtual reality web experiences and manage VR space and assets simply through the WordPress customiser [17]. |
| **VIAR360** | Is the most intuitive authoring and publishing platform that reduces the time, effort and knowledge required to create highly engaging immersive training and learning experiences from 360° videos and photos. Viar360 lets you create immersive learning scenarios that your learners can experience in "Panorama mode" on their devices or in "Virtual Reality" using VR headsets. Viar360 makes it possible for you to import 360° media assets and add hotspots, regular media files, quizzes or other interactive elements to engage your learners with real-life scenarios. With Viar360 you can take "virtual tours", "be in the shoes of X", train "safety drills", experience "crises management", and much more [18]. |
| **VIRTO [19]URS** | Is Ikon's patented software solution for the creation, distribution and visualization of VR content using a single integrated platform. Virtours offers high quality virtual experiences designed for business and customers. A complete platform to create, distribute and enjoy VR content simply, quickly and easily [19]. |
| **SIMLAB SOFT** | SimLab is a complete, easy, affordable and feature-rich solution that allows users to communicate ideas in 3D with ease. SimLab has all the tools needed to import models, create dynamic visualisations, render, build simple VR scenes, all to create fully interactive VR training sessions. [20] |

Table 3: Virtual Reality SDK.

VR designers must use a completely different approach and set of tools to create immersive experiences and interfaces, with an unlimited 360° creative space.

Some 3D creation software are:

| | |
|---|---|
| **UNITY3D (DESIGN + GAME ENGINE).** | |
| **GOOGLE VR BLOCKS** | |
| **BLENDER 3D (FREE, OPEN SOURCE)** | |

*Table 4: 3D Creation* Software.

### 3.1.2. Augmented Reality

AR software helps create computer-enhanced immersive experiences for virtual tours, gaming environments, and training simulations. AR tools can also be used in retail to help customers virtually try the product before the purchase is made [21].

## Augmented Reality Software. Types:

AR is a relatively new and growing technology, with many new types continuing to emerge. In the table below, the main types of AR software found on the market nowadays are listed:

| | |
|---|---|
| **AR VISUALIZATION SOFTWARE** | This type of software enables organizations to create immersive experiences for consumers to interact with. AR visualization software users can upload 3D content and scale the image, adjust the colour, and incorporate the additional details needed to give the best user experience possible. |
| **AR CONTENT MANAGEMENT SYSTEM (CMS)** | An AR CMS lets users bulk upload raw 3D content that will eventually become the basis for AR experiences. This content can be managed and edited within the platform. |
| **AR SDK** | These tools allow users to build digital objects that will blend into the real world that will eventually become fully fledged AR experiences. |

| | |
|---|---|
| **AR WYSIWYG EDITOR SOFTWARE** | This software enables users with limited to no coding background to create customised AR experiences. These tools have drag-and-drop capabilities that let users upload 3D objects and drop them directly into previously designed scenes. |
| **AR GAME ENGINE SOFTWARE** | These solutions give game developers the framework for creating AR video game experiences. Using AR game engine software, users can create and edit 3D characters that can interact with the real world. |
| **AR TRAINING SIMULATOR SOFTWARE** | AR training simulator software leverages AR technology to train employees for certain jobs. |
| **INDUSTRIAL AR PLATFORMS** | These solutions are typically used by organizations in the industrial field. These tools include interactive AR content that improves these employees' productivity, effectiveness, and safety. |

Table 5: Augmented Reality Software. *[21]*

## AR Software Features

- Content management: many AR solutions, regardless of the specific category they fall into, provide users with the ability to store and manage their content. This can range from raw 3D content that will serve as the basis of an AR experience to content that has already been designed.
- Editing: AR solutions should allow users to edit the 3D model they upload to the platform. Users can scale the image, adjust the colour, and incorporate any additional details needed.
- Hardware integration: in order to provide the intended AR experience for a consumer, the software must integrate with devices that support AR software. This includes glasses, Android and Apple mobile phones, and tablets.
- Drag-and-drop: some AR development solutions are designed to be user-friendly for those with little to no coding experience. Tools like this offer a WYSIWYG editor, which allows users to upload 3D objects and insert them into previously designed scenes so that they eventually become AR experiences.

- Analytics: some AR tools, such as products in the AR visualization software space, will provide analytics capabilities for users. This lets businesses see how consumers interact with the 3D object within AR mobile applications, which should be supported on both Apple and Android devices.
- Upload content: AR software products allow businesses to upload 3D content necessary for their specific business purposes. This is particularly relevant for AR training simulators, as businesses need to ensure the software will support the content needed for trainees to learn the job at hand [21].

## SDKs (software development kits) used in AR.

To develop an AR application, there is a need to use AR platforms which enable the developers to implement AR applications with predefined features of AR. In the following table, the 9 most representative AR SDKs for both Android and the IO operating system are introduced.

| | |
|---|---|
| **ARKIT** | ARkit is an AR framework which allows developers to create augmented reality applications and games for iPhones and iPads. This SDK supports either iOS 11 or 12 version. ARKit provides 2D image detection (trigger AR with posters, signs, images) and 2D image tracking, the possibility to embed objects into AR. This SDK also empowers to recognise spaces and 3D objects and place virtual objects on surfaces. In the new updated version of ARKit there is a possibility to implement games which can be played between two iPads by playing two different people. |

| | |
|---|---|
| **ARCORE** | ARCore is another developing platform for AR which is developed by Google. This platform also supports for both Android and iOS devices, but the minimum version of the Android devices should be 7.0 and for the iOS it should be 11. There are three main capabilities which are embedded in ARCore:<br>• Motion tracking: which tracks the phone position relative to the surroundings.<br>• Environmental understanding: to detect the size or location of surfaces, from horizontal and vertical. It can also detect the angled surfaces.<br>• Light estimation: to estimate the real-life lighting conditions.<br><br>Mainly ARCore is created based on real-time position tracking and integration of virtual and real objects. It allows to place objects, texts, or any information within the physical surroundings. |
| **VUFORIA** | AR framework which helps developers to create AR experiences. It has the functionalities such as recognition of different types of visual objects (box, cylinder, plane), text and environments recognition, VuMark which is the combination of picture and QR code. There is also a functionality used in Vuforia called 'Vuforia Object Scanner' which allows to scan and create object targets. The recognition process can be implemented by using the database (local or cloud storage). Unity plugin can be also integrated and used by Vuforia. They are also some other capabilities of Vuforia for AR content:<br>• Vuforia Model targets: This feature enables to have object recognition by shape. It will help track images, scanned objects, special marks (encoded), text and surfaces.<br>• Vuforia Ground Plane: This is a capability for Unity engine which permits to locate the augmented content on ground or surfaces.<br>• Vuforia Fusion: This feature is embedded to solve the fragmentation in AR and enable cameras, sensors and external frameworks for example ARKit. |

| | |
|---|---|
| **WIKITUDE** | AR platform which supports different platforms including Android, iOS, Windows for tablets, smart glasses (Epson Moverio, Vuzix M100, ODG R-7). This SDK also supports different development frameworks such as Native API, JavaScript API, Unity3D, Xamarin, Titanium and Cordova. Wikitude also enables with any different knowledge of development to download SDK and a sample app, read the documentation, and start implementing an AR application. Wikitude has also some AR features such as image recognition, object recognition, 3D markerless tracking, ARKit and ARCore support. Since Wikitude updates regularly the SDK the following capabilities can be offered also by Wikitude:<br>• Scene recognition: This feature allows to augment large objects for outdoor gaming, construction, etc.<br>• New extended recording and tracking of objects: Enables to scan and see augmented objects beyond markers.<br>• Instant targets: It provides possibility to save and share instant augmentations.<br>• Unity live preview: This capability is used for AR-view feature into Unity editor to test the SDK features.<br>• Windows support. |
| **MAXST** | Maxst is an AR SDK which supports different platforms including Android, iOS, Windows, Mac OS, and Unity. This framework consists of different features including instant tracker, visual SLAM, object tracker, image tracker, cloud recognition, marker tracker, QR code tracker, QR/Barcode reader and smart glasses calibration. The generation of image database is online via Target Manager, but developers can also request for a module that allows to train target image offline at a cost. |
| **DEEPAR** | It has the capability of detecting faces and facial features in real time, based on patented data models and machine learning techniques. The rate of recognizing is fast and is about 70 facial points at 60 frames per second. Furthermore, DeepAR's engine performs precise image rendering which is improved for mobile and web apps. DeepAR supports different platforms including PC, Android, iOS, Windows, WebGL. |

| | |
|---|---|
| **EASYAR** | It is an AR SDK which supports different platforms such as Android, iOS, UWP, Windows, Mac, and Unity Editor. The EasyAR includes features such as 3D object recognition, environment perception, cloud recognition, smart glass solution and app cloud packaging. EasyAR is easy to integrate, and it has a good documentation, and the examples are understandable. |
| **ARTOOLKIT** | Open-source library for AR. It includes the following functionalities:<br>• Single-camera or stereo-camera and camera position/orientation tracking<br>• Tracking of simple black squares<br>• Tracking of planar images<br>• Camera calibration and optical stereo calibration<br>• Plugins for Unity and OpenSceneGraph<br>• Optical head-mounted display support<br>• Free and open source software<br>• Fast enough for real time AR applications<br>ARToolKit supports different platforms including Android, iOS, Linux, Windows, Mac OS and Smart Glasses. |
| **XZIMG** | AR SDK which is developed for real-time face tracking and to create AR based apps. These implemented apps are appropriate for desktop apps, mobile apps, and web browsers via a Unity plugin. This AR SDK supports different platforms such as Android, iOS, and Windows. Xzimg includes three major products:<br>• Augmented Vision: This feature is embedded for computer vision functionality, marker recognition and tracking which developers can apply it on smartphones and Windows platforms.<br>• Augmented Face: It is used for the face recognition of human in videos, and it can be as a part of Unity plugin.<br>• Magic Face: This feature provides non-rigid face tracking, refactoring from augmented face and improving with other features such as face replacement and face detection or tracking. |

| | |
|---|---|
| **MS DYNAMICS 365 GUIDES** | Microsoft Dynamics 365 Guides is a MR application for Microsoft HoloLens that helps operators learn during the flow of work by providing holographic instructions when and where they're needed. These instruction cards are visually tethered to the place where the work is done, and can include images, videos, and 3D holographic models. With Dynamics 365 Guides, you don't need specialised 3D or programming skills. |
| **MS DYNAMICS 365 REMOTE ASSIST** | Software for remote assistance and training purposes. Dynamics 365 Remote Assist is an out-of-the-box communication platform that allows video and/or voice collaboration (like Skype) through Microsoft Teams. Participants can interact with digitally placed content in the world around them, share drawings and share documents. It can be used on a HoloLens 1 or 2, a mobile device (iOS/Android) and a computer. For the best experience, a HoloLens device is recommended. |

Table 6: Software development kits used in AR (SDK). *[22]*

To compare completely the different features of mentioned SDKs, the following figure is represented:

| | Wikitude | ARKit | ARcore | Vuforia | MaxST | DeepAR | EasyAR | ARToolKit | Xzimg |
|---|---|---|---|---|---|---|---|---|---|
| Maximum distance capture (m) | 2.4 / 5 | 1.5 / 5 | 1.0 / 3 | 1.2 / 3.7 | 0.5 / 0.9 | 0.7 / 5 | 0.9 / 2.7 | 3 / 3 | 0.5 / 1 |
| Recognition stability of immovable marker | 6 | 9 | 9 | 10 | 7 | 8 | 7 | 8 | 4 |
| Recognition stability of movable marker | 6 | 7 | 6 | 6 | 2 | 7 | 3 | 6 | 3 |
| Minimum angle recognition | 10 | 30 | 50 | 30 | 50 | 35 | 35 | 10 | 45 |
| Minimum visibility for recognition overlapped marker | 100% | 50% | 75% | 20% | 50% | 10% | 10% | 100% | 25% |
| 2D Recognition | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3D Recognition | ✓ | ✓ | ✓ | ✓ | ✓ | – | – | – | ✓ |
| Geo-Location | ✓ | ✓ | ✓ | – | – | – | – | – | – |
| Cloud Recognition | ✓ | ✓ | ✓ | ✓ | – | – | – | – | – |
| SLAM | ✓ | ✓ | ✓ | ✓ | ✓ | – | – | – | – |
| **Total (rating)** | **8.0** | **7.5** | **7.7** | **7.7** | **5.2** | **4.7** | **4.4** | **2.8** | **3.1** |

*Figure 13:* SDKs feature comparison

## AR 3D Viewers

| | |
|---|---|
| **AUGMENT** | The platform for 3D and AR product visualization, consists in an AR 3D viewer, composed by an application for mobile devices and a web-based platform, in which its users can register their own markers and associate them with 3D models and other virtual elements. Augment offers planar marker tracking and tracking via cloud storage **[23]**. |
| **AUMENTATY SCOPE** | Aumentaty is an AR platform that works with Creator and Scope. Creator is software that allows you to create your own AR project. It currently runs on Windows, is free and easily downloadable. Without programming skills, you can generate AR scenes with 3D files with or without animation, photos, videos, texts, links or even routes with geolocation.<br>Once the AR scene has been created and published, you can view the result using the Scope app, which allows you to create a temporary marker to view the augmented reality without having to have the marker created in the project, just click on the image [24]. |
| **BLIPPAR** | It's an AR 3D viewer that provides their own smartphone application and a web-based platform so that their users can register their markers and link them with many visual and interactive assets. BlippAR allows the user to track planar targets via cloud. It also instantiates a computer vision module with Artificial Intelligence (AI) and Deep Learning (DL) algorithms, increasing the application's capacities by making possible that it eventually learns to recognise different things that the user may direct it to-wards [25]. |

*Table 7: AR 3D Viewers examples.*

## AR Content Management Systems

An AR content management system (CMS) is used to bulk upload raw 3D content that will serve as the basis for AR experiences. Users can manage their AR content within this platform, as well as edit it using the product's drag-and-drop capabilities. These editing functionalities enable users to make changes to their content, such as adding colour and various textures to their 3D products.

An AR CMS may also have the capability to function as an AR SDK for a more customizable AR experience. This content is typically used to create various AR apps for mobile devices. These solutions also offer reporting and analytics, so that companies can better understand the behaviour of the audience using their content. An AR CMS should not be confused with a VR CMS, which is a platform that allows users to upload, manage, and publish virtual reality content.

For such a product to be included in the AR CSM category, it must:

- Allow 3D content to be uploaded onto the system
- Offer drag-and-drop editing capabilities
- Manage all created content within the platform
- Publish AR experiences from the solution [21]

| | |
|---|---|
| **ZAPWORKS** | ZapWorks is the most robust AR toolkit for companies who want to push the boundaries of creativity and storytelling. Using the ZapWorks ecosystem, you can rapidly build, publish, analyse, and scale immersive AR experiences across the complete customer journey [26]. |
| **ENVOLVERAR.** | EvolveAR provides a full set of AR features that will help you create, play, and deliver a totally immersive user. It contains all the major Augmented Reality features like videos, audios, action buttons (CTA), images, 360° videos, and 3D models [27]. |
| **ITSILESIA.** | With fully scalable solutions Itsilesia can prepare a source of information or an educational tool operating on plenty of different platforms – starting from web pages and web applications, through mobile applications, interactive touch tables, desktop applications, up to advanced 3D virtual reality simulators [28]. |

*Table 8: CSM for AR. Examples.*

### 3.1.3. Mixed Reality

Although the paradigm of MR is different from that of VR and AR, the current methodologies used to create VR and AR experiences will be used to develop mixed reality applications and skills in the future. Current methodologies used to create VR and AR experiences will be used to develop MR applications and skills in the future. It will be necessary to work with the specific development kit for each of the new devices but using current engines such as Unreal Engine or Unity.

MR comprises two different processes:

- On the one hand, we find the insertion of real elements into the virtual environment. For this purpose, the physical, three-dimensional object or person is registered in the virtual world in real-time via a computer interface. This is done by means of immersive devices, which allow the creation of 360-degree virtual environments. Furthermore, they feature an opaque display screen and use camera sensors and gyroscopes to identify the position of the subject and adapt it to the virtual environment [29].
- On the other hand, the introduction of a virtual element into a real, physical environment is done by pre-reading the space with a video camera. The computer system creates interface marks, which are usually black and white prints on a rigid support. These marks are captured by the camera, generating a code that will allow the computer to represent the virtual images of the real elements. This process is possible thanks to holographic devices that make it possible to see, through transparent screens, the real environment with digital holograms that can be interacted with. In other words, they make it possible to create environments from virtual holograms added to the real world [30].

Any MR system consists of a number of components:

- The interface: The interface translates the information between the user and the MRI system.
- The graphics engine: The graphics engine is responsible for graphically representing the 3D environment.
- The simulation: This is in charge of defining how each virtual element will act [31].

## Libraries for MR development:

| | |
|---|---|
| **MRTK** | MRDK is an open-source toolkit with a developer community supported by Microsoft, which enables the development of MR applications in Unity for Windows 10. The toolkit provides a set of ready-to-use prototypes and pre-built models to help developers create content faster. It is also compatible with most mixed reality devices such as: Acer Windows Mixed Reality, HP Windows Mixed Reality, Lenovo Explorer, Asus Windows Mixed Reality or HoloLens [32]. |
| **OPENHMD** | OpenHMD provides a free and open-source API4 for developing cross-platform software (Android, OpenBSD, Linux, OS X, Windows) for MR devices. OpenHMD offers a plugin for the Unity development engine to control camera tracking and rotation but does not support user position tracking and is therefore limited to head tracking. It also has a great compatibility with MRI devices such as: Oculus Rift, HTC Vive, Sony PSVR, Deepoon E2, etc [33]. |
| **BUILD WAGON** | Build Wagon is a web-based development environment for exclusive use with Hololens, allowing to write Javascript code stored in the cloud for multiple developments. It also has an online emulator5 that allows to simulate your projects. Build Wagon has four versions, a free version in which development is limited to one project and 1 GB of space, the plus version with unlimited projects and 2GB of space in the cloud ($35), the Professional version ($125) and the enterprise version with better features ($200) [34]. |
| **MIXCAST** | MixCast is an SDK designed to develop MR applications and videos from VR. It is compatible with major development engines such as Unity and Unreal allowing for faster development. MixCast software creates a real-world video output into which it adds virtual elements [35]. |

*Table 9: Libraries for mixed reality development.*

4 *http://openhmd.net/doxygen/0.1.0/openhmd_8h.html*
5 *https://buildwagon.com/holoemulator.html*

## 3.2. Hardware

VR, AR and MR hardware have undergone significant improvements in recent years, becoming much smaller, lighter, more comfortable, more powerful, and much cheaper. Some models for each of the technologies under study are shown below.

The main devices that can currently be used to generate an experience within the continuous spectrum of virtuality (VR/AR/MR) are shown below. Some of these devices only have the capacity to support one of the technologies, while other devices have the capacity to support all three.

The devices that have the capacity to develop experiences in the field of MR are currently in the middle of research. Most of these devices only have libraries for the development of applications (SDK) in beta phases for this specific environment. This makes it necessary to produce a synergy resulting from the collaboration of the application programming teams and the developers of the device's own SDK. This synergy must be translated into a "feedback" or feedback between the teams, as a result of experimentation and debugging, providing the necessary solidity and reliability to give the final push to MR towards the user and turn it into a revolution that will facilitate our presence in a new experience where the virtual is integrated with the physical and vice versa.

| IMAGE | DEVICE | DEVELOPMENT PLATFORMS | TECHNOLOGIES | | | LEVEL OF IMMERSION |
|---|---|---|---|---|---|---|
| | | | VR | AR | MR | |
|  | Smartphone /Tablet | Unity<br>Unreal<br>Nativo | X | X | | Non-immersive |
|  | Google Card Board | Unity<br>Unreal<br>Nativo<br>WeebVR | X | X | | Immersive |

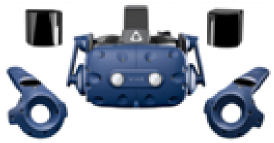
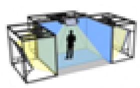
| IMAGE | DEVICE | DEVELOPMENT PLATFORMS | TECHNOLOGIES | | | LEVEL OF IMMERSION |
|---|---|---|---|---|---|---|
| | | | VR | AR | MR | |
|  | HTC Vive | Unity<br>Unreal<br>Nativo<br>WeebVR | X | | | Immersive |
|  | Oculus Rift | Unity<br>Unreal<br>Nativo<br>WeebVR | X | X | | Immersive |
|  | HTC Vive Pro | Unity<br>Unreal<br>Nativo<br>WeebVR | X | X | X | Immersive |
|  | CAVE | Nativo | X | | | Semi - Immersive |
|  | Oculus Rift S | Unity<br>Unreal<br>Nativo | X | | | Immersive |
|  | Hololens 2 | Unity<br>Unreal<br>Nativo<br>WeebVR | | X | X | Immersive |

*Table 10: Hardware for AR, VR, and MR.*

The following tables show a comparison of VR and AR headsets, where the manufacturer, software platform, field of view and prices among other features of these devices can be compared.

