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Creating Virtual Field Trips for Education: A Comparison of Software and Tools for Creating Virtual Field Trips with 360° Images

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Abstract

Virtual Reality (VR) has gained more importance in the educational sector. A possibility of using VR in education can be Virtual Field Trips (VFTs). This work analyses the possibilities of creating VFTs with different software/tools, output devices, and 360° cameras in the educational sector. The preparatory work, with the recording of own 360° images, is described, including the involved time and comparison of 360° cameras. With a comparison, four categories of software/tools for creating a VFT are analyzed under the aspects of the needed technical equipment, the time effort, the needed skills to create the VFT and the level of immersion and interactivity, and the convey of technical content through the VFT. For the creation and use of a VFT a software/tool and an output device is necessary. The creation of 360° images requires a 360° camera, which is very time-consuming, concerning the everyday workload of teachers. Three of the tested software/tools require through a graphical user interface a low level of skills for creating a VFT. The created VFT with the different software/tools offers different levels of immersion and interaction. It is possible for teachers to create their own VFT, but the accompanying time and cost can limit the possibilities during the everyday work.

Introduction

The potential of Virtual Reality (VR), to revolutionize education has been discussed for decades. VR can be defined as *'[…] a computer-generated digital environment that can be experienced and interacted with as if that environment were real' (Jerald, 2016)* With the launch of consumer-priced Head-Mounted-Displays in 2013 and a couple of years later, the new technology VR was made accessible to the broader public, research, and education (Jensen & Konradsen, 2018). Thus, VR has been an established technique in the fields of gaming, tourism, education, architecture, enterprise productivity, and web content (Abhijit et al., 2017; Martín-Gutiérrez et al., 2017). However, due to rapid technological development, VR is expected to be implemented within a few years in various disciplines (Jensen & Konradsen, 2018; Makransky et al., 2021).

Especially, during the actual COVID-pandemic, VR gained importance, and the advancement of digitalization in classes increased (Bheda et al., 2021; Bürki & Buchner, 2020; Makransky et al., 2021). Due to their features and use, VR has been in more talks with the ongoing pandemic (Bheda et al., 2021). VR can help people feel closer to each other and connect people to family and the workplace during social distancing (Nalluri et al., 2021). VR-based meetings can effectively solve pre-pandemic meetings (Nalluri et al., 2021). For students and clients, many universities worldwide started, during this pandemic, to apply virtual worlds and applications, for example, a virtual space for students to conduct study groups and to communicate with academic advisers at the University of Florida in the USA (Attallah, 2020). Nevertheless, using VR applications in schools is still a slow process (Bürki & Buchner, 2020). VR technologies in education can help pupils learn and build their skills because they might attract them to learn and motivate them (Bheda et al., 2021).

There is a long tradition of fieldwork in geography and certain sciences (biology, environmental sciences). The nature experience brings the students to the complexity of the real world. The direct experiences foster deep learning, and the personalised learning outcomes from field trips positively affect long-term memory (Minocha et al., 2018). However, physical field trips are becoming less frequent, and there is a reduction in all learning levels due to expense limitations or safety issues (Alsaqqaf et al., 2019; Minocha et al., 2018).

Virtual Field Trips can be an opportunity to use VR in education and bring back a kind of fieldwork into classes with long traditions of fieldwork. Minocha et al., 2018 did a year-long research project on how the mobile VR application *Google Expeditions* can bridge VFTs with physical field trips. For the research, 20 educators used VFT from the application '*Google Expeditions'* based on 360° images for classes in geography and science. The research shows that the expeditions with the '*[…] 360-degree visual authenticity, 360-degree navigation, and 3D view give a first-hand experience of the physical location and its context*' (Minocha et al., 2018). The students gain spatial awareness and relationships through the 360° images of the VFT in '*Google Expeditions'*. After the research, they concluded that VR would be most effective when combined with other technologies, like videos, podcasts, or mobile Apps (Minocha et al., 2018).

With spatial orientation, the geography subject offers a good opportunity to use VR glasses. So, visiting normally inaccessible places like a glacier or a time like the Mesozoic is possible, which could not be experienced in real (Bürki & Buchner, 2020; Jitmahantakul & Chenrai, 2019; Minocha et al., 2018). VFTs are one opportunity for using VR in the educational sector. Especially in earth and environmental science courses, like geography, VFTs play an essential role (Hou & Fang, 2012). They have been developed as computer-based VFTs since the 2000s (Jitmahantakul & Chenrai, 2019). For example, during the COVID-19 pandemic, Arthurs, 2021 designed a VFT to teach the course 'Introduction to Field Geology' remotely. Three cameras took visual data to bring the field to the students. A standard *Go-Pro* camera took wide-angle videos for general reconnaissance, and an '*Insta360 Pro'* took high-resolution 360° panoramic images to independently explore the environment of the students while turning around and zooming in and out in 3D virtual reality settings converted out the panoramic images. The third camera was a digital SLR camera, where 2D photos of yellow number tents with printed ruler gradations were taken to *'[…]aid the students in making and describing observations*' (Arthurs, 2021). A pre- and post-instruction test shows that digital fieldwork improves the students' knowledge of field-related geologic terms (Arthurs, 2021).

The study by Jitmahantakul & Chenrai, 2019 concludes that using a 360° VR environment (iVFT with cardboards) in geoscience classrooms shows an improvement of 22-28% in the learning gain of students from three different high schools. These results can be explained by the advantage of virtual environments to enable a close-up experience and observation so that the students can have the feeling of presence and fun of learning (Jitmahantakul & Chenrai, 2019).

It shows that using VR, particularly VFT, in the educational sector is justified. Nevertheless, creating iVFT concerning the curriculum and the content of the subject and lesson in school can be challenging, especially for teachers needing expertise in technology and programming. Aside from that, creating or integrating VFT is time-consuming (Minocha et al., 2018; Thürkow & Gläßer, 2004). Likewise, there could be the need to create own VFT if the existing VFT does not match the lesson planning or the idea of a matching VFT, but '*[…] computer and software skills and available tools at schools may be limited to design and develop VR environments […]*' (Jitmahantakul & Chenrai, 2019). So, existing works show the advantages of using VR in classes on the one hand and the other hand, which it is challenging to create and implement VFT in classes. Some articles on VFT and Virtual Learning environments mention the uses of different software and tools for creating VFT (Chua et al., 2019; Jitmahantakul & Chenrai, 2019; Keller et al., 2018; Lin & Wang, 2021; Minocha et al., 2018; Riemer & Nowotny, 2020; Zhao et al., 2020), but do not get instructions for the use or show the advantages and disadvantages. So, if teachers want to create their VFT or Virtual Learning Environment with this software or tool, the time aspect comes up because they must obtain all information independently.

Based on the known advantages of VR in geographical education, this paper wants to focus on this lack. It aims to compare software and tools for creating a VFT based on 360° images with the focus that people in the educational sector, like teachers without high expertise in technology and programming, can create their own VFTs. For this objective, the following research questions are formulated:

1. What do teachers need to create a VFT?
    a. Which equipment is necessary to create and use a VFT?
    b. What effort is involved in the creation of a VFT?
    c. What skills do teachers need to create a VFT?
2. How do