## Headset matrix

| | CATEGORY | PRODUCER | LINK | SOFTWARE PLATFORM | TARGET PRICE | CONSUMER/ BUSINESS | GRAPHICS | WIRE-LESS/ WIRED | CONTROLLERS | DOF | TRACKING | EYE-TRACKING | AR-PASSTHROUGH | EXTRAS | DISPLAY TYPE | RE-FRESH RATE | FIELD OF VIEW | WEIGHT | BATTERY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oculus Go | VR | Oculus (facebook) | oculus.com/go | Oculus | €159(32GB)/ €219(64GB) | Consumer | 2 | Wireless | Go controller (1) | 3DOF | Inside out | No | No | / | LCD 1280 x 1440 | 72Hz | 101° | 468g | 1,5-2 hours |
| Oculus rift S | VR | Oculus (facebook) | oculus.com/rift-s | Oculus | €449 | Consumer | 4 | Wired | Oculus controllers (2) | 6DOF | Inside out | No | Yes | / | LCD 1280x1440 | 80Hz | 110° | 500g | PC powered |
| Oculus Quest | VR | Oculus (facebook) | oculus.com/quest | Oculus | €449(64GB)/ €549(128GB) | Consumer | 4 | Wireless | Oculus controllers (2) | 6DOF | Inside out | No | Yes | / | OLED 1600x1400 2x[ren] | 72Hz | 110° | 571g | [illegible] |
| Oculus Quest | VR | Oculus (facebook) | business.oculus.com/products | Oculus | $ 999 | Business | 4 | Wireless | Oculus controllers (2) | 6DOF | Inside out | No | Yes | / | OLED 1600x1400 2x[ren] | 72Hz | 110° | 571g | 2-3 hours |
| HTC VIVE | VR | HTC | vive.com/eu/ product/vive | SteamVR | €599 | Consumer | 4 | Wired | Vive controllers | 6DOF | Extern | No | No | / | AMOLED 2160x1200 | 90Hz | 110° | 555g | PC powered |
| HTC vive pro | VR | HTC | www.vive.com/eu/ product/vive-pro | SteamVR | €679 | Consumer | 5 | Wired | Vive controllers | 6DOF | Inside out | No | Yes | Wireless adapter sold separate | OLED 1600x1400 2x[ren] | 90Hz | 110° | 470g | PC powered/ wireless 2.5 hours |
| HTC vive Cosmos | VR | HTC | www.vive.com/ eu/product/vive-cosmos-xr | SteamVR | €799 | Consumer | 5 | Wired | vive cosmos controller | 6DOF | Inside out | No | Yes | / | LCD 1440x1600 2x[ren] | 90Hz | 110° | 645g | PC powered |
| Valve index | VR | Valve | store. steampowered. com/valveindex | SteamVR | €1.079 | Consumer | 5 | Wired | Valve index controllers | 6DOF | Extern | No | No | / | LCD 1440x1600 2x[ren] | 80-144Hz | 130° | 500-600g | PC powered |
| HTC vive pro eye | VR | HTC | vive.com/eu/ product/vive-pro-eye | SteamVR | €1.439 | Business | 5 | Wired | Vive controllers | 6DOF | Extern | Yes | No | / | OLED 1440x1600 2x[ren] | 90Hz | 110° | 470' | PC powered |
| Varjo VR-2 | VR | Varjo | varjo.com/ products/vr-2-pro | Steam VR/ OpenVR | $4,995 | Consumer | 5 | Wired | Varjo controllers | 6DOF | Inside out | Yes | Yes | / | OLED 1920x1080 2x[ren] AMOLED 1440x1600 2x[ren] | 60/90Hz | 87° | 605g | PC powered |
| Varjo VR-2 (business) | VR | Varjo | varjo.com/ products/vr-2-pro | Steam VR/ OpenVR | $4,995 | Business | 5 | Wired | Varjo controllers | 6DOF | Inside out | Yes | Yes | / | OLED 1920x1080 2x[ren] AMOLED 1440x1600 2x[ren] | 60/90Hz | 87° | 605g | PC powered |
| Samsung HMD odyssey+ | VR | Samsung | microsoft.com/ en-us/windows/ windows-mixed-reality | SteamVR | $279.00 | Consumer | ? | Wired | Mixed reality controllers | 6DOF | Inside out | No | No | / | 2880 x 1600 AMOLED | 60-90Hz | 110° | 590g | PC powered |
| HP Reverb Virtual Reality Headset | VR | HP | hp.com/us-en/vr/ reverb-vr-headset. html | SteamVR | $664.41 | Consumer | ? | Wired | Mixed reality controllers | 6DOF | Inside out | No | No | / | 2160x2160 2x[ren] | 90Hz | 114° | 453g | PC powered |
| Pico Neo 2 | VR | Pico | pico-interactive. com/us/neo2.html | Pico digital platform | $699 | Business | ? | Wired | Two 6DoF controllers | 6DoF | Inside out | Yes | Yes | / | 4K | 75Hz | 101° | 350g | Wired |
| HP Reverb 2 | VR | HP | hp.com/us-en/vr/ reverb-g2-vr-head-set.html | Windows mixed reality | $599 | Consumer | ? | Wired | 2 | 6DoF | Inside out | No | ? | / | 2160x2160 LCD | 90Hz | 115° | 500g | Wired |

*Table 11: Virtual Reality headset comparison table.*

## Headset matrix

| | CATEGORY | PRODUCER | LINK | SOFTWARE PLATFORM | TARGET PRICE | CONSUMER/ BUSINESS | GRAPHICS | WIRE-LESS/ WIRED | CONTROLLERS | DOF | TRACKING | EYE-TRACKING | AR-PASSTHROUGH | EXTRAS | DISPLAY TYPE | RE-FRESH RATE | FIELD OF VIEW | WEIGHT | BATTERY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hololens 2 | AR | Microsoft | microsoft.com/ en-us/hololens/buy | Windows 10 | $3500 | Business | AR | Wireless | Hands | 6DOF | Inside out | Yes | Yes | Not available every-where | 2048 × 1080 px (per eye) | n/a | 52° | 566g | n/a |
| Vuzix Blade Smart Glass | AR | Vuzix | vuzix.com/ products/blade-smart-glasses | Android | [illegible] | Business | AR | Wireless | voice | 6DOF | Inside out | No | Yes | / | [illegible] | n/a | n/a | [illegible] | n/a |
| Vuzix M300XL | AR | Vuzix | vuzix.com/ products/m300xl-smart-glasses | Android | € 1.338,80 | Business | AR | Wireless | Android control buttons, touchpads, voice | 6DOF | Inside out | No | Yes | / | 16:9 nHD | n/a | 16,7° | n/a | 2-12 hours |
| Epson Moverio BT-300 | AR | Epson | epson.be/products/ see-through-mobile-viewer/moverio-bt-300 | n/a | [illegible] | Consumer | AR | Wireless | Touchpad | 6DOF | Inside out | No | Yes | / | 1280x720 Si-OLED | 30Hz | 23° | 69g | 6 hours |
| Everysight Raptor | AR | Everysight | everysight.com | n/a | [illegible] | Consumer | AR | Wireless | 1 controller | 3DOF | Inside out | No | Yes | / | n/a | n/a | n/a | n/a | n/a |
| Dreamworld AR | AR | Dreamworld | dreamworldvision. com | Android | [illegible] | Consumer | AR | Cabled | 2 controllers | 6DOF | Inside out | No | Yes | / | n/a | n/a | n/a | n/a | n/a |
| iPhone SE | AR | Apple | apple.com/ iphone-se/ | iOS | $399 | Consumer | AR | Cell-phone | / | / | / | No | Yes | / | Retina HD | / | / | [illegible] | [illegible] hours |
| Pixel 4 XL | AR | Google | store.google. com/[illegible] | Android | [illegible] | Consumer | AR | Cell-phone | / | / | / | No | Yes | / | 1440 x 3040 P-OLED capacitive touchscreen | / | / | 193g | 14 hours |
| Galaxy S20 | AR | Samsung | samsung.com/us/ mobile/galaxy-s20-5g/ | Android | [illegible] | Consumer | AR | Cell-phone | / | / | / | No | Yes | / | 1440 x 3200 Dynamic AMOLED 2x capacitive touchscreen | / | / | 163g | [illegible] hours |
| Nreal | AR | Nreal | nreal.ai/ | Custom SDK | $499/ dev kit: 1199 | Consumer | AR | Wireless | 1 3DoF touchpad | 6DoF | Inside out | No | Yes | / | ? | ? | 52° | 88g | ? |

*Table 12: Augmented Reality headset comparison table.*

One of the advantages of VR is the ability of watching immersive videos. Creating virtual twins and 360º simulations for training is safer, less intrusive, more scalable than on-site practice, and much more realistic than passive Slides.

In these videos, the images can be viewed in 360 degrees, i.e., the field of vision covers the entire environment around the camera that is recording. To understand what 360-degree videos are, we can say that it is like being enclosed inside a TV or computer screen in the shape of a ball where a complete image is shown on that super screen.

With 360-degree videos, it is not only the front image that is displayed but through movements of the computer mouse, the finger on the mobile phone or virtual reality glasses, all the surrounding images are seen, being able to see what is there and what is happening behind us, on the floor, on the sides, etc. and to experience first hand what is happening at all angles as we feel inside the image.

To record 360-degree videos, a special camera capable of recording images at a wide angle is needed.

There are cameras that with a single lens are able to reach 180 degrees of vision but to make this type of video requires 2 cameras strategically placed so that the 2 images overlap and merge to form one.
The best-known cameras are the Samsung Gear 360, the Nikon Myssion 360, or the LG 360 Cam but none of them reach the 4k image quality offered by GoPRO cameras [36].


*Figure 14:* 360° cameras.

For the processing of this type of 360 videos, it is also necessary to use specific software. Such as, for example, the following:

| | |
|---|---|
| 3DVista | This software allows the creation of high quality panoramas, full interactive virtual tours and 2D and 3D floor plans.<br>More info: *http://www.3dvista.com/* |
| Matterport | Matterport is the standard for 3D space capture. This end-to-end platform transforms real spaces into immersive digital twin models. It's much more than just panoramic photos: Matterport allows everyone to capture and connect rooms to create fully interactive 3D models.<br>More info: *https://matterport.com/* |

*Table 13: Processing software 360° videos.*

Below is a table comparing 360° video with VR, AR and MR technologies, showing some of the advantages and disadvantages of each.

| | 360° VIDEO | 3D -VR | AR | MR |
|---|---|---|---|---|
| EXAMPLE | Present, Empathy, Engine block group A<br>• https://www.youtube.com/watch?v=oR bmLBWdEoI<br>• https://www.recruitmenttech.com/this- is-how-walmart-uses-virtual-reality-to-hire-new-managers/ | Logistics, Engine block group B.<br>• https://www.youtube.com/watch?v=Q wjyyCXd514<br>• https://www.youtube.com/watch?v=d q2RSlslQcU | Procedural<br>• https://www.youtube.com/watch?v=G5 qnu15WOuU | • https://www.youtube.com/watch?v=RpXyagutoZg<br>• https://www.youtube.com/watch?v=1QFMPo5k6po |

| | 360° VIDEO | 3D -VR | AR | MR |
|---|---|---|---|---|
| **ADVANTAGES** | • Very high realism<br>• Faster VR production<br>• Expandable with your own 360° content (depending on architecture module)<br>• Possible to create your own content (if suitable equipment) | • Unlimited adaptable and expandable<br>• Complete freedom of play<br>• All scenarios are possible (including what is impossible in reality due to safety or production)<br>• Full interaction with 3D objects<br>• Powerful, visual feedback: you see 'live' what is happening depending on your actions | • Easily usable (smartphone or tablet)<br>• User maintains contact with the environment | • *Object recognition: integrating digital images with the environment*<br>• *User maintains contact with the environme nt* |

| | 360° VIDEO | 3D -VR | AR | MR |
|---|---|---|---|---|
| **DISADVANTAGES** | • Adjusting existing video images afterwards is not possible: videos must be filmed again<br>• Limited interaction with 360° content: via pop-up screens where choices can be made (branching)<br>• Scenarios are limited: you can only film what is really possible in terms of safety, organization and feasibility<br>• Feedback remains limited: also, here you only see what is possible in terms of safety, organization and feasibility | • Realism is less (computer animation), unless it is worked out very high-end<br>• Development is slower and there is more chance of bugs<br>• Making content yourself is difficult: tools have a very high learning curve; unless very simple experiences | • No object recognition or integration with the environment: the digital image is added to elements from the environment | • *Expensive equipment (entry-level model from € 2,000)* |
| **COLLABORATIVE LEARNING** | • Not possible | • Ideally suited for collaborative learning / design thinking | • Possibly depending on design | • Ideally suited for collaborative learning / design thinking |

| | 360° VIDEO | 3D -VR | AR | MR |
|---|---|---|---|---|
| **DESIGNATED FOR** | • Creating awareness<br>• Letting you experience unfamiliar situations<br>• Forms of training where 'live' interaction is not required (reaction of the environment through selection menu)<br>• Soft skills training (without real time feedback) | • Analyzing installations or models<br>• Train procedural skills<br>• Forms of training where live interaction is required (environment reacts immediately to own actions)<br>• Hards skills training (with real time feedback) | • Assisted learning / learning on the spot<br>• Remote assistance<br>• Forms of training where object recognition is not required: fixed setup, fixed procedure | • *Assisted learning / learning on the spot*<br>• *Remote assistance*<br>• *Forms of training where object recognition is required: fixed setup, fixed procedure* |
| **SOFTWARE** | • Uptale, Wonda, BrioVR, CenarioVR | • Unity, Unreal | • Vuforia | |
| **HARDWARE** | • All VR headsets, usually 3Dof is sufficient (Oculus Go) | • All VR headsets, here 6Dof is often an added value (Oculus Quest) | • Smartphone or tablet that support AR (Apple: ARkit; Android: ARcore)<br>• AR smart glasses (hands-free): Vuzix; iriStick, Nreal | • Hololens, Magic Leap |

*Table 14: Table comparing different technologies. Examples, advantages and disadvantages. [37]*

4

## How can these technologies be useful in education in the field of wood and furniture?

# 4. How can these technologies be useful in education in the field of wood and furniture?

Virtual reality and augmented reality (VR/AR) will change many jobs in the future. This will not only change the work itself, but also the training for the job. Clearly defined competencies and job descriptions for AR/VR have been missed so far. It is exactly what the Virtual Dimension Centre (VDC) has now identified [38].

*Figure 15:* Learning environment with VR.

While the job description and the training changes, it is necessary to teach basic knowledge of a new technology already during the training. VDC has now taken a closer look at which job profiles can benefit from VR & AR and which knowledge domains would be important for this. VR & AR are cross-sectional technologies and methods that can encompass a variety number of knowledge domains. These include [38]:

- User Interface Design
- Hardware Development
- Software Development
- Industrial Engineering
- Computer Graphics
- Acoustics
- Haptics
- Perception/cognition psychology

Those marked orange imply use in the wood and furniture sector.

In addition, for practical use, there is often concentrated knowledge from the application field (such as design, maintenance, ergonomics, industrial engineering, marketing communication, etc.) and from the industry.

These are the fields of application [38]:

→ **Documentation:**

The Virtual Environment is used to store and retrieve positional, structural, procedural and behavioural knowledge (example: construction inventory, industrial workflows).

→ **Education and training:**

The Virtual Environment is used to teach positional, structural, procedural and behavioural knowledge (example: training in the use of machinery)

→ **Cooperation:**

The Virtual Environment is used to share positional, structural, procedural and behavioural knowledge, both locally concentrated and dislocated (example: spatially distributed design review)

→ **Assistance:**

The Virtual Environment is used to assist the user during an activity performed in reality at runtime (example: assistance with maintenance or assembly).

→ **Geometry definition:**

The Virtual Environment is used to define 3D objects or to evaluate the correctness of their definition (examples: Visibility analyses, accessibility analyses, buildability analyses, ergonomics).

→ **Design & layout:**

The Virtual Environment is used to define or evaluate other design aspects besides geometry (examples: colours, light, materials, usability).

→ **Data analysis:**

The Virtual Environment is used to spatialise any data that have manifestations in multiple dimensions, making them accessible to human evaluation (example: cluster analyses, visual analytics).

→ **Logic:**

The virtual environment is used to define or evaluate logical relationships. This is particularly useful where the logic has a geometric effect, for example in the control of kinematic (3D) systems (examples: robotics, automation technology).

→ **Marketing & sales:**

The Virtual Environment is used to provide information and/or messages about a product to the buyer, possibly also to engage the buyer in a dialogue about the product based on the digital representation (examples: sales configurators, virtual showrooms).

→ **Behavioural research:**

Studying the behaviour of people in a virtual environment that can be manipulated almost at will is studied.

→ **Therapy:**

Embedding a person in a virtual environment gives them an experience and feeling.

## 4.1. New teaching methodologies

Section 4.1 discusses some teaching methodologies that are related to new technologies and 21st-century skills. To reinforce these methodologies, in points 4.1.3 and 4.1.4, the importance of AR and VR in education as immersive technologies is discussed. To conclude the section, the above is complemented with some examples of the use of these technologies in education and in the furniture and wood sector.

### 4.1.1. The SAMR Model – Created by Dr. Ruben Puentedura[6]

Puentedura's SAMR model shows how technology can be integrated into the classroom. It can either complement traditional teaching or develop it completely [6].

Today, we are mostly still in the substitution or enhancement phase. This means that digital media is used either to replace an analogue medium or to extend it. The former is the case, for example, when instead of printed textbooks their digital counterparts as PDF files are used or

*6 Dr. Ruben Puentedura is the Founder and President of Hippasus, a consulting firm based in Western Massachusetts, focusing on transformative applications of information technologies to education. http://www.hippasus.com/team/rrpuentedura.html* when a smartboard is used merely to replace the chalkboard. We can speak of an extension when digital textbooks are used that not only replace the printed book but are also equipped with multimedia elements. These can be explanatory videos that can be called up with a click or AR elements [6].

However, the aim of modern teaching should be to change teaching thanks to the available technology by developing tasks further (modification) or even setting tasks that would not even have been unthinkable in the past (redefinition). For example, instead of a traditional poster with pictures and texts, one can create a multimedia poster for a group work with a tool like Glogster, which can contain video and audio files in addition to pictures and texts. Finally, one can also define tasks in a completely new way by having pupils create explanatory videos for each other or when - for example in foreign language lessons - one visits distant countries with the help of VR or even create virtual worlds oneself, for example, based on the reading of a novel. Audio elements can be incorporated if necessary. Exchange contacts with pupils from another country can also be made possible in this way. Of course, this cannot replace a real language bath in another country, but if a trip abroad is not possible, then virtual reality is the closest possibility to this experience [6].

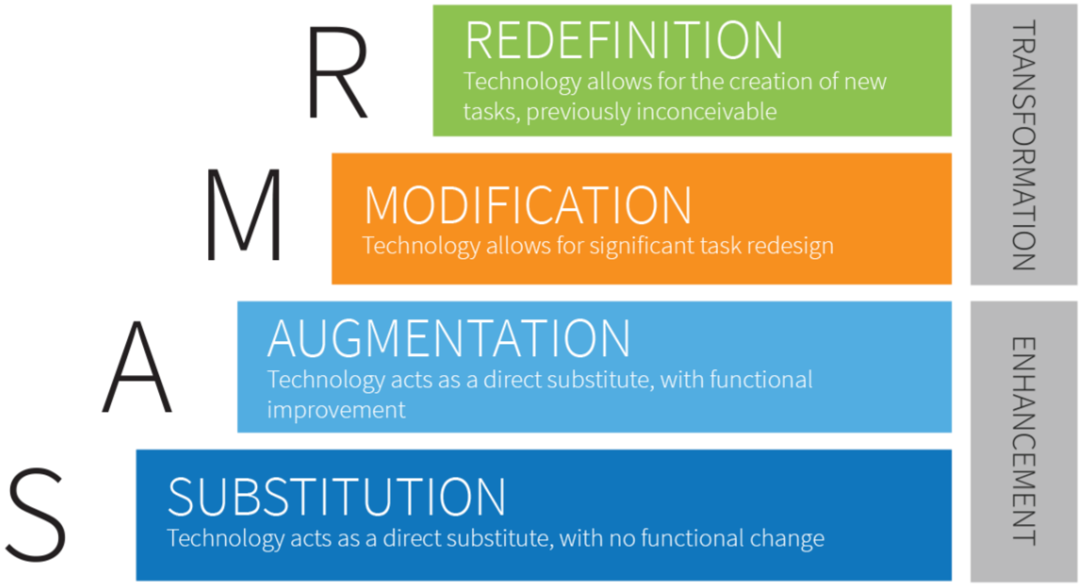



*Figure 16:* The SAMR Model – Framework created by Dr. Ruben Puentedura.

## 4.1.2. The 4K-Model of learning

Unlike the SAMR model, the 4K model of learning is not about technology, but about competences that are particularly important in the 21st century: communication, collaboration, creativity and critical thinking are considered some of the key competences of today [6].

These should be acquired and fostered in school, and digital media can be helpful in this. VR can play a key role here. It can be used to train at least the first three, and if the task is well thought out, all four key competences mentioned. If pupils do not only use VR passively but also build virtual worlds together on a certain topic, they train these key competences quite incidentally. They network their self-researched knowledge in a new way and can give free rein to their creativity. Meanwhile, the teacher is available as a contact person and can support the pupils individually so that everyone can realise their full potential. The virtual spaces created in this way can then be made available to others, who can use them as a starting point for new creations [6].


*Figure 17:* 21st - Century Skills.

Virtual scenarios can also be conducive to critical thinking: Instead of reading about historical events or past cultures in books and learning about them through old photos, virtual reality can provide a kind of time travel. Through the immersive experience, an impression of history can be experienced and, through the emotions it evokes, can become more relevant to some students than two-dimensional images, texts, or films. And augmented reality can also be used profitably in this way. Think, for example, of scenes from everyday life of any time, over which culture- and time-specific information can be superimposed. These enable the viewer to break away from their cultural and present-day standpoint and to change perspective [6].

### 4.1.3. VR: Importance and use in education

Developments still revolve mainly around video games and entertainment, although some applications can also be used in education. Google allows virtual field trips with students with its Google Cardboard applications and the Google Expeditions app. Other companies have jumped on this bandwagon and are now developing educational content themselves. VR allows users to interact with all manner of objects and systems, including those that are too small, too large, or perhaps too dangerous to experience in real life. With VR, students can assemble, disassemble, manipulate, and modify objects and environments in ways that were not possible before.

VR education can help students expand their knowledge about more complex concepts that cannot be explained otherwise. Furthermore, VR can ensure high engagement levels among both students and teachers. With virtual reality, it engages the senses, emotions, and cognitive functions of the brain, harnessing the most powerful aspects of retention. Now, from manufacturing to customer service, organisations are jumping on the bandwagon, realising that virtual visits in training can really affect their bottom line.

There are now apps that allow students and teachers to create their own content for VR glasses. But interesting applications for education are also coming onto the market again and again for higher-priced glasses such as the Oculus Rift or the HTC Vive [39].

Table 15 shows some existing educational apps and services for VR:

| EDUCATIONAL APPS AND SERVICES FOR VR | |
|---|---|
| Google Expeditions | Google Arts and Culture |
| Boulevard | Google StreetView |
| Google Earth VR | Unimersiv |
| NYT VR | Arte 360 |
| Cornelsen & Samsung | CoSpaces |
| YouVisst | EON VR |
| Tilt Brush | Facebook Spaces |
| Oculus Rooms | vTime |
| Minecraft | Second Life |
| Sansar | High Fidelity |
| Edorble | Beloola |
| Fieldscapes VR | SimLab |

Table 15: Educational Apps and services for VR.

### 4.1.4. AR: Importance and use in education

AR applications can complement a standard curriculum. Text, graphics, video, and audio can be superimposed into a student's real time environment. Textbooks, flashcards, and other educational reading material, when scanned by an AR device, produce supplementary information to the student rendered in a multimedia format. Students can participate interactively with computer generated simulations of historical events, exploring, and learning details of each significant area of the event site [40].

Thanks to AR, it is easy to design paper worksheets interactively. The preparation on the teacher's side only has to be done once per school year or can be done by larger teams of teachers once for all colleagues in a subject and a school. All that needs to be done is to upload the triggers (objects such as pictures that are recognised by the app when users look at it through the camera) on a platform such as Aumentaty and add overlays - preferably in a shared account. As soon as a student follows the account, he/she can use all the content [41].

On the one hand, one can put different triggers on the worksheet, which - when scanned with the app Aumentaty scope, for example - show tips, learning videos or additional tasks, or one can create the entire worksheet or a single task as a trigger and show the solutions on the sheet as an overlay [41].

Finally, one can also provide task sheets that contain a multimedia part (e.g., videos for listening/viewing comprehension or MP3 files for listening comprehension in foreign languages or for simulations in science lessons) with a trigger for the corresponding content [41].

Existing educational apps and services for AR:

| EDUCATIONAL APPS AND SERVICES FOR AR | |
|---|---|
| Quivervision Education | FaceRig |
| Mirage | Elements 4D |
| Sky Map | Star Walk 2 |
| Google Expeditions AR | Gamar |

Table 16: Educational Apps and services for AR.

## 4.2. Examples

**VR laboratory environment as an experimental space for students** [42]

In the ViRAI project, VR will be used as a learning tool, e.g., to familiarise students with spatial and interactive content. At the same time, VR will also be taught as a tool for engineers. "The project is one of our contributions to the digitalisation of teaching. We want our graduates to master the latest technologies," said Dr. Manfred Dangelmaier, ViRAI project coordinator. The laboratory environments at the cooperating Fraunhofer IAO offers the appropriate equipment to bring the latest VR applications to life [42].

A similar project of Fraunhofer IAO can be found in the following link:
*https://www.iem.fraunhofer.de/content/dam/iem/dokumente/forschungsprojekte/forschungsprojekt-ivipep.mp4*

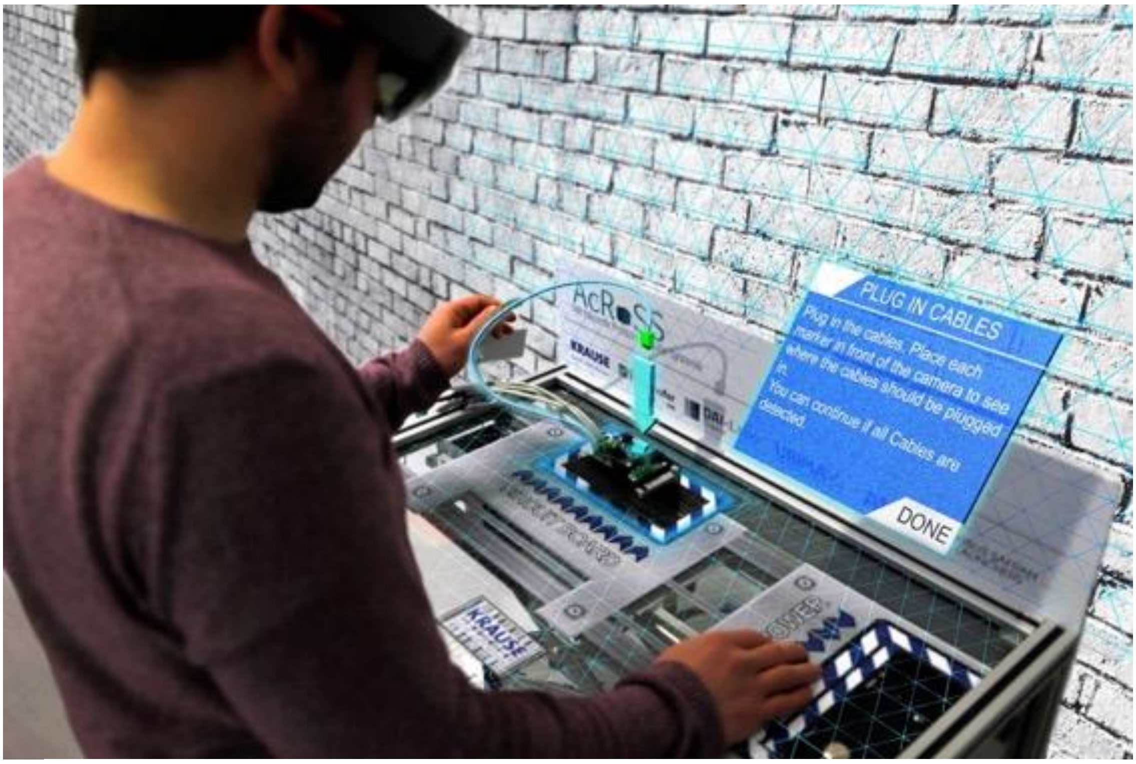



*Figure 18:* Interactive instruction with AR for repairs.

**Furniture industry related Innovation - VR game application** [42]

VR is used both for the project exercises "Fundamentals of Product Development" and in the lecture "Virtual Engineering". In the exercises, students should gain more practical experience with VR. It is helpful that many VR game applications are also used on the home PC. In addition to the usual construction tools (CAD), software for 3D modelling and from game development is also used. This is used to develop technical objects (such as furniture), provide them with materials and interaction options and stage them with suitable lighting in a realistic environment.

Figure 19: Practice example of a VR Kitchen by Life-Kitchens.co.uk.

The experiences from the project are the basis for the further digitalisation of teaching. The interdisciplinary team of researchers from the Institute of Human Factors and Technology Management IAT at the University of Stuttgart, the Ludwig Uhland Institute for Empirical Cultural Studies at the University of Tübingen and the Fraunhofer Institute for Industrial Engineering IAO are also investigating how the culture of teaching and learning is changing through the use of VR and AR in engineering education through the project "Virtual Reality in University Engineering Education (ViRAI)" [43].

**Virtual Collaboration Labs (VCL) at KIT** [42]

VR technology is also used at KIT and Mannheim University of Applied Sciences and is supported by the Ministry of Science with funds from the digital@bw digitisation strategy. For example, it is common practice at KIT and Mannheim University of Applied Sciences to introduce students to measurement and simulation technology separately in practical courses and lectures. For this, the students and teachers must be physically present in the laboratories. In the funded project, existing virtual platforms - based on modern 3D visualisation technology - are to be made usable by means of VR/AR techniques. In the process, available VR/AR hardware technologies will be made usable for teaching with apps on standard mobile phones. This allows for interdisciplinary and practical training [42].

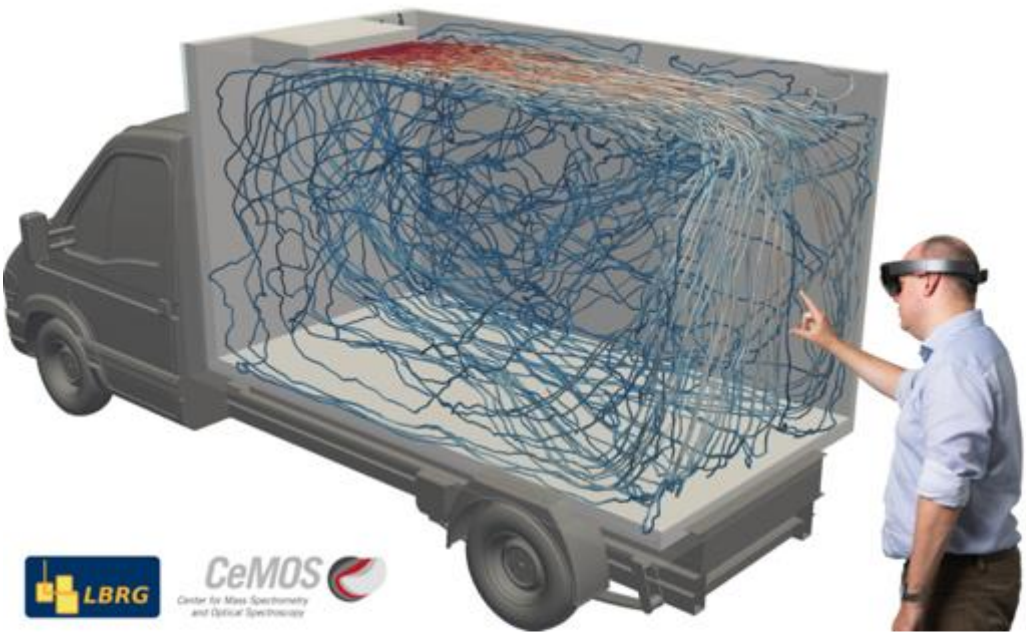



*Figure 20:* Virtual reality visualization of the simulated speed and temperature distribution inside a truck represented by coloured streamlines.

**Wood industry related Innovation - Craftguide with the carpenters' guild Munich** [44]

In the CraftguideVR machine course, students are able to saw a board to a right angle on a sliding table saw and gain valued insight into the machinery of a carpenter.

The start-up from Bavaria made its market entry official at the International Crafts Exhibition. Now the young founders Johannes Nies (industrial designer), Theo Strauß (carpenter) and Maximilian Jakasovic (computer scientist) want to take off.
The craftguide team works closely with the craft organisations. The course for carpenters was didactically structured according to the training requirements of the Munich Carpenters' Guild. The user is guided through the various work steps via flashing interface elements and is also warned of dangers.

The vision of craftguide is an online platform that provides craft expertise for all trades (such as construction, wood, electrical and metal trades) and connects any actors from industry and education [44]. This includes both training providers in craft training and further education as well as machine and plant manufacturers. Craftguide wants to span the arc from the chambers of crafts to the guilds to the training companies to trainers and apprentices. On the other hand, the machine manufacturers are also in demand. Johannes Nies: "Craftguide can only create VR and AR applications with the original 3D data of the machines.

At the heart of the platform are courses in a virtual environment that enable independent learning of manual work techniques and professional handling of the machines.
Since the representation of the machines is based on original CAD data, the appearance and range of functions of the virtual working environment correspond to the respective real machine.
Craftguide does not aim to replace physically real-life training, but to complement the skills in direct handling of the machine. "This builds a bridge between craft theory and practice, making it easier for trainees to understand and correctly apply work techniques." Occupational safety is improved through hazard-free machine and safety instructions.

The first manufacturers have already recognised the potential of craftguide during prototype development and have actively participated. They help to transfer current technologies and processes to the training companies and thus facilitate the craft's step into the digital age [44].

The mentioned methods used and developed for education have different potentials. On the one hand they teach students how to use VR, AR, and MR in general. On the other hand, it teaches them to visualise, create and design their own products within this space but also how to use the machinery to produce it.


*Figure 21:* Craftguide.

The implementation of information makes learning easier and the 3D images are a good way to understand and memorise learned content. There is a huge advantage in including the digital methods into a study environment in the wood and furniture sector. It benefits in terms of safety (trying out new machinery), getting to know elements of Industry 4.0 (using VR and AR for production) and by turning 2D content into a fun and interactive 3D environment.

**WOOD-ED table. Virtual training simulator.**

The carpentry and woodworking profession can be dangerous. This is especially true when trainees have just begun to familiarize themselves with the machines, hand positioning and the precise movements. Instructors aim to create a safe environment for apprentices to acquire the proper gestures for wood cutting.

WOOD-ED TABLE is a solution that allows to train trainees for the carpentry and joinery trades in complete safety. With this training table, it is possible to reproduce the environment of 4 different machines: band saw, circular saw, jointer, and shaper.
The apprentice can therefore experience his/her future work in full immersion, without any risk of injury. He/she will develop self-confidence before using real machines in real conditions.
In addition, with this virtual training, students' skills acquisition can be evaluated thanks to the tracking of movements [45].


*Figure 22: Wood-ED Table. Source: Mimbus.com*

**Mixed Reality with Dynamic 365 Guides**

Dynamic Guides 365 is a software platform designed by Microsoft. Personalised manuals and interactive instructions can be created. Using holograms, videos, photos.

This software can be used to train users in specific machine work, such as step-by-step machine start-up, resolving error messages, changing tools… This can range from a simple machine to a complex computer-controlled machine.

These guides can also be used to provide information on different materials, tools and connections.

The big advantage is that this software is an empty platform and can be built according to the user's wishes, which makes its use in VET training for the furniture sector very beneficial for the large number of applications.


*Figure 23: Mixed Reality with Dynamic 365 Guides. Source: VITW*

In addition to these examples directly related to the educational sector, there are a wide variety of applications of these immersive technologies within the furniture and wood sector. They play an important role in almost all processes, from design, production and logistics to marketing and sales.

Some examples of these applications are as follows:

**Augmented Reality Measurements App**

These types of apps make it easy to take quick measurements of different objects in different situations using a mobile phone and AR.

To measure something, the mobile user simply points their camera at a surface and allows the device to detect its size characteristics, then places pins to measure any distance on that surface. [46]

Augmented reality measurements allow users to quickly capture accurate measurements without the need for reference objects, tape measures or counting steps. This makes it easy to create reference plans for interior design and remodeling work.


*Figure 24:* MyClaim App. Augmented Reality Measurements.

#### Visualisation of furniture in virtual reality in a physical shop

This experience was designed by Microsoft and Hevolus Innovation and the implementation was carried out by Natuzzi. Using photographs, measurements and, optionally, CAD files, the customer's room is recreated using 3D technology. Thanks to virtual reality devices, customers can see the result without having moved any furniture in real size. [47]

*Figure 26: Furniture selling experience wtih VR. Source: Natuzzi.*

*Figure 25: Furniture selling with VR. Source: Natuzzi.*

#### Mixed Reality with Trimble Connect and HoloLens

Trimble Connect for HoloLens uses mixed reality technology to bring 3D content off the screen and into the real world, providing project stakeholders with enhanced 3D design review, coordination, collaboration and project management processes [48].

This platform allows the creation of 3D drawings of kitchens, tables, cabinets and more. It turns any furniture and spaces created into a fully visual object in the room. Using HoloLens, a kitchen can be placed in the planned space to check if it is optimal for the client. Self-designed furniture can be placed life-size with HoloLens in the room for which it is intended. Designers can see their furniture in real size. See if it meets expectations and if it fits the space. It makes everything more visual than a 3D rendering on the screen.

Trimble connect can be used with drawings made in SketchUp and AutoCAD.

*Figure 27: Mixed Reality with Trimble Connect. Source: VITW.*

**Augmented reality integrated into machinery in the wood and furniture sector**

Augmented reality is being applied to the development of intelligent tools that help workers to make their work more comfortable, faster and safer.

One of these tools is Shaper Origin, a practical numerical control machine that, through the recognition of markers, facilitates the work with wood. Shaper origin is a powerful hand tool that ensures that your cuts are exactly where you want them thanks to augmented reality technology.

How Origin Works?

Origin uses a visual marker system to orient himself on the work piece. Simply apply an adhesive tape around the area to be cut, then you have to scan the surface to generate the map and finally you have to locate the design by pressing a button in the working area. Origin knows what you want to cut and watches the workpiece to stay oriented to the plan.

Precision motors continuously fine-tune the spindles position as you follow your design, keeping cuts precise and on track. The tool remembers its position so you can pause and restart your work. If you move too far off course the blade automatically retracts, avoiding mistakes.

This is one of the applications where augmented reality is a key technology for the improvement of tools [49].

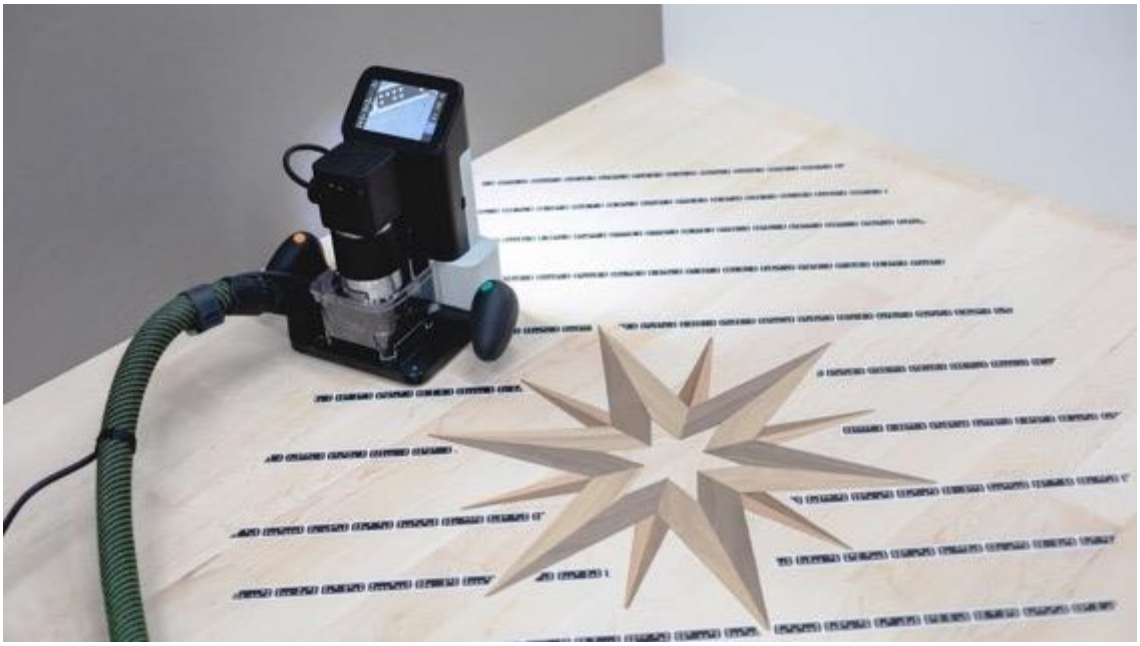


*Figure 28: Medallion Flooring Inlay with Shaper Origin.*

*Figure 29:* Shaper Origin.

## 4.3. The importance of VR, AR, and MR technologies used with people with disabilities

The ALLVIEW project includes the development of content to support companies in the wood sector and related VET providers in the development of socially responsible business in the wood sector. This is addressed in work package 4 "CSR - Corporate Social Responsibility". The idea of CSR is based on 3 main pillars: Sustainability, Inclusiveness and Accessibility, targeting as many people with fewer opportunities as possible: (immigrants, disabled, people with social disadvantages in general). It is for this reason and to improve the synergy between work packages, that it is considered important to mention in this report the positive impact of the use of these technologies as tools for integration and improvement in social groups with disabilities or disorders. Starting from the definition of these disabilities, the advantages of using AR and VR for these social groups are discussed, also including the case study QuotidianaMente.

### 4.3.1. Definition of disabilities and disorders

The term "disability" defines the personal condition of those who, following one or more impairments, have a reduced ability to interact with the surrounding and social environment compared to what is normally considered. In this regard, those who have a disability are those who are less independent in carrying out certain daily routine activities and interacting with social life.
Compared to the notion given by the "International classification of impairments, disabilities and handicaps" - (ICDH), the "International classification of functioning, disability and health" - (IFC), states that "disability" is the consequence or the result of a relationship between the health condition of the person, personal and environmental factors. In this regard, each person, given their health conditions, can find themselves in an environment with characteristics that can limit or restrict their functional capacity and social participation.

There are different types of disabilities and disorders, in this document authors will deal with those that can be matched with the technologies chosen:

- Intellectual disability - it is a neurodevelopmental disorder, and it is characterised by below-average intellectual functioning that is often associated with adaptive functioning, namely: communication, self-control, social skills, personal autonomy, use of available social resources, and recognition of personal safety, along with the demonstrated need for support.

- Physical disability – this term refers to a condition of impairment of the bodily structures and functions that affect the performance of daily activities. Physical or motor disability can result from brain impairment or from trauma to the peripheral nervous system. There is also a congenital physical disability originating from a genetic anomaly.
- Autism spectrum disorder (ASD) – these disorders impair a person's normal social relationships, language, and behaviour. Autism Spectrum Disorders are characterised by a severe and generalised impairment in 2 areas of development: the one of communication and social interaction skills and the one of the area of interests and activities.
- Deafness and hearing impairment – these disorders are various both in type and in intensity. Deafness is defined as the total loss of hearing abilities. Instead, we speak of hearing impairment when the hearing loss is partial.
- Specific Learning Disorders (SpLD) – they are type of Neurodevelopmental Disorder that do not allow the ability to learn or use specific academic skills in one or more areas of reading, writing, math, listening comprehension, and expressive language, which are the bases for other academic learning.

### 4.3.2. Advantages of the use of AR/VR technologies with people with disabilities

To date, the use of technologies is systematically applied to educational environments. For "educational environments" it is not intended only "school environments" but also all those contexts within which a person with disabilities can be stimulated and educated to learn. In this context, it is important to focus on "assistive technologies" for teaching, which are now a fundamental part of the life of every person with disabilities and disorders. In this regard, it is necessary to mention that there are various areas within which there is an increased predisposition to introduce and use technological tools into the lives of people with disabilities and disorders. Their use, indeed, facilitates the work on communication, tolerance, and the increase of attention.

VR/AR/MR can provide great support in this field. There are numerous studies on the use of virtual reality in various educational contexts with different kinds of users for diagnosis and needs: individuals with autism spectrum disorder, with intellectual disabilities, with hearing disorders, with physical disabilities and with neurological disorders.

Furthermore, people with disabilities are an unused target group of highly qualified talents and in this sense, the technologies of AR, VR, and MR make work more accessible to them.

Augmented reality and people with disabilities and/or disorders - AR technology allows people to expand reality as we know it, through the addition of artificial and virtual data and information, conferred by high-tech multimedia devices. It represents an enrichment of the sensory functions. In this regard, thanks to this technology, a person with disabilities or disorders will be able to receive much more information to carry out certain activities in the work routine or even for simple learning. Sensory stimulation will also facilitate the communication and relationship aspect among individuals.


*Figure 30:* Rehabilitation and AR/VR.

Virtual reality and people with disabilities and/or disorders – the use of this technology was based on the application of three different approaches as Muscott, Gifford, 1994[7] explains. These three approaches are passive, exploratory, and interactive approach. In the first approach, the passive one, users listen, see, and feel what happens in the surrounding and virtual environment but they cannot take control of the actions. In the exploratory one, however, users move freely but cannot act on the surrounding virtual environment. In the third approach, the interactive one, users become the actors of the virtual environment.

The innovation of VR lies in the fact that it allows people to create situations that are very similar to the real environment, thus increasing the value of educational intervention in disadvantaged people.

Below, it is listed an analysis of the advantages and benefits that people with different disabilities and disorders can have in using these kinds of technologies.

Intellectual disability - in general, people who have both moderate and profound intellectual disabilities encounter two obstacles in the learning phase, namely both limitations in cognitive processes and the main difficulty in accessing correct learning.

VR, AR, and MR technologies can provide numerous new advantages in this field. Indeed, these technologies allow people with intellectual disabilities to have a better level of involvement and greater self-confidence in carrying out tasks in real life with a lower level of anxiety and greater motivation.

Physical disabilities - people with motor and physical disabilities will be able to improve the spatial ability of orientation and navigation thanks to the 3 technologies selected. These technologies, indeed, will allow the creation of environments within which people with disabilities can try the path to be followed numerous times to then be safe and have more motivation as well as have a better sense of orientation and problem-solving [50].

Autism spectrum disorder (ASD) - in people with ASD, the real world is chaotic and confusing. These are unable to manage their anxieties within the context in which they find themselves, then generating poor performance in the various tasks assigned. Furthermore, some

7 *https://psycnet.apa.org/record/1995-31138-001*

components of communication such as gestures, facial expressions, intonation are often confusing and stressful in people with ASD.

In people with ASD, whose perception is mainly based on the visual channel, the use of the virtual reality application would seem more appropriate and effective and the possibility of manipulating the surrounding environment is also effective.

Thanks to the characteristics of virtual reality, it is possible to individualise, isolate, reduce and in general monitor the number of stimuli so that they are more tolerable for the person. Colours, tactile components, and other parts can be altered to make them less confusing for ASD sufferers.

In this use, however, we must not forget that in people with autism spectrum disorder, since computer-mediated interactions can increase compulsive behaviours, these can create situations that are not advantageous for their social interaction.

Deafness and hearing impairment - in these cases the use of technology is important for 3 fundamental factors: the first is a greater development of cognitive skills, the time component, and narrative skills.

Specific Learning Disorders (SpLD) - these disorders characterise not only children in the learning age but also adults who have never had a specific diagnosis of the disorder. The development of new learning models thanks to the use of new technologies can certainly improve the cognitive abilities of the person with SpLD. Through the creation of specific exercises, it will be possible to improve motor skills, visual, spatial, memory, motivation etc. In this field these technologies are very effective and there are already numerous studies that have brought excellent results.

### 4.3.3. A case study: QuotidianaMente

One of the case studies that the authors of this document want to present in this area, which combines the use of VR technology with disabilities, is the Italian project "QuotidianaMente".

Through this project, thanks to the use of VR, the specialists in the sector have able to examine the daily needs of a person with intellectual disability, facilitating their daily life through immersive exercises, thus ensuring greater independence and greater acquisition. safety and work capacity.

The QuotidianaMente project carried out by the Molise region, a region of central Italy, was financed through the 2017 Plan Objectives of the Ministry of Health. An initiative designed and implemented by the ETT Company, which obtained the 2017 National Innovation Award at SMAU 2017 in Milan - the main Italian fair dedicated to Information and Communication Technologies (ICT), also being considered the most significant in its category (inequalities, equal opportunities, resilience), within the National Sustainable Public Administration Award, 100 projects to achieve the 2030 Agenda Goals.

*Figure 31: People with intellectual disabilities who experiment with the technologies used by the "QuotidianaMente" Project.*

The project consists in the development of special interactive environments created with VR technology in which everyday life scenarios are simulated.

The disabled user, wearing a special viewer, is projected into a virtual space in which he or she can move and be guided in carrying out the actions in the correct way.

The technologies used, specifically are Windows Mixed Reality with the Lenovo Explorer viewer and the related controllers, as these have been considered comfortable, usable, and transportable for users with disabilities. The interaction takes place using devices that allow the user to simulate the use of hands and the execution of actions specifically identified in the main results of the project.

Allview

# 5

## State of the Art of the different technologies in the field of education.

# 5. State of the Art of the different technologies in the field of education

New technologies are increasingly integrated into different teaching methodologies and their use in education has a positive impact on academic learning. On one hand, it increases students' motivation and interactivity. On the other hand, it encourages cooperation between students and promotes initiative and creativity. The inclusion of new technologies in the classroom has meant a paradigm shift in education today, where both, students, and teachers, have had to adapt the way they teach and learn. There are several studies that talk about the inclusion of AR/VR/MR technologies in the field of education and the advantages and benefits they bring to cognitive development.

In the following, the current state of these technologies in the field of education is analysed through a research of different studies available on the internet and listed in table 34 (Annex 1), and the analysis of surveys prepared and conducted by the consortium of Allview with the specific target groups: students, organisations and teachers who have worked or are currently working with these immersive technologies.

For this work, more than 110 surveys were analysed, divided between those addressed to students, in which 85 students were consulted, and those addressed to teachers or organisations, in which 27 responses were obtained. The results are shown in sections 5.1 and 5.2 below.

The surveys were conducted in English and have been translated into German, Spanish and Slovenian in order to reach a larger number of people in the target groups.

## 5.1. Survey for teachers and organisations that have worked or are currently working with these technologies

This section analyses the survey responses of the 27 participants, teachers, and organisations from different European countries, especially from Germany, Slovenia, Spain, and Belgium.

This survey is composed of 17 questions, grouped into 5 parts. What is intended to be extracted and analysed from each of the parts is:

### Part 1

Position and type of organization → Identify the situation and position of teachers and the type of school where they have worked with these technologies.

### Part 2

Technologies used and their application → Analyse the origin of virtual and augmented content used in the classroom, to see how ALLVIEW can support and benefit education with the creation of concrete virtual content. This can help us to determine what kind of exercises to develop, identify the software and hardware tools that are currently being used in education, and reveal the need for teacher training in this area, which can be developed in future actions or collaborations, giving sustainability to ALLVIEW.

### Part 3

Benefits gained from the use of these technologies in the classroom → To highlight the benefits that these technologies bring to the classroom, and to gather information on the different methodologies for integrating them in the classroom as complementary tools for cognitive understanding.

### Part 4

Case Studies → Current examples of integration of these technologies in education.

### Part 5

Added Value → To find out teachers' satisfaction with the use of AR, VR and MR technologies.

### 5.1.1. Graphs and analysis of responses

→ **What is your position in your organisation?**

→ **In what type of organisation do you teach/Work? (VET centre, HE centre/University...)**

The vast majority of the respondents are teachers and work in Higher Education (HE), VET schools and secondary schools. Therefore, the answers to these questions mainly refer to the use and implementation of these technologies in HE and VET schools. The following table shows the answers of the 27 instructors.

| WHAT IS YOUR POSITION IN YOUR ORGANISATION? | IN WHAT TYPE OF ORGANISATION DO YOU TEACH/WORK? (VET CENTRE, UNIVERSITY...) |
|---|---|
| Teacher | Vocational college (EQF 5) |
| Teacher | Vocational college (EQF 5) |
| Teacher of practical lessons | VET (EQF 4) |
| Teacher | Vocational college (EQF 5) |
| Teacher of practical lessons | VET (EQF 4) |
| Teacher of professional-theoretical subjects | VET (EQF 4) |
| PDI | University |
| Head of central research service of a public university | University |
| Professor | University |
| Professor of vocational training | Secondary School |
| Professor of Technology | Secondary School |

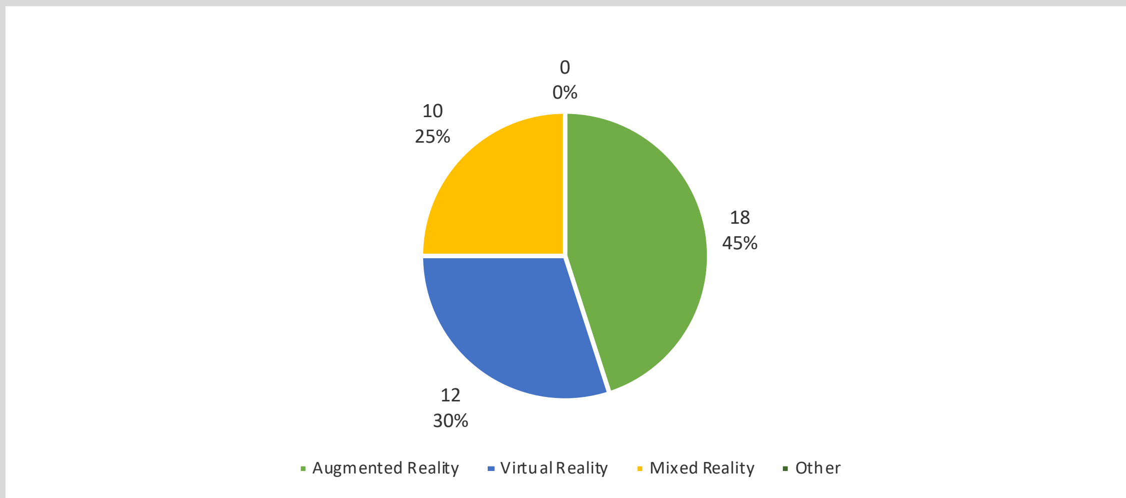
| WHAT IS YOUR POSITION IN YOUR ORGANISATION? | IN WHAT TYPE OF ORGANISATION DO YOU TEACH/WORK? (VET CENTRE, UNIVERSITY…) |
|---|---|
| teacher | university |
| Project manager and expert in STEAM field | No profit organisation - Training centre |
| Teacher | VET Centre |
| HMC | VET |
| Instructor | Vocational college |
| Teacher | VET |
| HMC-Lab instructor | MBO |
| Teacher | VET Centre |
| Teacher | VET Centre |
| Lecturers | University |
| research assistants | university |
| Research assistant | University |
| Head of Department Seminar for Teacher Training and Continuing Education | Vocational seminar |
| Master student, HiWi | University |
| Vocational school teacher | Vocational training centre |
| Teaching | University |

*Table 17: Position and type of organization.*

→ **Which of these technologies (AR, VR & MR) have you worked within your organisation?**

45% of contributors have worked with AR, 30% with VR and 25% with MR. This suggests that AR is more common in the classroom than the other two technologies, but this is not necessarily the case. This may be due to:

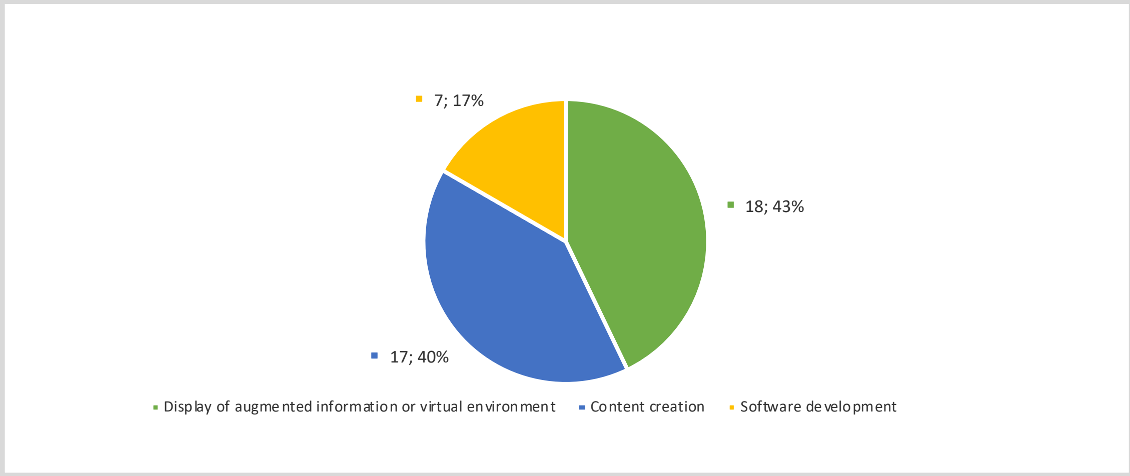
- Specific use being made of the technologies.
- Investment by schools in hardware and software is required for inclusion.
- Level of teacher training and development.




*Graphic 1: Technologies that teachers have worked with.*

→ **What use has been made of these technologies?**

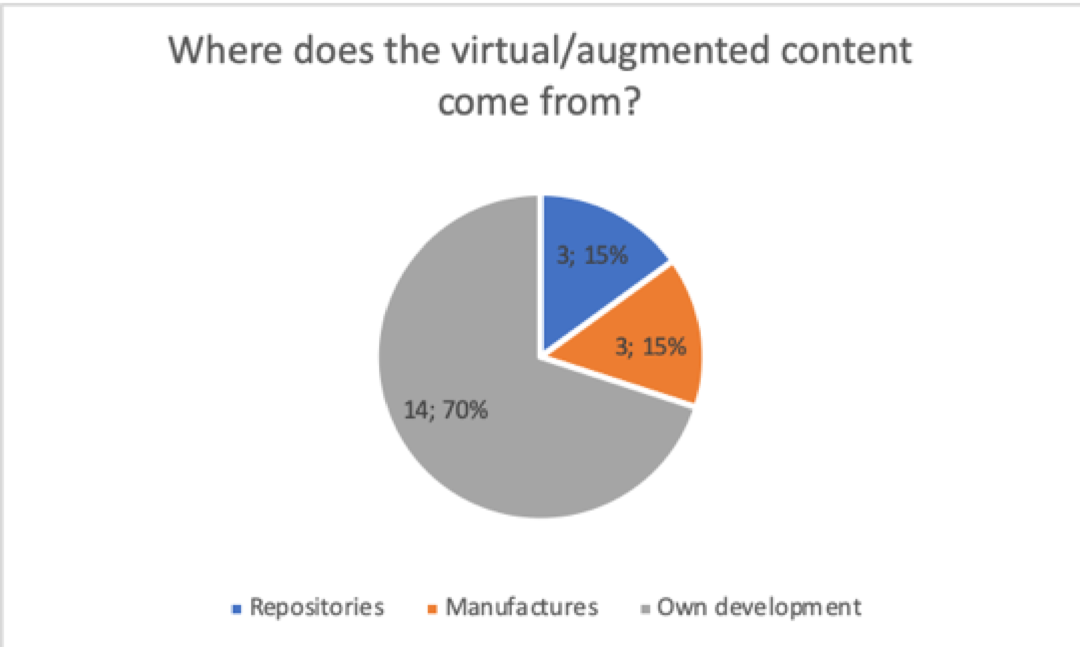
Of the options for using the technologies, 43% of respondents have used them to display augmented information or virtual environments, 40% for content creation and 17% for software development. The following questions discuss the responses to the three options in depth.




*Graphic 2: Use made of the technologies.*

→ **If you have chosen "Display of augmented information or virtual environment" Where has the augmented information or virtual environments used in the classroom been obtained?**

As you can see in the table below, this is a free-response question in text format. The answers have been grouped together to obtain the quantitative data shown in the graph 3. Mainly 15% of the content comes from open access repositories, another 15% from hardware and software manufacturers and 70% is created by both students and teachers, mostly using 3D design software.




*Graphic 3: Origin of augmented or virtual content.*

| ANSWERS: |
|---|
| Open access or self-developed repositories |
| Self-developed or student-developed |
| 3D models previously developed by students have been used. |
| We use 3D designs developed by students in class. |
| We created them from a scratch, form the ideas that teachers and students provided to us. Then we used different app for android and IOS |
| Most of them have been created with CAD design software such as Inventor, but we have also used internet repositories. |
| by work that was created by students, a virtual exposition |
| Microsoft HoloLens2 |
| They have been obtained by downloading from repositories and also students' own designs. |
| They have been developed by the students. |
| Partly self-created Partly the combination provides the platform to be taught and explanatory notes |
| Partly created by the students themselves or loaded into the environment using CAD data |
| Partly from the internet / shop of Oculus; partly created by colleagues themselves |
| Manufacturer CAD data, models from https://grabcad.com/ |
| We developed them in class with design programmes: Inventor, Sketchup... |
| We use 3D models designed by the students. |

*Table 18: Teachers' answers on the origin of augmented or virtual content.*

→ **If you have chosen "Content creation", What kind of information/contents have you created? (3D models for Augmented Reality, texts or videos, virtual environments…)**

With regard to the creation of content created for didactic use, 3D models stand out, followed by content in video and text format, with virtual environments for simulation being less common.

| **ANSWERS:** |
| --- |
| Video content |
| Text and video content |
| Text and video content |
| videos and virtual environments |
| All of the above, + gamification, AR applications, interactive digital twins |
| Virtual environments for simulation |
| 3D models for AR. |
| 3D models for Augmented Reality |
| texts |
| We created 3D models, text, some video, and Audio for developing learning materials |
| Interior designs |
| 3D design of different parts and complete products for AR. |
| 3D models, videos and texts. |
| Presentations, 3d models |
| GameObjects in the form of robots, safety protection fields, texts, display of information (e.g., axis angle of the robot), elements for controlling robots |

| |
|---|
| Robot simulation |
| 3D designed parts and explanatory videos. |

*Table 19: Type of content created.*

→ **What Software and Hardware have been used? (3D modelling software, Unity, A-Frame, Vuforia, HoloLens...)**

**ANSWERS:**

| |
|---|
| Unity |
| None |
| Hardware for 3D |
| Computer, camera, and CAD programs |
| Unity, Vuforia, Blender, cospaces, etc. ... |
| 3D Modelling software (Catia, Solidworks, blender...) Animation and rendering software (3DSMax, Maya...) Unity, Vuforia |
| Software: Unity, Vuforia, AR Foundation<br>Hardware: Oculus Rift, Leap Motion, smartphones. |
| 3D modelling software and AR visualisers. |
| Software de modelado 3D: SolidWorks, AutoCad, Inventor. |
| Rihno and Fusion for the 3D model, for the graphics suite Adobe and for the AR some App as Classroom! |
| Inventor, Author and furniture companies Apps. |
| vectorworks, sketchup |
| Rhino, IronCAD, HoloLens, SimLab soft, keyshot, vectorworks, steam. |

| |
|---|
| Vectorworks |
| Vectorworks and Nomad to see it in a room |
| Inventor, SolidWorks and AUGMENT AR. |
| Software: - Unity - 3D-Software: - PTC Creo - Blender<br>Hardware: - Valve Index |
| 3D-Design programme and Augmented-Reality-Visualisier |

*Table 20: Software and hardware used.*

From this question, we can extract the most used software and hardware currently used in training centres by both teachers and students. According to the answers in table 4, we can see that the software used can be organised into:

- 3D modelling software: Blender, SolidWorks, Catia, Cospaces, AutoCad, Inventor, Rhino, Fusion, Sketchup, Vectorworks, IronCAD
- Rendering software: keyshot, 3DSMax, Maya…
- AR y VR viewers: SimLab soft, Author, Augment AR, Nomad
- Software Development Kit and engines: Vuforia, Unity
- Hardware: Valve Index, Oculus Rift, Leap Motion, Smartphones, Computer, Camera

→ **Has teacher training been necessary to reach this point? If so, where did you look for the training? (Training provider website, in your organization, self-taught, etc.)**

Most of the teachers surveyed have trained themselves in the use of these technologies. Comparing this answer with the previous ones, we can understand that most of the contents created are 3D models, probably to be shown through AR applications, since, although they have developed contents for virtual reality, these are more complex, and the necessary training is more specific.

**ANSWERS:**

| |
|---|
| No |
| I learned myself |
| I don´t know |
| No |
| I had prior knowledge |
| self-taught |
| Self-taught |
| Yes, training was necessary. The training was self-taught. |
| No |
| No, as we worked with simple practices. |
| self-taught |
| We get knowledge thanks to EU project and then we train the teachers |
| Self-taught. |
| self-taught |
| autodidact |
| Self-taught |
| I haven't had the necessary training, just playing with the technology. I wish I had more time for it cause in notice it's a lot... We are looking for an external partner now who can develop an assignment/instruction with/for us. |
| Self-taught training. |

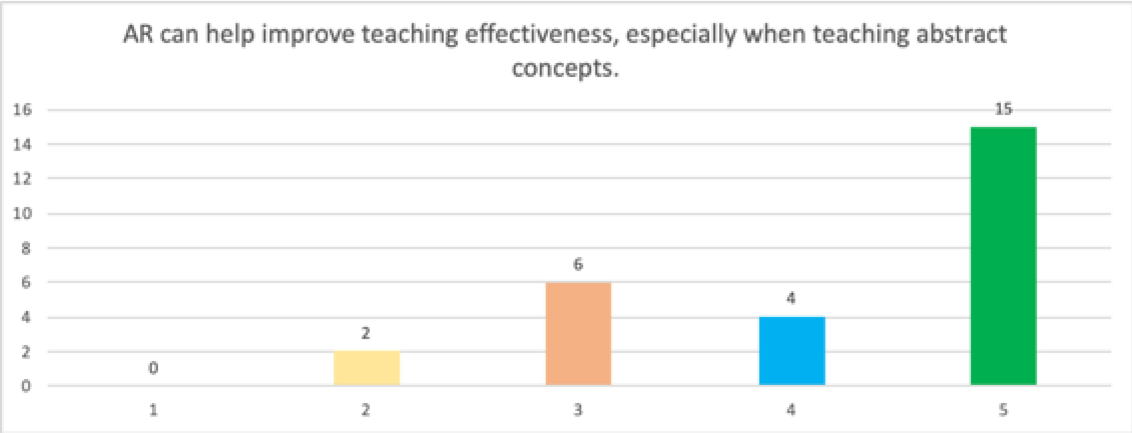
| |
|---|
| Self-taught, but I would like to do a course. |
| Self-taught |
| yes, websites |
| Self-taught and via YouTube tutorials |
| No, so far there is also little |
| YouTube tutorials and Udemy course for the basics |
| In my case, I am self-taught, but we hunt for simple things. |
| Self-taught |

*Table 21: Need for specific training.*

→ **Benefits obtained for the teacher and the organization. (Evaluate from 1 to 5, with 1 being the lowest and 5 the highest value.)**

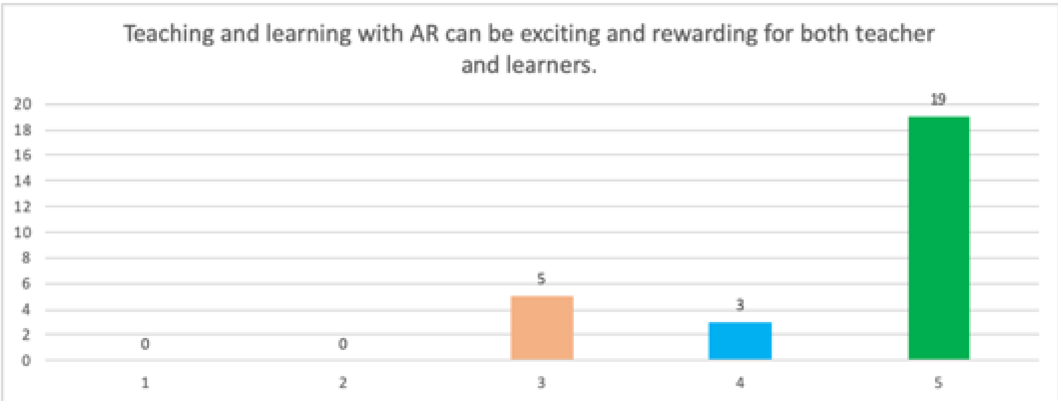
In the nine statements referring to the benefits obtained by the teachers with the use of these technologies, more than 92% of the evaluations are between 3 and 5 in all of them, which indicates that the level of satisfaction with both the implementation and the results obtained is very satisfactory.

On the statement " AR can help to improve teaching effectiveness, especially when teaching abstract concepts.", more than 55% of respondents set the highest score (5 points), 14.8% set 4 points and 22.22% set 3 points. Only two respondents set a low score of two points. As conclusion 92.6% of the teachers surveyed consider that Augmented Reality improves teaching effectiveness.



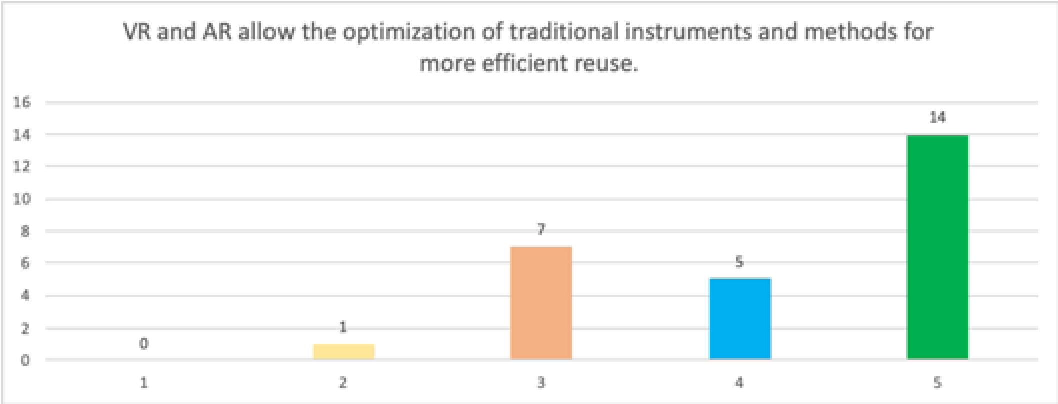

*Graphic 4: Improving teaching effectiveness with augmented reality.*

100% of respondents rated the statement in Graphic 5 "Teaching and learning with AR can be exciting and rewarding for both teacher and learners" with a score between 3 and 5, and more than 70% gave it a score of 5 points. We can affirm that they consider that teaching and learning with AR can be exciting and rewarding for both students and teachers.



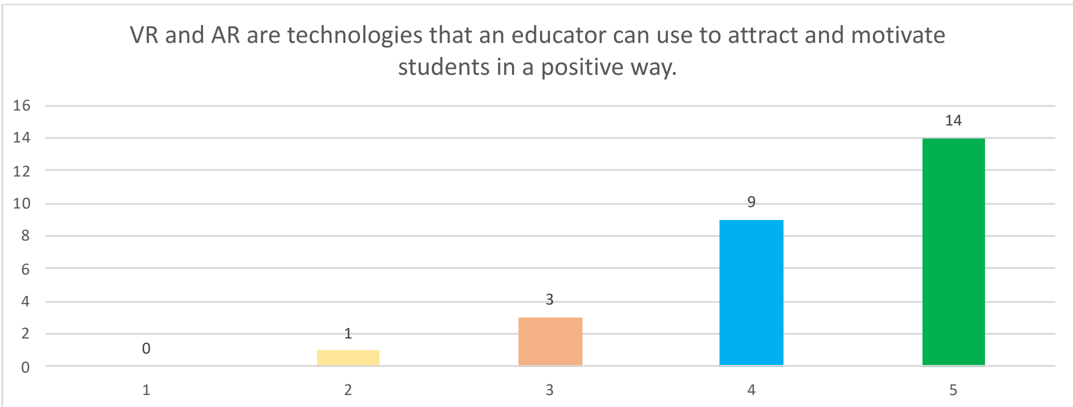

*Graphic 5: Learning with AR can be exciting and rewarding.*

26 out of 27 respondents (96.3%) rated the statement "VR and AR allow the optimization of traditional instruments and methods for more efficient reuse." (graphic 6) between 3 and 5. Only one of the teachers rated it with a low score of 2.



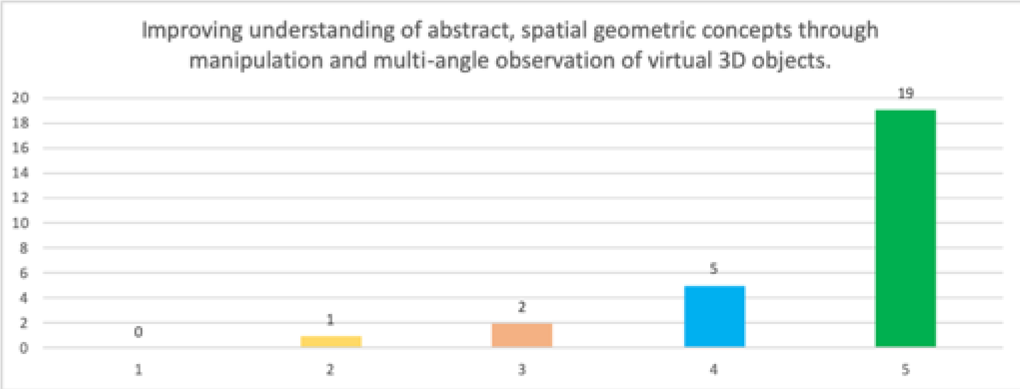

*Graphic 6: VR and AR are tools that help the improvement of traditional methods.*

More than 96% of respondents rated the statement of graphic 7 positively. 23 out of 27 teachers (85.2%) gave a score of 4 and 5, stating that these technologies are good tools to engage and motivate students.



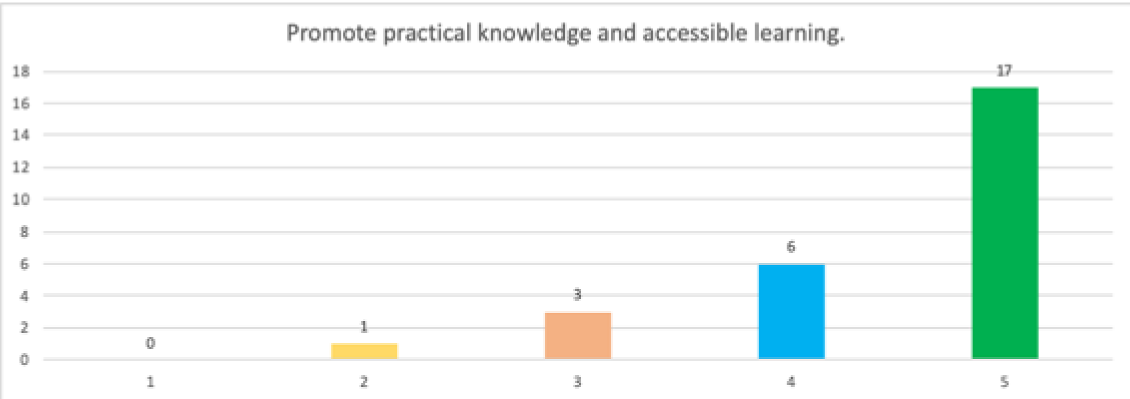

*Graphic 7: AR and VR as tools for teachers to improve student motivation.*

As we can see in graphic 8, 85.2% of the teachers consider with a high score, between 4 and 5, that with the use of these technologies the teacher is better able to explain complex and abstract concepts.



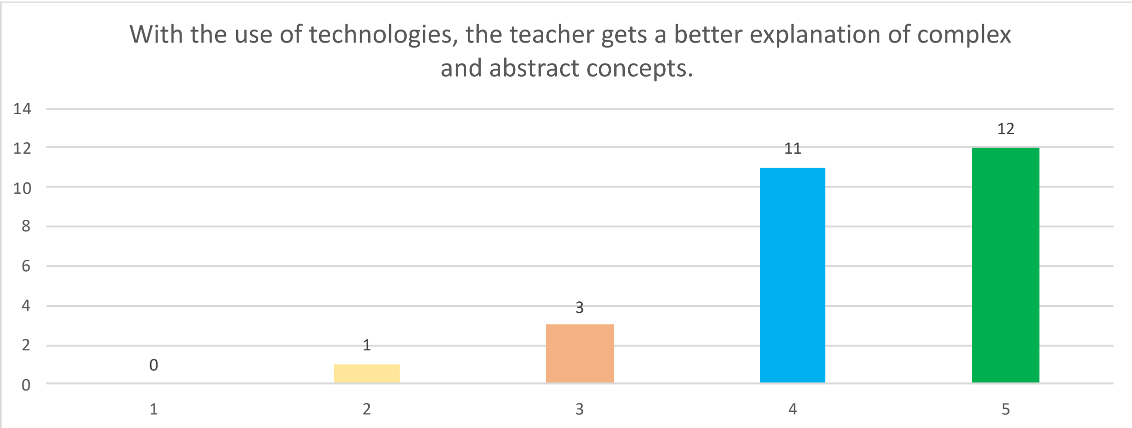

*Graphic 8: Improving the explanation of complex and abstract concepts with the use of VR, AR, and MR technologies.*

85.2% of the teachers consider with a high score between 4 and 5 that the use of these technologies promotes practical knowledge and accessible learning, as the graphic 9 shows.




*Graphic 9: AR, VR and MR promote practical knowledge and accessible learning.*

Almost 90% of the teachers surveyed rated the statement in graph 10 between 4 and 5, stating that the use and integration of technologies in the classroom improves the understanding of abstract geometric and spatial concepts.

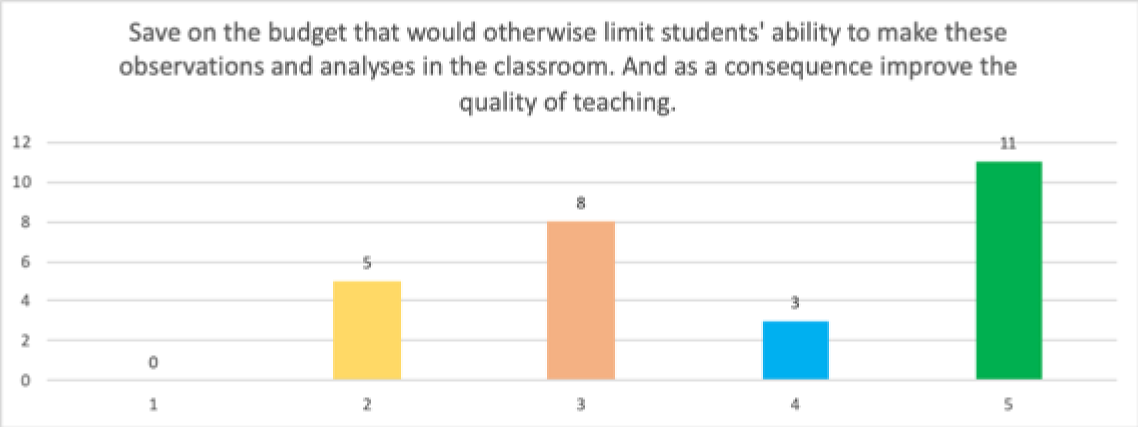



*Graphic 10: Improved understanding through three-dimensional visualisation of concepts*.

Regarding the statement "Allow students to experiment and practice in a safer environment before being exposed to certain work practices", 25 out of 27 teachers rated it between 3 and 5, and 77.8% between 4 and 5. Only two teachers gave a low score of two points, so these technologies are considered to be good tools that help to improve quality, safety and learning during the performance of certain practices, such as those that require the use of dangerous machinery.


*Graphic 11: AR, VR and MR are tools that help to improve quality, safety and learning during training.*

The statement in graphic 12, which deals with the budget savings involved in working with these technologies, taking into account the improvement in teaching with their application, is the question that received the lowest rating from teachers, with 52% of positive responses rated between 4 and 5, and 48% rated between 2 and 3. Even so, the balance indicates that a greater number of teachers who are working or have worked with these technologies in the classroom consider that there is a possible saving and improvement in the quality of teaching, since 81.5% (22) of the respondents rated this question between 3 and 5.




*Graphic 12: Improved quality of education and budget savings.*

→ **What teaching methodology have you used for the inclusion of these technologies in the classroom?**

| ANSWERS: |
| --- |
| For group work |
| Explanation, independent work |
| Did not use |
| 3D Environment |
| Demonstration, explanation and supervision of students work |
| Active, collaborative and project-based methodologies. Reverse class. |
| "AR for improving spatial vision in representation systems. Inverted classroom. Recreation of immersive virtual experiences for training. Gamification". |

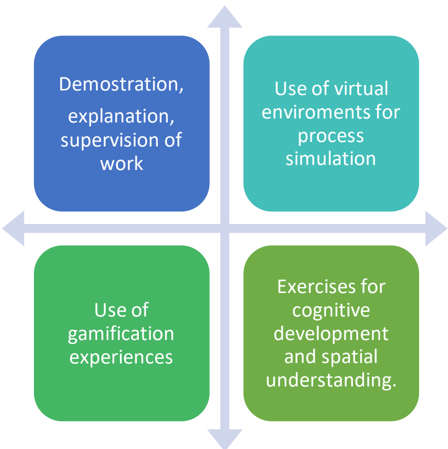
| |
|---|
| "Depending on the subject, I have used the following:<br>- Use of virtual environments for process simulation.<br>- Use of gamification experiences in learner recruitment tasks.<br>- For the augmented reality teaching itself, the students themselves have developed their own applications". |
| Methodology for cognitive enhancement of learning |
| Intrusive methodology for the improvement of transversal competences. |
| We at first made a brief overview about the technology, its use the benefits that it has in the different learning environment then we realise an exercise with it and test the others already realised. |
| I have included activities in the practical sessions, where students developed simple 3D models, exported them in Obj or STL format, uploaded them to the AUGMENT website and then displayed them through the viewer on their smartphones. |
| we created a virtual exposition of the work normally was showed in a real-life expo. now because of covid the expo was with VR |
| Students makes a design of interior and visualises it in renders and AR |
| I haven't yet. |
| In the practical part of the design subject, with the intention of preparing students to work with and take advantage of AR. From prototyping to the marketing phase. |
| The students have presented their design work through the AR by means of an explanatory video, as it was not possible to do it in person due to the covid. |
| First consider what content needs to be taught and in what order. A kind of script is created and the examples used to explain the content are considered, and then it is decided whether the examples are meaningful enough or whether they need to be supplemented. |
| Theses in the field of robotics. VR / AR is ideal here because the student can familiarise himself with robotics without being exposed to any danger. |

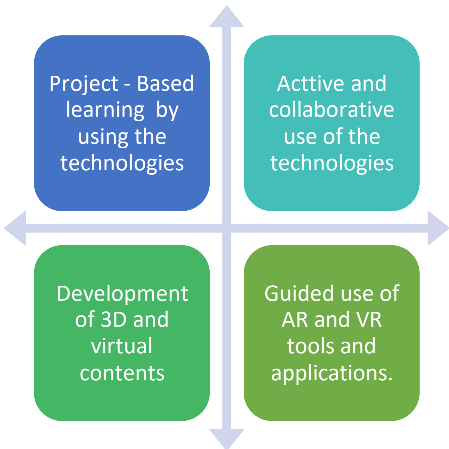
| |
|---|
| I used an integrative methodology where at the same time I explained the theory, I showed the examples through augmented reality. |
| I introduced the use of AR in the practical part of the course and the result was beneficial especially in distance learning. (Covid). |

*Table 22: Integration methodologies.*

After analysing the questions from teachers who have already worked with these technologies in education (table 6), two general types of methodology can be distinguished.
Methodologies for the inclusion of these technologies in the classroom:

- **Those in which technologies are used for explanation, demonstration and supervision of students' work, including gamification.**
- **Those in which content has been created. Project-based and collaborative classes.**




The application of the different methodologies for implementing and including these technologies in teaching will depend on their intended use, the subject to be taught, the knowledge of the teaching staff and the existing resources in the training centre.

→ **Do you think that the use of these technologies is an enabling tool for education?**

On the question of whether teachers consider these technologies to be used as driver tools that favour education, 100% of the respondents think that they are.

There are some comments indicating that there are not enough resources (software and hardware) to be used in the classroom. In addition, they indicate that there is a need to invest more in both material and teacher training.

| ANSWERS: |
|---|
| Yes, but not yet |
| Yes, as stated in question 10 |
| Yes and no |
| For theoretical courses yes, but not for practical courses |
| yes |
| It can be if optimised content is created and used judiciously. |
| Yes |
| Yes, its integration in the classroom has many benefits. |
| Yes |
| Of course, yes. |
| Yep, it is the new future for the education. |
| Yes, definitely. Not only do students show interest, but their productivity and creativity increase. |
| yes, I see a lot of possibilities |
| Yes, very much. |
| Yes |
| yes, I really do, but the time you have to invest is quite much and the knowledge of making an actual/ useable instruction its quite a big step for a beginner in particularly. |
| Yes, absolutely |

| |
|---|
| Yes |
| Yes |
| Yes |
| Yes, for example in the field of robotics. |
| It goes like this. So far, there is hardly any useful software that could be used in the classroom. |
| In any case, XR has wide applications. |
| Yes, they are very useful, both to strengthen cognitive learning and to attract students' attention. They learn faster. |
| Yes |

*Table 23: Technologies as tools to support education.*

→ **Could you provide the informative link of a case study or your own experience on the use of this technology?**

**ANSWERS:**

| |
|---|
| Positive experiences |
| No |
| No, because I don't have them online |
| Development of a PC Assembly Simulator (not yet published, preliminary version on p. 63 of https://repositorio.upct.es/bitstream/handle/10317/7558/isbn9788416325832.pdf)<br>Development in a TFG of a game with AR for student recruitment:<br>https://repositorio.upct.es/handle/10317/7236 |
| it is still developing, and I only see a lot of good new things in the future. |
| Videos are on Allview teams |
| importing a space or interior in a classroom. |

| |
|---|
| https://www.linkedin.com/posts/prof-dr-ing-fahmi-bellalouna-73519461_interesting-use-case-how-to-apply-ar-technology-activity-6771050969623994369-S_YI |
| https://www.youtube.com/watch?v=xW1EMBVmAW4 |

*Table 24: Case Studies.*

From the four links provided by the teachers, we highlight the following case studies:

**Development of a PC Assembly Simulator** [8]

Under this teaching innovation project, a VR experience has been developed for the assembly of computers. This experience will be used in laboratory practices, allowing a laborious task to be carried out in a short space of time and with high motivation. In addition, another version of the software has been developed that will be run on a conventional PC, without VR. Preliminary tests have been carried out with both versions of the software, which indicate that the VR version offers a more satisfactory experience.

Two prototypes have been developed for use with students, a VR prototype, and a PC prototype. The VR prototype is based on the use of an Oculus Rift HMD (Head-Mounted Display) to which a Leap Motion sensor for hand tracking has been attached. To use this prototype also requires a PC that meets the minimum specifications for VR given by the manufacturer ("Oculus Rift Minimum Requirements", 2018).

Figure 18 shows two screenshots of the VR prototype. In them, virtual hands that reproduce the movements of the user's hands, move devices towards their insertion place (previously users have had to open the slots where the devices are to be inserted).

From the results of the tests, it could be concluded:

- The use of VR is more motivating for the participants compared to a mouse-driven desktop application. The level of satisfaction with the experience is also higher.
- Both applications can facilitate autonomous learning. This point needs to be studied in more detail.

*8 Universidad Politécnica de Cartagena. Proyectos de Innovación Docente. Coordinadora: M. Eugenia Sánchez Vidal.*

- The time for performing assembly tasks is considerably reduced. There are no time-consuming tasks such as fitting components perfectly or screwing them together. A significant improvement in the time taken to complete tasks was seen once participants became familiar with the mechanisms for handling the parts.

In addition, there were other advantages to running a simulator:

- It is possible to automatically validate that the participants have performed a task correctly without the need for intervention by the teacher or monitor.
- Testing is safer as there is no need to connect components to a PC connected to the mains. However, for VR, a certain amount of space is needed for testing and to avoid collisions with physical objects.
- As it is not necessary to purchase the physical components of a PC, it is possible to reduce costs if VR equipment is already available.

It should also be borne in mind that space should be left free around the user to avoid collisions with furniture and other objects in the vicinity.

Conclusions:

In the teaching innovation project described above, VR has been applied to the assembly of personal computers. In addition, another desktop version of the software has been developed, which will allow all students in a laboratory group to carry out practical exercises simultaneously. The use of VR has been shown to increase motivation and satisfaction with the experience, while both versions reduce run times (compared to the use of physical devices). Limitations of VR include the equipment required, the additional space needed, and the time spent on developing the software if it is not available [51].

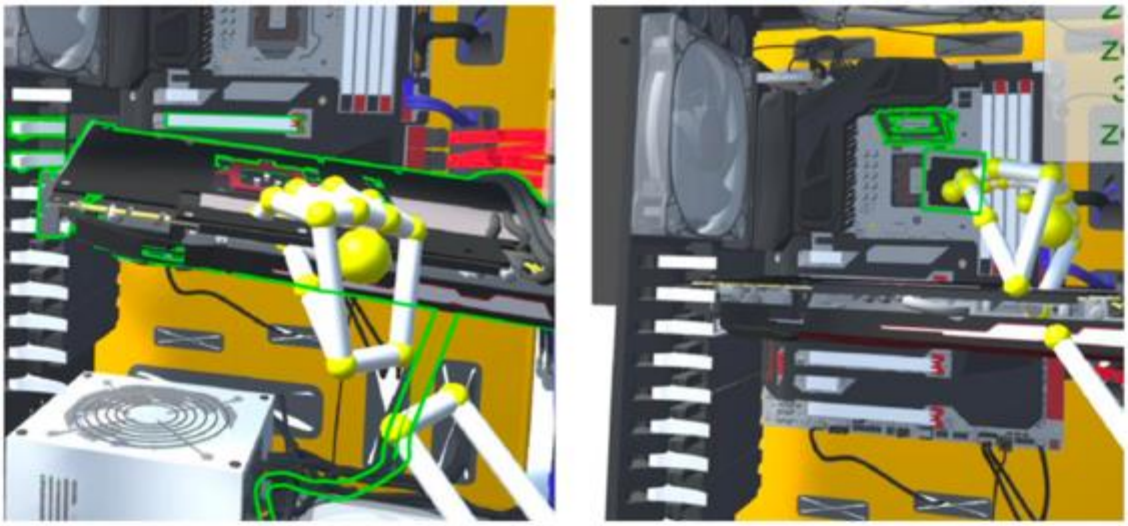


*Figure 32: PC Assembly Simulator*

**The HoloSupport project**[9]

The HoloSupport project at St Paulus School aims to support students in the use of CNC machines. A CNC machine refers to the computer control of the machining functions of machine tools. To learn to work with the different CNC machines, students rotate from machine to machine, and usually cannot remember all the basic actions. When the students rotate, the teacher cannot explain to each student at the same time, so unfortunately the students have to wait very often. With this project, the aim is to solve this problem with MR, specifically with Microsoft Hololens. The student will be accompanied by the Hololens during the basic operations of the machine in order to learn how to work with them. In addition, PowerApps will be used to evaluate the student and verify that everything has been well understood. Furthermore, the learner will always have to follow the safety guidelines of the specific machine before starting another procedure. This project will support the teacher to reach more students at the same time, reducing waiting times for the students. The student will learn new technologies and become more prepared for the future. Getting in touch with this technology can be a good preparation for the students and even a good start with training for a later career. This system can be used in all parts of technical education, whether for large CNC machines or a simple drill press.

*9 The HoloSuppot project. St Paulus School. Coordinators: Bram Van and Sacha Thermote.*

**Creation of an augmented reality application.**[10]

Creation of an augmented reality application with which 3D designs are positioned in a real physical environment. In this case it is about buildings, and its interior can be explored by controlling certain commands through the application.

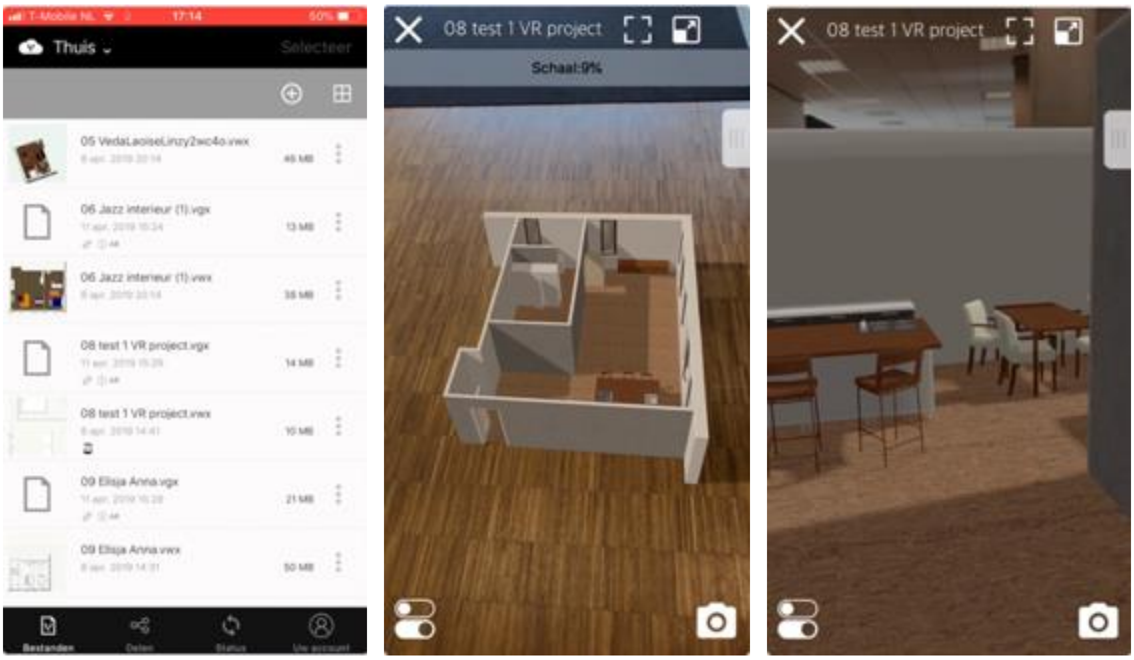
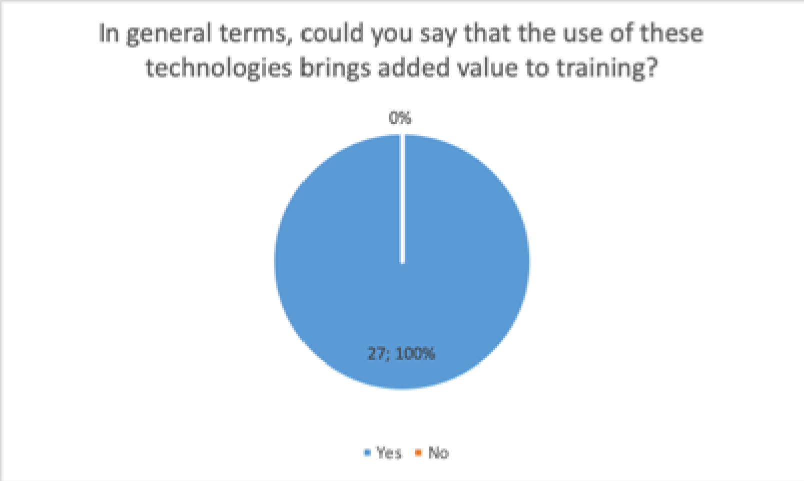



*Figure 33: Example of the positioning of a house floor with an AR application.*

→ **In general terms, could you say that the use of these technologies brings added value to training?**

100% of the teachers surveyed answered Yes to this question, stating that the use of these technologies brings added value to training.

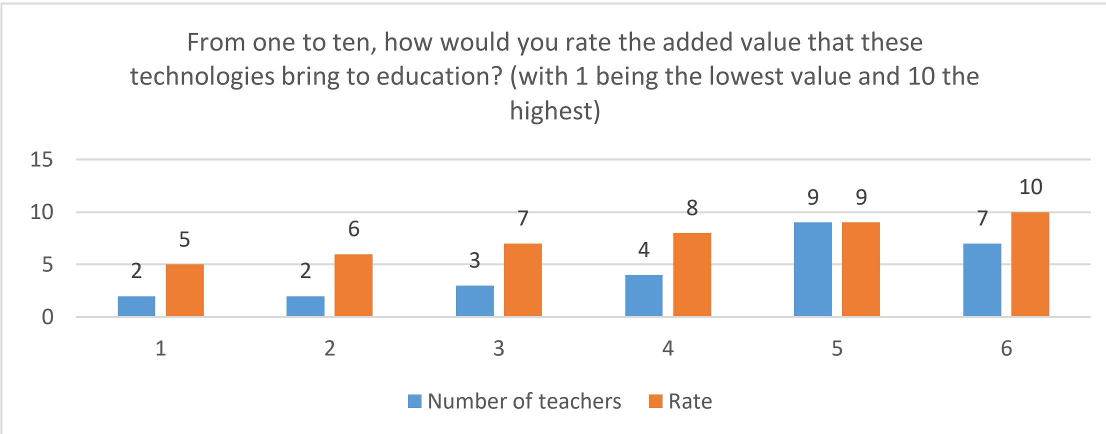
*10 Creation of an augmented reality application for educational purposes. HMC mbo vakschool – The Netherlands.*




*Graphic 13: Increasing the added value of leaning with the use of AR, VR and MR technologies.*

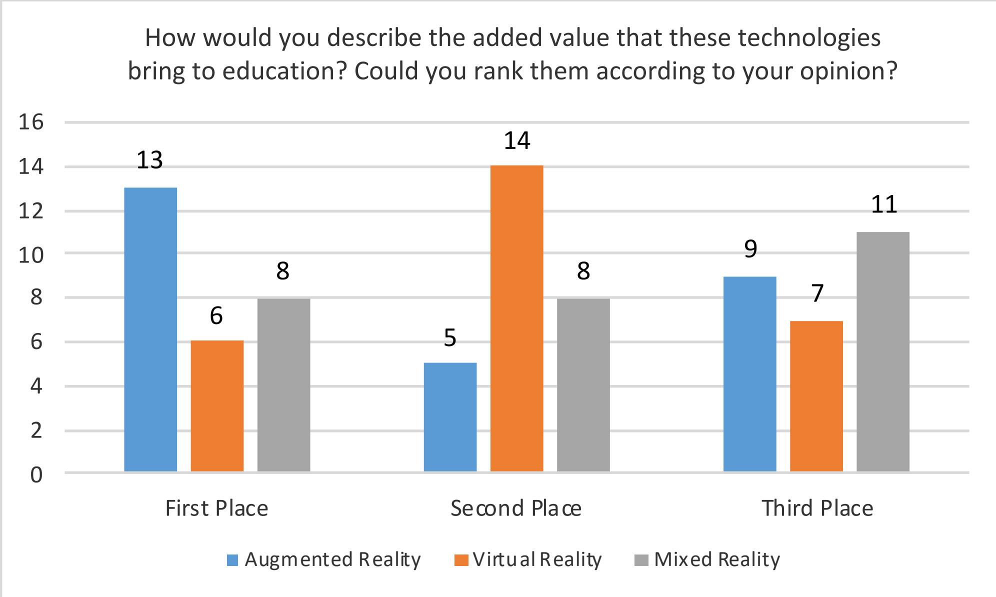
→ **From one to ten, how would you rate the added value that these technologies bring to education? (With 1 being the lowest value and 10 the highest)**

Teachers were asked to rate on a scale of one to ten the added value that these technologies bring to education. 100% of the respondents rated it above five, where more than 85% rated it between 7 and 10 and 60% between 9 and 10. Therefore, most of the teachers who have worked with these technologies consider that their use brings quality added value to education.




*Graphic 14: Rating between 1 and 10 of the added value that these technologies bring to education.*

→ **How would you describe the added value that these technologies bring to education? Could you rank them according to your opinion?**




*Graphic 15: Ranking of technologies according to the added value considered by the teaching staff.*

If we analyse the data in the first column, where teachers have positioned the technology that they believe brings most added value to education, we see that Augmented Reality predominates over Virtual and Mixed Reality, with percentages of 48.15% for AR, 22.22% for VR and 29.63% for MR. Virtual Reality predominates in second position and Mixed Reality in third.

This question goes hand in hand with the next one, answers in table 10, where respondents comment on their choice. From these answers, based on teachers' experiences, we highlight the following according to technology:

**Augmented Reality:**

Good results with low cost of implementation in the classroom. Both because of the ease of use and the possibility of creating and obtaining resources in a simple way, and the availability of hardware to display augmented information. Good results in its implementation with minimal effort on the part of teachers and students.

**Virtual Reality:**

Virtual Reality allows the teachers to simulate any experience, without limitations. Both Augmented Reality and Mixed Reality complement the real world, but they are limited to what is in the real world.

VR is the cheapest at the moment. Otherwise, it depends on the use case which technology is best suited.

**Mixed Reality:**

The use of mixed reality can bring more solutions and can also give a great insight into the technologies used. For the wood and furniture sector, there is a lot to develop in the future, and there are many benefits in implementing Mixed Reality in the classroom. AR and VR technologies need less effort for implementation.

| REGARDING THE PREVIOUS QUESTION, COULD YOU COMMENT ON YOUR CHOICE? |
|---|
| Actually no. |
| I don't have enough experience to explain. |
| I don't know because no one has shown me this in practice yet. |
| Mixed really is best suited for my students |
| Based on my own teaching experience |
| The best thing is somewhere in between |
| "Virtual Reality allows us to simulate any experience, without limitations. Both Augmented Reality and Mixed Reality allow us to complement the real world, but we are limited to what is in the real world". |
| AR supports added value for both teachers and students, enhancing the teaching-learning experience at a low cost. |
| Augmented reality is a tool accessible to all schools and students. There is no need to invest financial resources. |

| |
|---|
| The use of the mixed reality can provide more solutions and also can give a great overview about the technologies used. |
| I choose AR, as it is the one I have worked with. And I have had good results. |
| For the wood and furniture sector, I think there is a lot to be developed in the future, and I see a lot of benefits in MR |
| AR is the most realistic option of the three |
| mixed and AR are the same for me if we talk about high value. Virtual reality is too much cost of your environment. |
| Because of its ease of use and low cost for integration in the classroom, we have only worked with Augmented Reality. |
| I believe that AR brings many benefits to education, as the educational scenario is enriched. |
| Especially in my subject I don't see VR as important, because we create 3D and deal with VR of our own projects all the time... I don't need VR as a working environment. |
| AR and VR: less implementation effort |
| I only have experience with Virtual Reality, but VR is the cheapest at the moment. Otherwise I think it depends on the use case which technology is best suited. |
| I think augmented reality can be integrated into teaching without having to buy equipment or hardware, and it is easier to develop "augmented" information, such as 3D models. |
| I only have experience with augmented reality and I think it is a very useful tool in teaching. |

*Table 25: Comments on the choice of ranking.*

### 5.1.2. General Conclusions

All three technologies (AR, VR and MR) have been used by teachers, with augmented reality being predominant. And the most common uses are displaying augmented or virtual information and content creation, with a smaller percentage working on software development. Regarding the origin of the contents, most of them are developed by both students and teachers, or are obtained from open access repositories or directly from the manufacturers.

The most commonly used software among teachers is mainly 3D design software and visualisers for both AR and VR, with development software and platforms and engines being less common. In terms of hardware, smartphones and virtual reality goggles predominate.

It would be useful for teachers to provide them with specific exercises to serve as an example for the development of their own, as well as providing a tool or platform with which to use these technologies in the classroom with the resources available to them.

The training they have obtained has been mostly self-taught. For the correct implementation of these technologies in the educational sphere, specific training for teachers should be considered, together with greater investment in hardware and software.

In the nine statements referring to the benefits obtained by teachers with the use of these technologies, the assessment was very positive, which indicates that the level of satisfaction with both the implementation and the results obtained is very satisfactory. The implementation methodology has been based on the use of these technologies to improve explanations, demonstrations and to encourage collaborative and project-based classes.
100% of the participants affirmed that these technologies are tools that help and facilitate both learning and teaching and that bring added value to training. However, they stressed that more needs to be invested in the resources necessary for their integration.

When it comes to evaluating the three technologies under study, they rank augmented reality in first place, virtual reality in second place and mixed reality in third place. But they highlight the benefits and classroom applications of all of them.

## 5.2. Survey for students that have worked or are currently working with these technologies

This section analyses the survey responses of the 85 participants, students from different European countries, especially from Germany, Slovenia, Spain, and Belgium.

This survey is composed of 11 questions that can be grouped into 4 parts, and what is intended to be extracted and analysed from each of the parts is:

**Part 1**

Level and topic of the student training → Identify the level of training of the students and the speciality where the study technologies have been applied.

**Part 2**

Technologies used → Identify the technologies most used by students in the classroom.

**Part 3**

Benefits gained from the use of these technologies in the classroom → To highlight the benefits that these technologies bring to the classroom, and collect information on how easy or difficult it can be for students to work with them in an educational context.

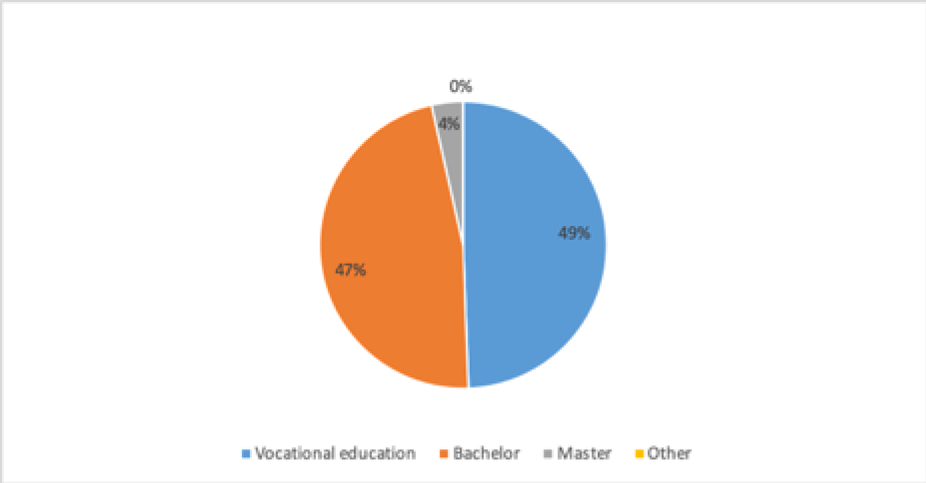
**Part 4**

Added Value → To find out students' satisfaction with the use of AR, VR and MR technologies.

### 5.2.1. Graphs and analysis of responses

→ **What is the level of your training?**

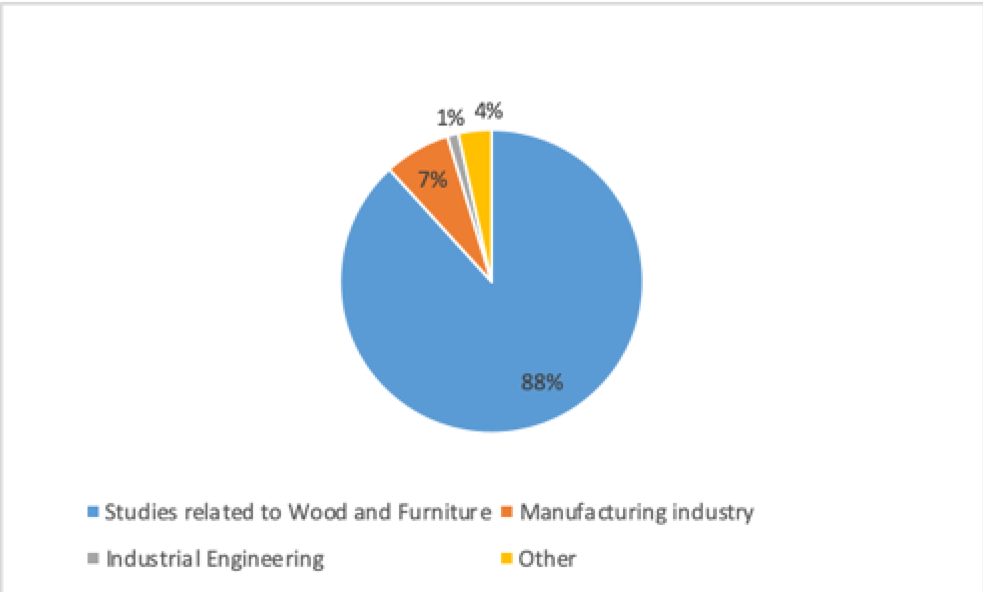
Of the 85 students interviewed, 49% are studying or have studied a vocational training course, 47% a Bachelor's degree and 4% a Master's degree.




*Graphic 16: Training level.*

→ **What is the topic of your training?**

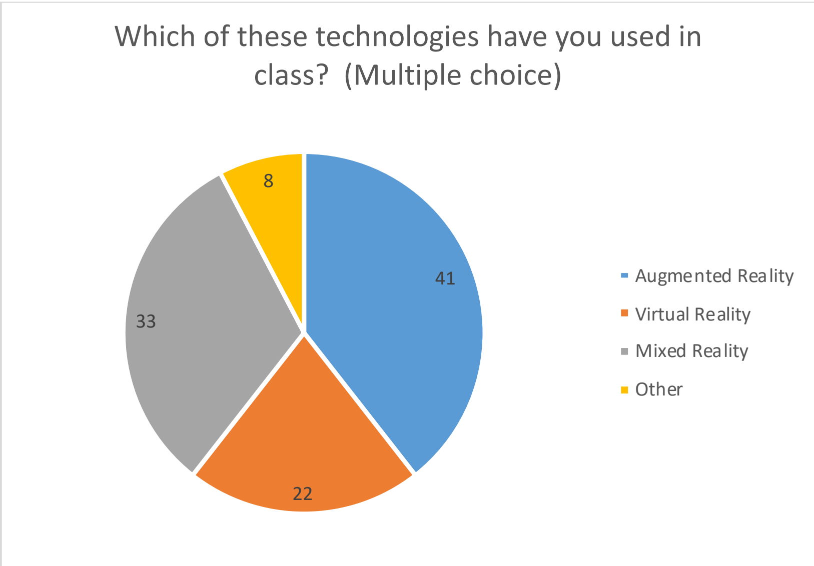
88% of the respondents are pursuing studies related to the main topic of the project "Wood and Furniture", 7% in industrial manufacturing, 1% in industrial engineering and 4% in other sectors such as Forestry and Telecommunications.




*Graphic 17: Training topic.*

→ **Which of these technologies have you used in class?**

This is a multiple-choice question, as students may have worked with one or more subjects. As can be seen in the graph, 41 of the 85 students have used Augmented Reality in their training, 33 have used Mixed Reality, 22 have used Virtual Reality. The use of AR and MR predominates, although the percentage of students who have used VR cannot be ignored.

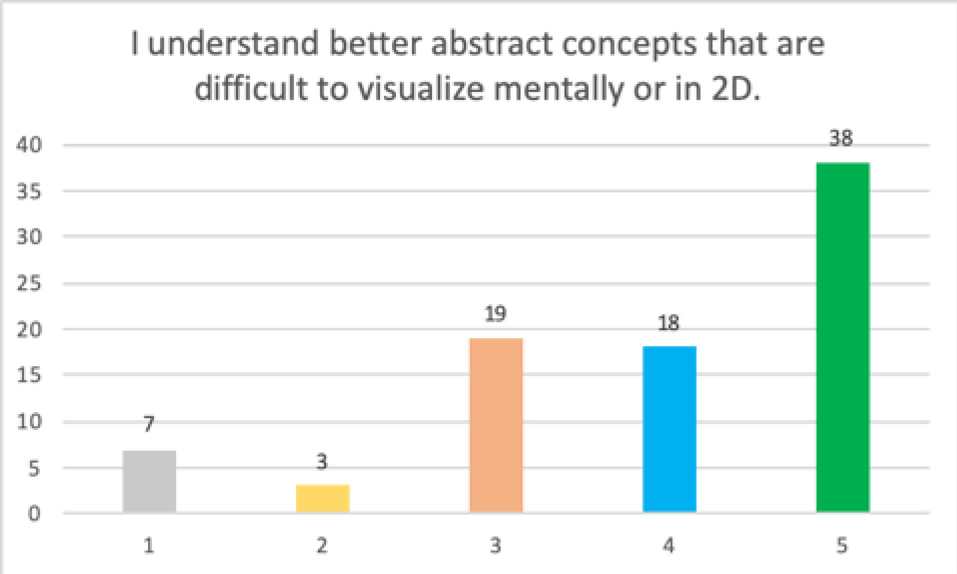



*Graphic 18: Technologies used in class.*

→ **Please, rate the benefits of working with those technologies. (Evaluate from 1 to 5, with 1 being the lowest and 5 the highest value.)**

In the eight statements referring to the benefits obtained by students with the use of these technologies in the classroom, between 85% and 92% of the respondents have given a score between 3 and 5 for all of them, and between 53% and 76.5% have rated them with 4 and 5 points, which indicates that the level of satisfaction with both the implementation and the results obtained is quite high for the students.
In the following, we see the results for each of the statements.

In the statement "I understand better abstract concepts that are difficult to visualise mentally or in 2D", 66% of the students gave a high score of 4 and 5, and 22% gave a score of 3, so we can say that 88% of the respondents understand abstract concepts better with the use of AR, VR and MR technologies. Only 12% of the students gave a low score of 1 and 2, of these 12% (10 students) half of them had difficulties when working with these technologies and 8 of them recommend teaching with traditional techniques. This level of dissatisfaction on the part of these students may indicate a lack of understanding of the technologies and difficulty in working with them, which can be solved with a more practical introduction to them. The fact that part of the training during the last academic year was online may also have influenced the lack of understanding on the part of a few students.

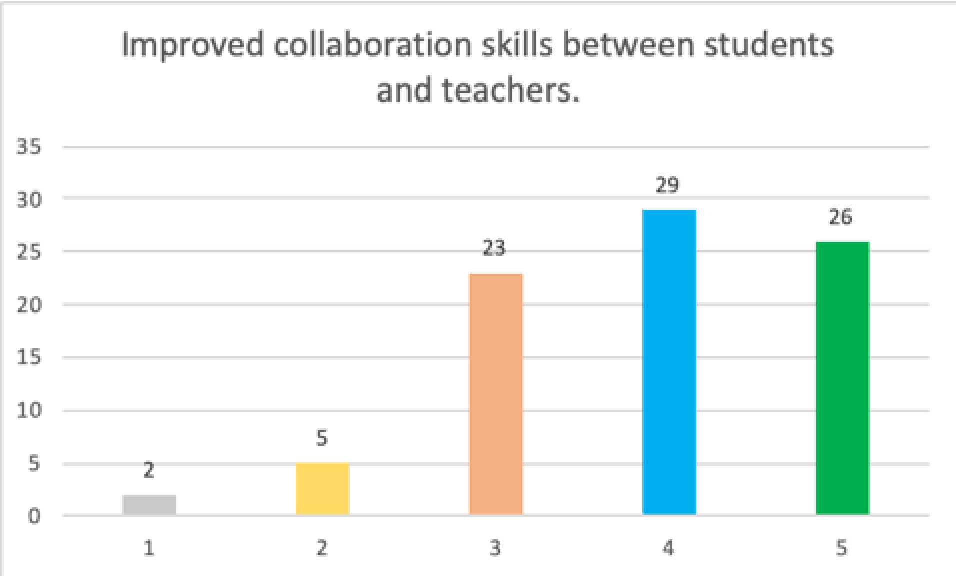



*Graphic 19: Better understanding of abstract concepts.*

As in the previous graphic, graphic 20 shows that 88% of the students rated this statement between 3 and 5 and 12% with a score of 1 and 2. Practical training can be started virtually and, once the concepts and processes are understood, real work can be carried out, which makes the learning process safer and more efficient.


*Graphic 20: Safer and efficient training in the workplace.*

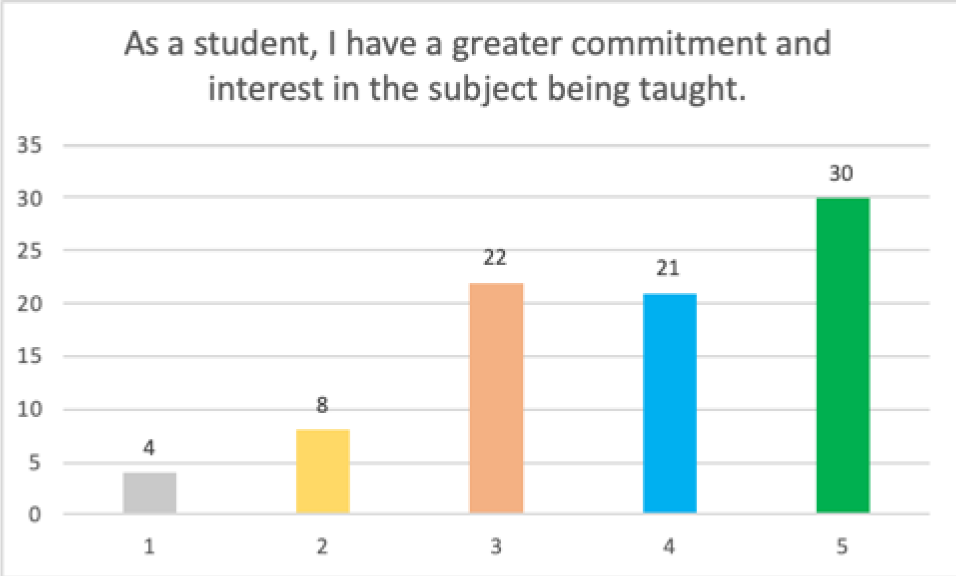
As can be seen in the following graphic, almost 92% of the respondents (78 students) affirm with a rating between 3 and 5, that the use of these technologies improves collaborative teaching and 65% give it a high rating between 4 and 5, so most of them have been able to experience an improvement in their learning with the adoption of collaborative work techniques through these technologies. Only 8% give this statement a low score between 1 and 2. 6 out of 7 of these students recommend traditional training over the use of these technologies but still 4 of them would recommend it to other students, this may be due to a lack of interest or understanding of these technologies.




*Graphic 21: Improvement of collaboration in the classroom.*

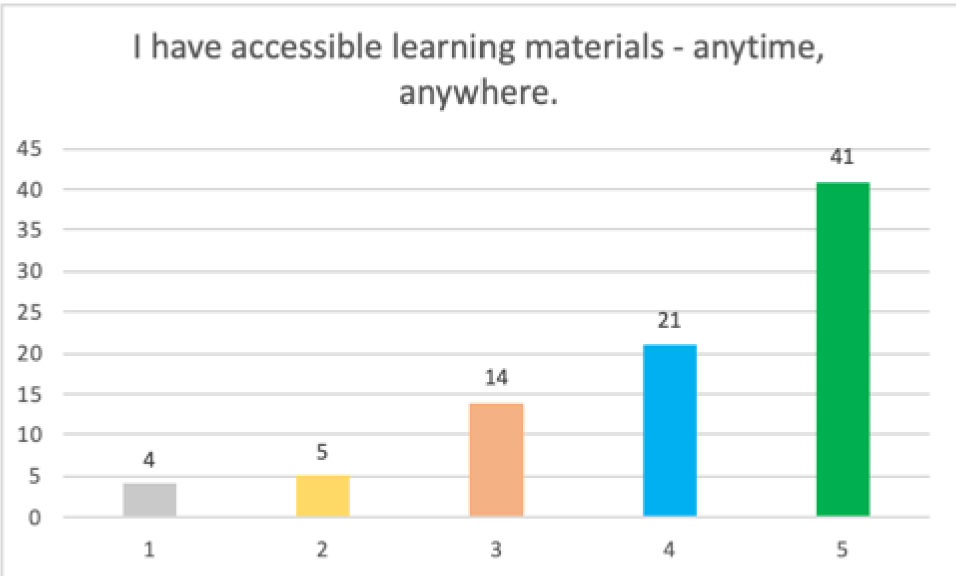
As can be seen in graphic 22, 86% of the students say that they are more engaged and interested in the subject taught using the technologies.

The remaining 14% (12 out of 85 students) rate this statement low, but 7 of them still recommend the use of these technologies. For a better analysis of the reason for this low score, in the table of responses in annex 3, it can be seen that most of the students who do not recommend the use of these technologies have had difficulties in working with them.



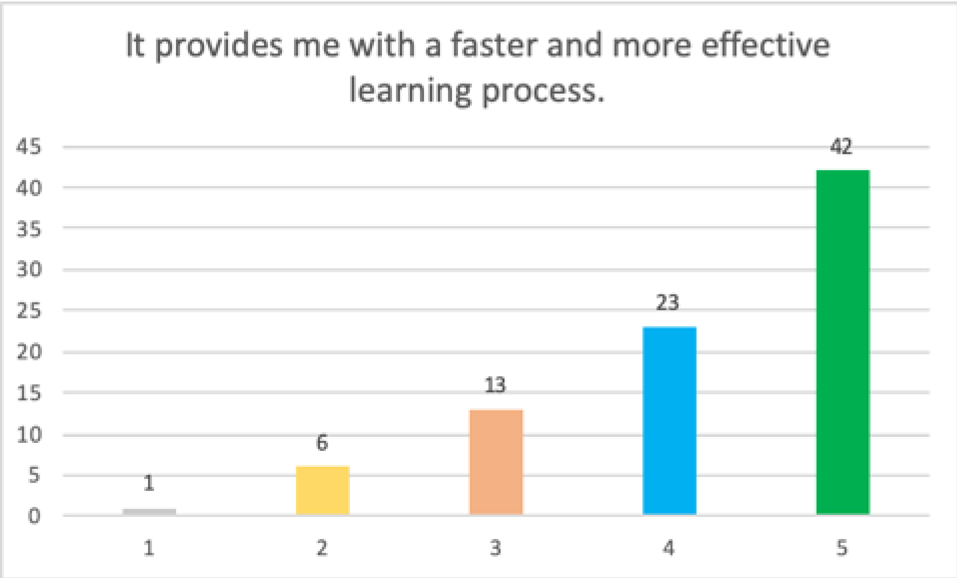

*Graphic 22: Improved interest and commitment in the subjects taught.*

The statement in graphic 23 was rated positively with a score between 3 and 5 by 90% of the learners, so that the accessibility of training materials at any time and place is one of the benefits of the use of these technologies, which continues to grow thanks to the ease of access to the Internet and the improved performance of mobile devices in recent years. Of the 9 students who gave a low score, 5 had difficulties in adapting to their use, which may be the reason for their low rating.



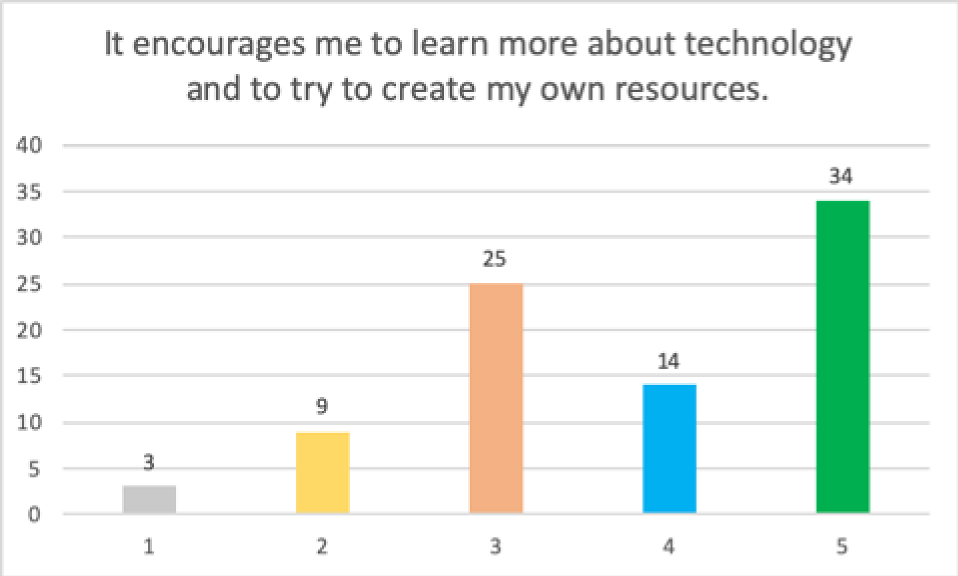

*Graphic 23: Better access to training materials.*

92% of the students rate the statement in graph 24 positively. 78 out of 85 students consider that the use of these technologies in the classroom provides a faster and more efficient learning process. There are only 7 students who have valued this benefit with a low score, and as in previous cases, we can see that they have had difficulties in adapting and do not feel comfortable working in the classroom with these technologies, although some of them continue to recommend them.



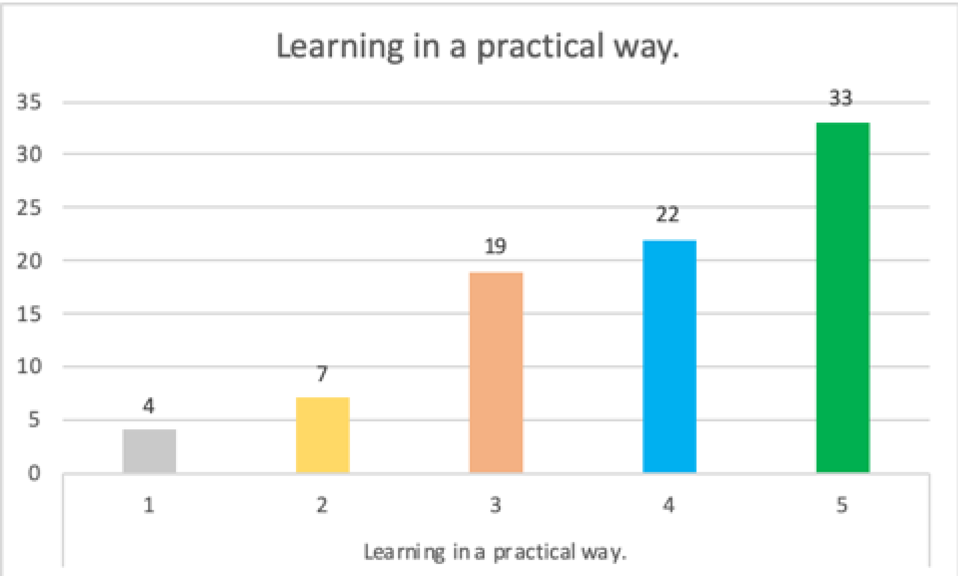

*Graphic 24: Improvement of effectiveness and learning process.*

More than 85% of the students say that the use of these technologies encourages them to learn more about AR, VR and MR and to create their own resources to work with them, which adds value to the training. Of the 12 students who scored this statement between 1 and 2, as in the previous questions, that these students have had difficulties in adapting to their use and prefer to train with traditional techniques.




*Graphic 25: Increased interest in technology and in creating one´s own resources.*

Today, getting the attention of young learners is becoming increasingly difficult. Student engagement and retention is increased when they learn with immersive technologies such as Augmented, Virtual and Mixed Reality. By learning through experience, they grasp concepts faster than traditional learning. As we can see in the graphic 27, 74 of the 85 students (87%) rate this statement with a high score between 3 and 5. 11 of the respondents rate it as a low score between 1 and 2.

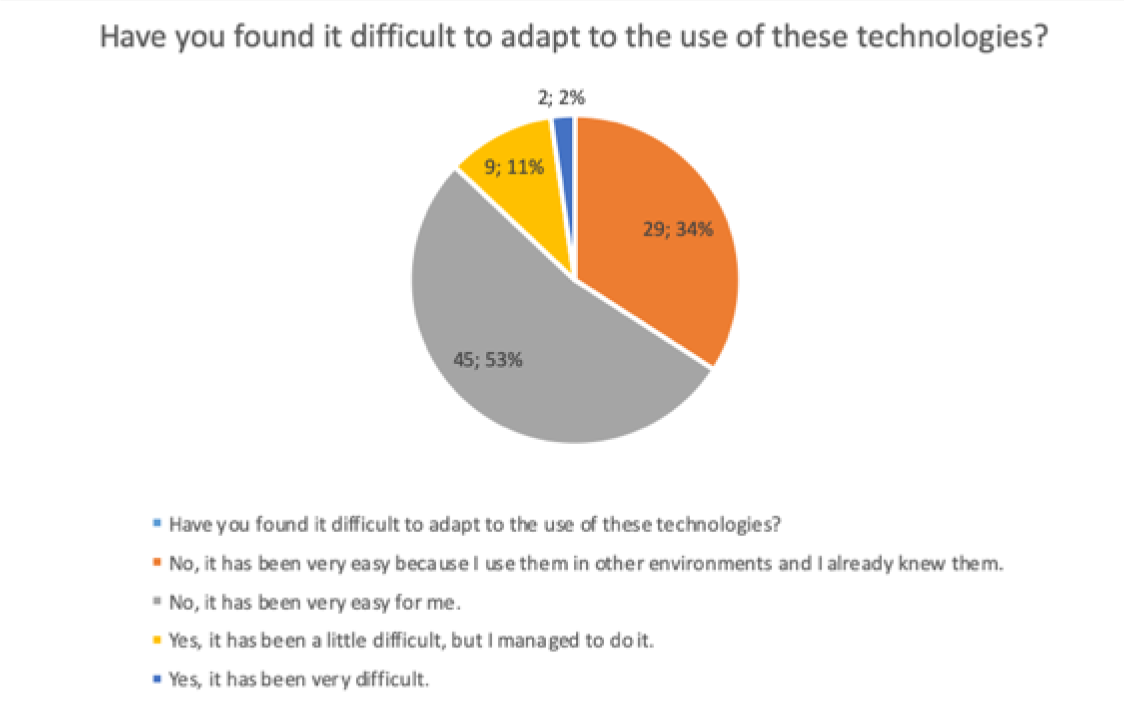



*Graphic 26: Learning in a practical way.*

Many of the students who have rated the statements between 1 and 2, are repeated in all statements, so from the sample of students interviewed only a small percentage of students are not 100% satisfied with the use of these technologies, we can say that most of them are not only satisfied but are improving their skills and competences to work with these immersive technologies.

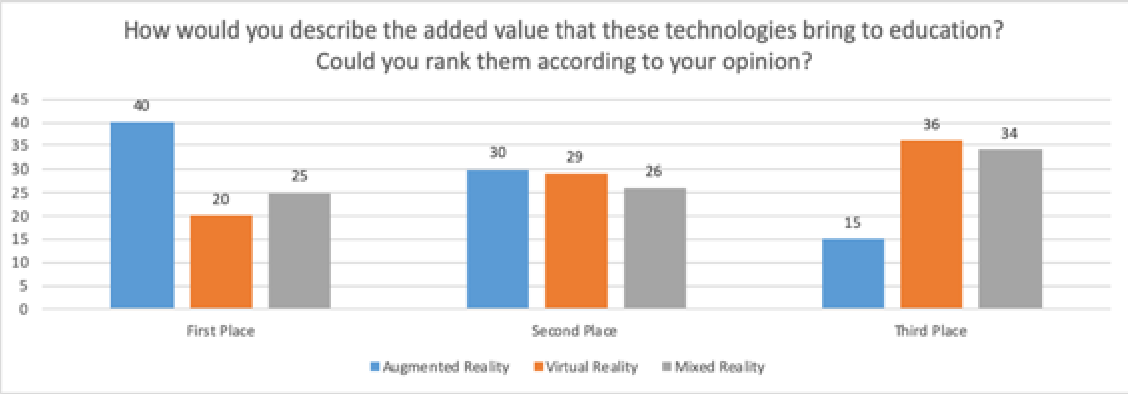
→ **Have you found it difficult to adapt to the use of these technologies?**

With regard to the difficulty of adapting to the use of these technologies, only 13% stated that they had had difficulties, compared to 87% who stated that they had adapted easily, either because they were familiar with the technologies beforehand or because they were easy to integrate into the learning methodology.




*Graphic 27: Adaptation difficulties.*

→ **How would you describe the added value that these technologies bring to education? Could you rank them according to your opinion? (placing first the one that provides the most added value)**




*Graphic 28: Ranking of technologies according to the added value considered by the students.*

If we analyse the data in the first column, where students have positioned the technology that they believe brings most added value to education, we see that Augmented Reality predominates over VR MR, with percentages of 47% for AR, 23.5% for VR and 29.5% for MR. MR predominates in second position and VR in third. If we compare these responses with those obtained in the teachers' survey, we see that the results and percentages are very similar, with only the change in VR and MR being highlighted, with teachers placing it in second and third place respectively.

This question goes hand in hand with the next one "Could you describe why you have chosen these technologies?", whose answers can be read in table 26, where respondents comment on their choice. Many of the students were unable to answer why they prefer one technology over another, but most of them gave their opinion, from these answers, based on students' experiences, we highlight the following according to technology:

**Students think that AR:**

- Is simple, intuitive, accessible and easy to use and that they have the possibility of using their own design and works to display then as augmented information.
- Promote learning.
- Is very useful for online classes, especially in Covid restriction period.
- Has many advantages, both in education and in furniture sales.

- Has many applications in manufacturing processes and it is a very useful technology.
- Has helped them to better understand the concepts, to become more interested in technology and in the topics covered in class.
- It is a tool for continuous learning.
- Has greater potential for practical use.
- Still forces you to go out on the field
- Is closest to reality.

**Students think that VR:**

- Allows more possibilities than other technologies as the whole environment can be virtual.
- Is so much easier than the others.
- Promotes learning in different ways.
- Is the most practical.
- Allows you to see everything in 3D.
- Is one of the most important branches of development for the future.
- Gives you an almost real experience that can be almost equated with a real world experience.

**Students think that MR:**

- Has the best layout
- Is the most effective.
- Is the technology where the "human" factor has more relevance.
- Is a combination and balance between the time the lectures take and the quality of education.
- Is a tool where they can put non-existent things/goods in a real virtual environment and test them before they are made.
- Is the easiest to understand even if they haven't met it before.
- Mixed Reality in the classroom. AR and MR technologies need less effort for implementation.

→ **Could you describe why you have chosen these technologies?**

**ANSWERS:**

| |
|---|
| Virtual Reality gives you an almost real experience that can be almost equated with a real world experience |
| I don't know exactly how to explain my choices. |
| In augmented reality, we come closest to reality. |
| I don't even know what these concepts are supposed to represent specifically. |
| I wouldn't be able to explain well, by feeling. |
| Virtual Reality is less useful than upgraded and mixed. |
| I ranked them in terms of their potential applicability in the wood industry. |
| Augmented Reality (as I imagine it) still forces you to go out on the field |
| Because I think virtual reality is one of the most important branches of development for the future |
| Because I know. that VR is the best! |
| Because I think Mixed Reality is the easiest to understand even if we haven't met it before. |
| It is good to have tools where we can put non-existent things in a real virtual environment and test them before they are made ... |
| Hard |
| It seems to me that the virtual world cannot yet completely replace the real one, but it is improving. |
| VR because here you see everything in 3d |
| I don't know |

| |
|---|
| That way seems best to me. |
| Because that’s how it’s most interesting |
| Because that's how I think it's best. |
| That seemed to me the best |
| Virtual Reality is the most practical. |
| We learn the most from reality |
| It seems to me that Augmented Reality is most important. |
| Because it promotes learning in different ways |
| Because I find it more appropriate |
| Due to the availability of technology and the price of it |
| Augmented Reality has greater potential for practical use. |
| I would choose Mixed Reality because it seems to me that this is a combination and balance between the time the lectures take and the quality of education. |
| I don’t understand the context of “reality”. I assume it has a connection to technology. Since I don’t support online education, I decided to put mixed reality first, as I feel like there’s the most “human” factor here. |
| Because virtual reality is more domestic. |
| Mixed Reality is the most effective. |
| The order is not exactly important |
| Better is always in the first place. |
| No |
| Because I like it |

| |
|---|
| Not really |
| I come to the conclusion, that I have to know the reality of life, while learning about other ways of use and knowledge. As the latest Virtual Reality, it only helps us in our easier work. |
| No |
| Because that makes the most sense to me |
| Because it's so much easier for me |
| Because it suits me well |
| No |
| This is, in my opinion, the best layout. |
| Because it suits me well |
| I don't know |
| After teacher's explanation |
| I don't know |
| I don't know |
| After much deliberation MR this best decision |
| So, I decided because this is the most suitable layout for me. |
| Augmented Reality has great advantages and applications in all manufacturing processes. And it is a tool for continuous learning. |
| Virtual reality allows more possibilities than other technologies as the whole environment can be virtual. |
| With augmented reality I can show my designs in a simple way by uploading them to the web and using a visualiser. |

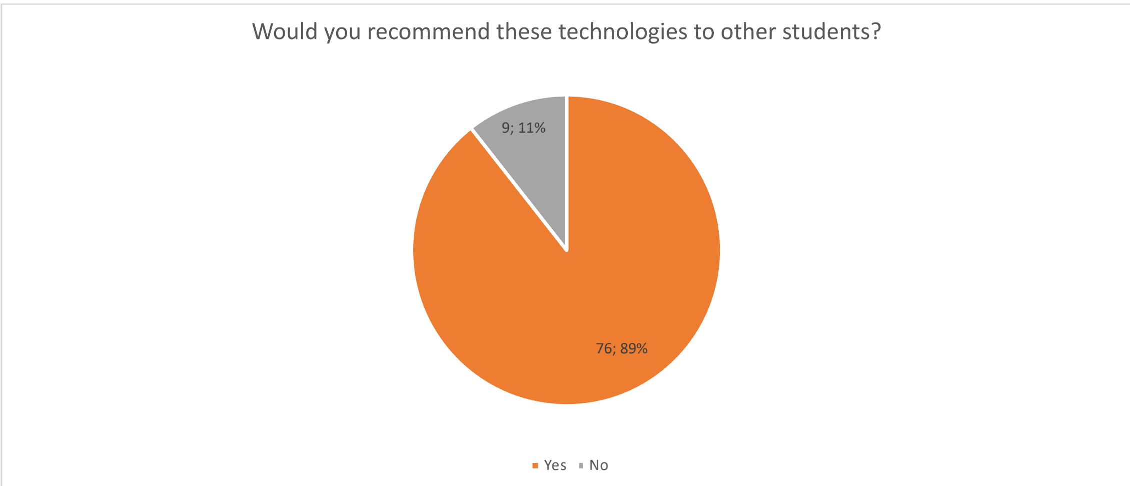
| |
|---|
| AR is the technology I have used the most. |
| I have only worked with Augmented Reality, I know virtual reality but I like AR better |
| I find augmented reality more interesting as it is easier for students to develop content, plus you can interact with the environment and overlay that augmented "information". |
| Augmented reality has helped me a lot in my studies to better understand the concepts, it has helped me to become more interested in technology and in the topics covered in class. Virtual reality is useful, but a little less so as special devices are needed. And I have never worked with mixed reality. |
| Both technologies have helped me this year to learn the concepts better, since the face-to-face classes were cancelled due Covid. |
| I have been working with them and I had a good experience. |
| I have more fun in class and more interest when we use these technologies. |
| Augmented reality has many applications in manufacturing processes and I think it is a very useful technology. |
| Augmented reality is very useful and easy to use in the furniture industry. |
| Augmented reality has many advantages, both in education and in furniture sales. |
| I like the possibilities that this technology offers and I find it easy to use. |
| AR and VR are very useful in education, especially if you have online classes. (Covid) |
| I like augmented reality and what I can do with this technology because it is accessible and easy to use. |
| Both augmented reality and virtual reality are intuitive tools that promote learning. However, they must always be accompanied by theoretical and practical training. |

| |
|---|
| From my point of view, it is easier to develop content for augmented reality, because with basic knowledge of using a WEB and a visualiser, you can show the developed 3D designs for other tasks. For example, an assembly. |
| The technology I have used the most is augmented reality, and as a student I think it is simple and intuitive. I can use my designs to work with it. |
| It is the technology I like the most and learn the most with. |

*Table 26: Comments on the Ranking / Position of technologies.*

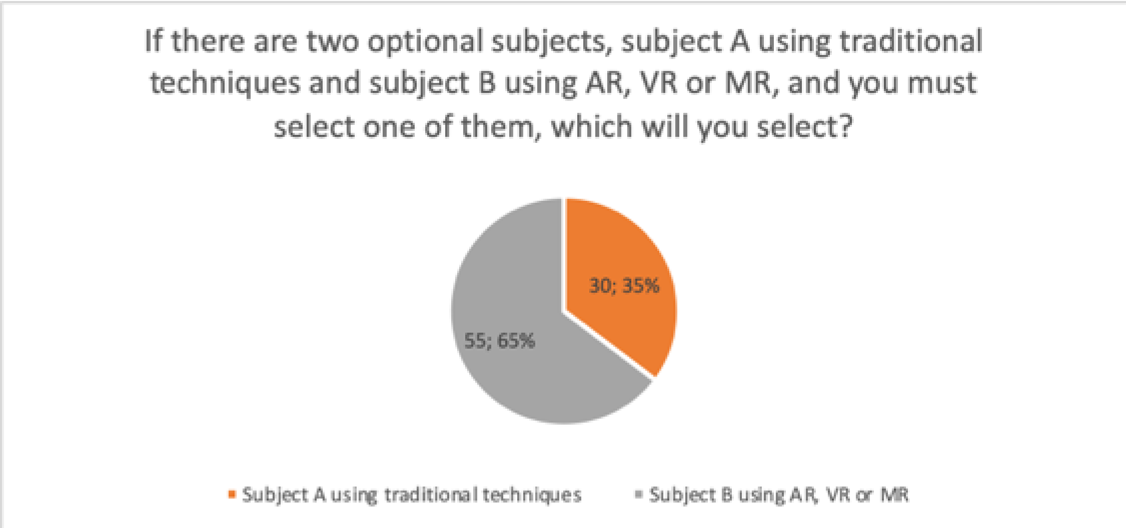
→ **Would you recommend these technologies to other students?**

89% of the students who have worked with these technologies would recommend them to other students. We can see that the degree of satisfaction remains within a few percentages in most of the questions in the survey.




*Graphic 29: Technologies recommendation.*

→ **If there are two optional subjects, subject A using traditional techniques and subject B using AR, VR or MR, and you must select one of them, which will you select?**




*Graphic 30: Traditional technics vs technological methods with AR, VR, and MR.*

Training is based on a methodology where these immersive technologies play an important role. 65% of the students surveyed opted for training based on the use of AR, VR and MR technologies, compared to 35% who still prefer traditional training.

### 5.2.2. General Conclusions

The background of most of the students interviewed is related to the wood and furniture sector, which makes this study relevant to the needs to be covered by the ALLVIEW project.

The participants have used all three technologies. Like teachers, AR has been the most representative. Through the use of these technologies, students state that they are able to understand abstract concepts better, they learn more safely and efficiently in practice, collaboration between students and teachers is improved, their interest in the subject matter covered in class increases and motivates them to continue learning about these technologies and to develop their own content. Visualising the content in 3D brings them many advantages, and the use of the technologies gives them added value, not only during learning but also for their future jobs.

Respondents found it relatively easy to adapt to the use of these technologies in the classroom. The vast majority would recommend them to other students and 65% prefer subjects taught using these techniques compared to 35% who opt for traditional techniques. Being able to show their own designs through a 3D device or environment and learning through these techniques increases their interest and facilitates the development of skills and competences, enriches education and training with immersive experiences and encourages active and autonomous learning.

# 6

# Main features and benefits for the purpose of the Allview project, and identification

# 6. Main features and benefits for the purpose of the Allview project, and identification of the best technologies, hardware, and software to be implemented

One of the objectives of this work package is to develop a series of exercises that serve as an example to show what is possible to achieve through immersive technologies (AR, VR and MR) as a support for training in the field of furniture and wood. To create three-dimensional experiences that motivate students, that help them to learn more about the technologies and to better understand the topics and concepts through them.

After launching a survey to gather the opinion of teachers and students and evaluate their responses, we can state that, when it comes to developing content, the most widely used technologies, both in terms of the resources available in the centres and the capacity to develop content for them, are VR and AR. The development of content and the implementation of the technology in MR is much more complex, among other things because it is the most recent technology and for which there is less information / specific training, as well as its high cost, both for software development and obtaining the necessary hardware.

On the other hand, also when talking about content creation, both teachers and students (most of them from the furniture and wood sector) agree that the most appropriate to their experience, skills and training is the creation of 3D models for AR and VR, videos, and virtual environments for training. This together with the types of methodologies used for integration of technologies in the classroom (Use of technologies to explain, demonstrate and monitor students' work, including gamification and content creation for collaborative and project-based classes), make VR and AR the most appropriate for education.

In addition to the fact that both AR and VR were the most highly valued by both teachers and students, these technologies are at a higher stage of development than MR, which is why there is more training and tools available for their implementation and at a more affordable costs, which makes the first two technologies more suitable to work in an immersive way in the classroom.

However, we do not want to leave MR out of the development of this WP, as we consider that it is a growing technology that can bring many benefits both didactically and cognitively, as well as prepare students and teachers for the technological changes of the coming years. After analysing several possibilities, the consortium has opted for the solution of using the Microsoft Dynamics 365 platform for the development of MR exercises. The aim of including this platform is to provide teachers with training in the form of a manual to guide them in the development of their own exercises. In this way, each centre will be able to develop specific exercises adapted to the needs and resources of the centre.

According to the studies and articles analysed for the preparation of this report, (listed in table 34 – Annex 1), and the advantages of the use of these technologies in the classroom for both teachers and students, we can say that immersive technologies (AR, MR & VR) including 360° videos bring the following benefits to the education sector, and in parallel, to the training sector in the field of wood and furniture:

- AR, MR, and VR can help to improve the effectiveness of teaching, especially when teaching abstract concepts.
- Teaching and learning with AR, MR and VR can be exciting and rewarding for both teacher and students.
- AR, MR, and VR allow the optimisation of traditional tools and methods for more efficient reuse.
- AR, MR, and VR, are technologies that the teacher can use to engage and motivate students in a positive way.
- With the use of technologies, the teacher gets a better explanation of complex and abstract concepts.
- Practical knowledge and accessible learning are promoted.
- Improves understanding of spatial and abstract geometric concepts by manipulating and observing multiple angles of virtual 3D objects.
- Allows students to experiment and practice in a safer environment before being exposed to certain work practices.
- Students better understand abstract concepts that are difficult to visualise mentally or in 2D.
- Safer and more effective workplace training.
- Improved collaborative skills between students and teachers.

- Learners develop greater engagement and interest in the subject being taught. VR can also enhance empathy and emotion during training, both of which help improve information retention.
- Hands-on learning.
- Accessible learning materials, anytime, anywhere.
- They provide a faster and more effective learning process.
- The use of AR, MR and VR in the classroom helps students learn more about technology and try to create their own resources. Learning by designing.
- Improves cognitive development.

## 6.1. Proposed development pathways and platforms to be used

The analysis carried out for the selection of the recommended technological pathways for the following steps in work package 3 is shown below, together with information on the specific hardware for content development and visualisation. These pathways correspond to the Virtual Reality environment that will be developed by the consortium in the next tasks. In addition to this, work will be done with other platforms as indicated previously: SimLab (for the development of VR exercises) and Microsoft Dynamics 365 Guides (for the development of Mixed Reality exercises). This analysis has been conducted based on the software and hardware research undertaken in section 3 of this document. For the selection of the technological path of the recommended technologies, a series of tables have been drawn up, which include the key factors for the choice of the different software and hardware, based on the knowledge of the most technological partners with some experience in the field of immersive technologies. In addition, the comparative tables between the different technologies and solutions, whether hardware or software based, for application development are shown against their corresponding key factors for analysis. As a continuation of the above, the 3D CAD information exchange formats are listed, which have been identified and studied through the analysis sheets elaborated for this purpose. This selection of formats is compared on the basis of key factors through a table to evaluate their capacity for incorporation into the project.

Finally, the technological path selection chart is shown, where the different alternatives are evaluated, and it is determined which set of technologies, solutions and tools will be the basis and germ for the development of the work package.

Lists of key factors applied in the analysis.

The tables below list each of the key factors against which the suitability of each technology, solution, or component to be incorporated and used in the development of the next task in the work package can be measured.

| ANALYSIS FACTORS FOR BASIC HARDWARE SOLUTIONS | |
|---|---|
| **PROCESSING** | Ability to process the developed solution. |
| **VISUALISATION** | Ability to generate the resulting image. |
| **INTERACTION** | Degree of interaction with the elements, whether virtual or physical. |

*Table 27: Factors for the analysis of basic hardware solutions.*

| ANALYSIS FACTORS FOR BASIC HARDWARE SOLUTIONS | |
|---|---|
| **MULTI-PLATFORM** | Ability to deploy the developed solution on multiple target platforms. |
| **CONTENT MANAGEMENT** | Flexibility in the incorporation of multimedia content. |
| **USABILITY** | Level of user-friendliness and training. |

*Table 28: Factors for the analysis of basic hardware solutions.*

| FACTORS FOR THE ANALYSIS OF 3D CAD INFORMATION INTERCHANGE FORMATS | |
|---|---|
| **STANDARDISATION** | Level of incorporation at both business and standard level. |
| **ENCAPSULATION** | Capacity to encapsulate the content and information linked to a 3D model |
| **TIME OF INCORPORATION INTO THE SOLUTION** | Speed of incorporation of the content into the solution. |

| | |
|---|---|
| **UNDERSTANDING** | Capacity to reduce the size of the information. |
| **MATERIALS** | Admission of materials and their level of fidelity once incorporated into the solution. |
| **LIGHTING** | Admission of lights and their level of fidelity once incorporated into the solution. |
| **ANIMATIONS** | Admission of animations. |
| **TEXTURE MAPPING** | Admission of texture maps. |

*Table 29: Factors for the analysis of 3D CAD information exchange formats.*

**Comparative analysis tables between the different technologies and base solutions against the key factors identified.**

| BASIC HARDWARE SOLUTIONS | | | | | | |
|---|---|---|---|---|---|---|
| | FACTORS | | | APPLICABILITY | | |
| | PROCESSING | VISUALISATION | INTERACTION | VR | AR | MR |
| BACKPACK | | | | | | |
| MOBILE DEVICE. | | | | | | |
| HMD | | | | | | |
| CAVE | | | | | | |
| HMD HOLOGRAPHIC | | | | | | |
| ENVIRONMENT DIGITISATION CAMERAS. | | | | | | |

*Table 30: Comparative analysis table of hardware solution.*

Level of adequacy for each factor:
High
Medium
Low

| BASIC SOFTWARE SOLUTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| | FACTORS | | | | APPLICABILITY | | |
| | MULTIPLATFORM | DEVICE INTEGRATION | CONTENT MANAGEMENT | USABILITY | VR | AR | MR |
| UNITY | | | | | | | |
| UNREAL | | | | | | | |
| AFRAME | | | | | | | |
| GODOT | | | | | | | |
| CRYENGINE | | | | | | | |
| AMAZON LUMBERYARD | | | | | | | |

*Table 31: Comparative analysis table of hardware solution.*

**Identification of 3D CAD formats for information exchange.**

| KEY FACTORS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3D CAD INFORMATION EXCHANGE FORMATS | STANDARDISATION | ENCAPSULATION | RUNTIME TO SOLUTION | COMPRENSION | MATERIALS | LIGHTING | ANIMATIONS | TEXTURE MAP |
| Wavefront (.obj) | | | | | | | | |
| Collada (.dae) | | | | | | | | |
| X3D | | | | | | | | |
| 3ds | | | | | | | | |
| glTF | | | | | | | | |

*Table 32: Analysis table for 3D CAD information exchange format.*

In the following chart, we can see the technological path for the development of an Immersive VR application resulting from the analysis and comparison of the key factors described above. The colour nomenclature used in the chart is the same as in the previous tables.

Chart for the selection of the technological Path.

| BASE SOFTWARE SOLUTIONS | BASIC HARDWARE SOLUTIONS | 3D CAD EXCHANGE FORMATS |
|---|---|---|
| Unity | Gboard | OBJ |
| Unreal | Vive Pro | COLLADA |
| A-Frame | Oculus Rift | X3D |
| Godot | Cave | 3DS |
| Cryengine | Magic Leap | glTF |
| Amazon Lumberyard | Microsoft Hololens | Recommended Technological Path |

*Table 33: Table for technology pathway selection.*

For 360° video creation, a Ricoh Theta Z1 type hardware/camera is recommended, which records 4K video and 360° spatial audio to represent a more realistic VR world. These types of virtual tours are teaching tools, and there is 360 video processing software such as those described in point 5 above, which simulate scenarios, situations and locations and use gamification or conditional actions to allow learners to play against each other and earn badges as they learn.

*Figure 34*: Camera Ricoh Theta Z1.

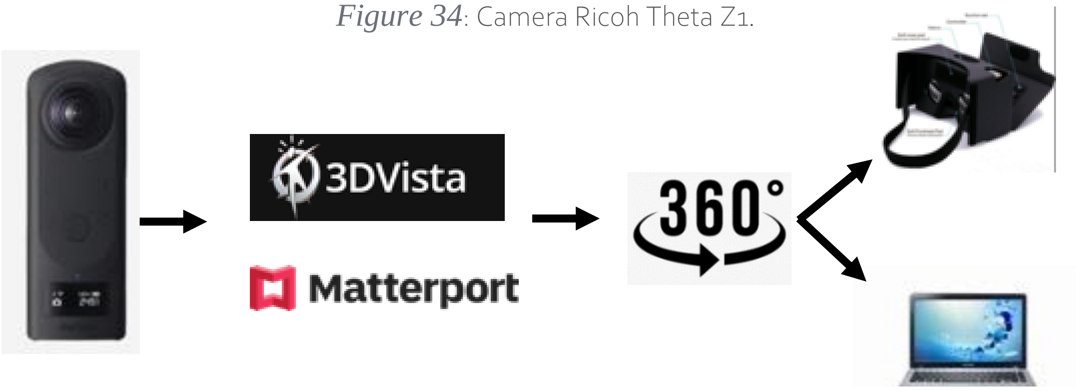



*Figure 35: Hardware and software for 360° videos.*

The use of SimLab software is also recommended as a possibility for the creation of a training application containing exercises related, for example, to the handling of complex woodworking machinery. This software provides certain tools for the production of this type of experience, so it is interesting to incorporate it for the development of the exercises. It can also be understood as a kind of CMS content manager, but instead of being dedicated to web development, it is focused on the creation of VR experiences and content. Therefore, SimLab can be an interesting platform for training centres to create their own content for simple Virtual Reality experiences without the need for specific development. https://www.simlab-soft.com/

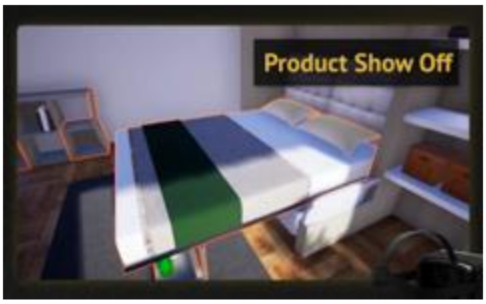



*Figure 36:* Virtual Reality experience with SimLab Soft. Screenshot from WWW.simlab-soft.com

SimLab SOFT

*Figure 37: SimLab Software Logo.*

As mentioned above, although it is currently not as integrated as VR and AR, we consider the inclusion of MR a plus in this work package, both because of the relevance and future of this technology, as well as the added value that can be brought through it to training in the field of wood and furniture in vocational training centres. For this, the Microsoft Dynamics 365 platform is a solution that we believe can bring many advantages and benefits to teachers and students.

Thanks to this platform, learning and training performance can be accelerated with different machinery adapted to each training centre. This improves learning and standardises processes with step-by-step visual work instructions that show users how to use their tools and parts in real work situations. Through mixed reality glasses (HoloLens), the user can navigate through the steps and work instructions and can also be evaluated at the end of the task. The student will benefit from an immersive training whose methodology will bring advantages to both the student and the teacher.

With this platform, it is possible, for example, to develop guides for the handling of dangerous machinery, where through the mixed reality glasses, step-by-step instructions for use are displayed, including warning and caution messages.

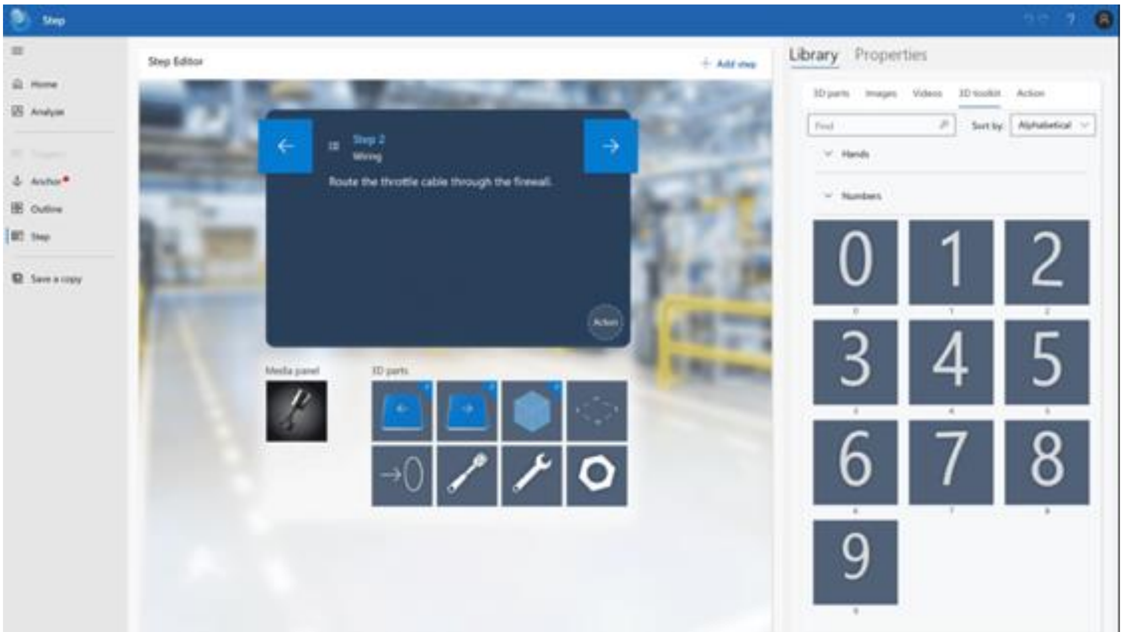



*Figure 38:* Warnings and cautions.


*Figure 39:* Editor´s interface.

*Figure 40: Actions with Microsoft HoloLens. Source: hmcollege.*

Allview

# 7 Conclusion

# 7. Conclusion

After the results of the previous surveys and the technology surveillance in AR/VR/MR, their application in the wood and furniture have been evaluated for training. The technologies considered most suitable to work with in future steps are MR (which encompasses the features of AR) and VR. For VR, immersive, non-immersive experiences and 360° videos have been considered.

It should be borne in mind that, in order to integrate these technologies in the classroom, the teacher has to go through a prior learning process and dedicate time to adapting the resources to the school's curriculum. Therefore, the type of technology to be used and the exercises to be developed have to be adjusted to their curricular needs and material and time resources.

These technologies will provide students and teachers with what is necessary to obtain the greatest benefit, since in addition to understanding and learning to work with these technologies, they will be able to develop new content, making their integration into the curriculum and teaching methodologies more harmonious and versatile.

Due to these conclusions, and to what has been explained in the previous point, we recommend as examples of exercises to be developed by the ALLVIEW project, those that can be developed through the following typologies:

- Development of 360º videos: creation of interactive 360º tours in places of training interest for the furniture and wood sector.
- Development of Immersive VR: development of an application showing characteristic pieces for specific types of furniture. In addition, to increase the added value of this type of exercise, it is recommended to show design recommendations, ergonomic measures, and possible materials.
- Handling of complex machines or machines with a certain degree of danger or difficulty in their handling, with the aim of preparing the student before facing the machine, increasing safety in the practical phase.
- Design of furniture in 3D for integration in a real environment by means of AR visualisers.
- Training manual with examples of exercises on the use of Microsoft Dynamics 365 and its advantages.

One of the aims of these exercises is to prepare students not only for commercial applications of technologies within the sector, such as retail applications and furniture showrooms, but also to help them understand concepts, processes, and geometries through them. From design and prototyping to the operation of a specific process or visualisation of a workstation. Another objective of this type of exercise is to support teachers to integrate these technologies into the different curricula of studies related to the furniture and wood sector.

Regarding the most appropriate software and hardware for the use of these technologies and more specifically for the development of the type of exercises proposed, we propose the ones explained in the previous point. To summarise in simplified terms:

**SOFTWARE:**

- 3D design software.
- 3D graphic development software and engine.
- Software development kits (SDK).
- Collaborative platforms.
- Visualisers.
- Content Management Systems (CSM)
- 360° video processing software

**HARDWARE:**

- Tablets
- Smartphones
- VR Headset
- MR Headset
- Computers
- 360° Cameras

The technical procedure to be followed for the development of tasks T3.2 "Development of AR, VR, MR base environments" and T3.3 "MR, VR, and AR toolkit" will be:

- Definition of needs
- Identification of the applications to be developed
- Definition of the requirements
- Low fidelity prototypes
- High fidelity prototypes
- Development and integration of contents
- Yield tests

The consortium's internal procedure:

- Identifying the background and know-how of the partners
- Identify who, what and how can support the performance of the tasks
- Task allocation
- Work monitoring and regular communications

With the results presented in this report, the aim is to create a stable basis for the creation of ten different experiences in VR and/or MR (including AR) that show what is possible to achieve through these technologies. Furthermore, they will serve as a pilot experience in WP5, to test and confirm that the chosen techniques have a huge potential for the educational field, and more specifically in the furniture and wood sector.

# 8

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# 9

# Annexes

# 9. Annexes

## 9.1. Annex 1.- Literature reviewed for research on the use of AR, VR and MR technologies in the classroom.

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*Table 34: Literature reviewed.*

## 9.2. Annex 2.- Surveys. Questions asked of teachers, training organisations and students

ALLVIEW is an amazing starting European project that gathers 22 partners from 7 different countries to create a European platform that will encourage all actors dedicated to training in the wood and furniture sector to work together. With this survey, we want to collect information to know which of these technologies (Augmented Reality, Virtual Reality and Mixed Reality) are more appropriate for use in the field of education.

We need your opinion and feedback to decide what are the most relevant technologies that should be covered by the project. We would very much appreciate if you could take a few minutes to answer that survey.

The three technologies referred to in this questionnaire are briefly defined below:

AR/VR/MR Definitions:

Augmented Reality (AR) is the overlaying of digitally created content on top of the real world. Augmented reality - or 'AR' – allows the user to interact with both the real world and digital elements or augmentations. AR can be offered to users via headsets like Microsoft's HoloLens, or through the video camera of a smartphone.

Virtual Reality (VR) is the use of computer graphics systems in combination with various display and interface devices to provide the effect of immersion in the interactive 3D computer-generated environment.

A Mixed Reality (MR) experience is one that seamlessly blends the user's real-world environment and digitally created content, where both environments can coexist and interact with each other. It can often be found in VR experiences and installations and can be understood to be a continuum on which pure VR and pure AR are both found.

### Identification of Technologies - Questionnaire for organisations and teachers.

### Questions for Teachers/Organizations:

1.- What is your position in your organisation?

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2.- In what type of organisation do you teach?

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3.- Which of these technologies have you worked with in your organisation? (Multiple choice)

- ☐ Augmented Reality
- ☐ Virtual Reality

- Mixed Reality
- Other - If your answer is "Other", please specify which one in the next question.

4.- If you have chosen the option "Other" in the previous question, could you specify which one?

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5.- What use has been made of these technologies? (Multiple choice)

- Display of augmented information or virtual environment
- Content creation
- Software development

→ Display of augmented information or virtual environment:

6.- If you have chosen "Visualization of augmented information or virtual environment" Where has the augmented information or virtual environments used in the classroom been obtained? (Question for writing)

→ Content creation:

7.- If you have chosen "Content creation", What kind of information have you created? (3D models for Augmented Reality, texts or videos, virtual environments...) (Question for writing)

8.- What Software and Hardware have been used? (3D modelling software, Unity, A-Frame, Vuforia, HoloLens...) (Question for writing)

9.- Has teacher training been necessary to reach this point? If so, where did you look for the training? (Training provider website, in your organization, self-taught, etc.) (Question for writing)

10.- Benefits obtained for the teacher and the organization. (Evaluate from 1 to 5, with 1 being the lowest and 5 the highest value.)

→ AR can help improve teaching effectiveness especially when teaching abstract concepts.

→ Teaching and learning with AR can be exciting and rewarding for both teacher and learners.

→ VR and AR allow the optimization of traditional instruments and methods for more efficient reuse.

→ VR and AR are technologies that an educator can use to attract and motivate students in a positive way.

→ With the use of technologies, the teacher gets a better explanation of complex and abstract concepts.

→ Promote practical knowledge and accessible learning.

→ Improving understanding of abstract, spatial geometric concepts through manipulation and multi-angle observation of virtual 3D objects.

→ Allow students to experiment and practice in a safer environment before being exposed to certain work practices.

→ Save on budget which would otherwise limit students ability to make these observations and analyses in the classroom. And as a consequence, improve the quality of teaching.

11.- What teaching methodology have you used for the inclusion of these technologies in the classroom? (Describe with two or three sentences)

12.- Do you think that the use of these technologies is an enabling tool for education? (Question for writing)

13.- Could you provide the informative link of a case study or your own experience on the use of this technology? (Question for writing)

14.- In general terms, could you say that the use of these technologies brings added value to training?

- ☐ Yes
- ☐ No

15.- From one to ten, how would you rate the added value that these technologies bring to education? (With 1 being the lowest value and 10 the highest)

16.- How would you describe the added value that these technologies bring to education? Could you rank them according to your opinion? (Placing first the one that provides the most added value and last the one that provides the least).

- ☐ Augmented Reality
- ☐ Virtual Reality
- ☐ Mixed Reality

17.- Regarding the previous question, could you please comment on your choice? (Question for writing)

## Identification of Technologies - Student Questionnaire

## Questions for Students:

1.- What is the level of your training:

- ☐ Vocational education
- ☐ Bachelor
- ☐ Master
- ☐ Other: ...........................

2.- What is the topic of your training?

- ☐ Studies related to Wood and Furniture
- ☐ Manufacturing industry
- ☐ Industrial Engineering
- ☐ Other.....................

- If you have chosen the option "Other" in the previous question, can you tell us what your studies are?

3.- Which of these technologies have you used in class? (Multiple choice)

- Augmented Reality
- Virtual Reality
- Mixed Reality
- Other

4.- If you have chosen the option "Other" in the previous question, could you specify which one?

Please, rate the benefits of working with those technologies. (Evaluate from 1 to 5.)

- I understand better abstract concepts that are difficult to visualise mentally or in 2D.
- Safer and more efficient training in the workplace.
- Improved collaboration skills between students and teachers.
- As a student, I have a greater commitment and interest in the subject being taught.
- Learning in a practical way.
- I have accessible learning materials - anytime, anywhere.
- It provides me with a faster and more effective learning process.
- It encourages me to learn more about technology and to try to create my own resources.

5.- Have you found it difficult to adapt to the use of these technologies? (one choice)

- No, it has been very easy because I use them in other environments and I already knew them.
- No, it has been very easy for me.
- Yes, it has been a little difficult, but I managed to do it.
- Yes, it has been very difficult.

6.- How would you describe the added value that these technologies bring to education? Could you rank them according to your opinion? (Placing first the one that provides the most added value and last the one that provides the least).

- Augmented Reality
- Virtual Reality
- Mixed Reality

7.- Could you describe why you have chosen these technologies? (Question for writing)

8.- Would you recommend these technologies to other students?

- Yes
- No

9.- If there are two optional subjects, subject A using traditional techniques and subject B using AR, VR or MR, and you must select one of them, which will you select?

- Subject A using traditional techniques
- Subject B using AR, VR or MR

Allview

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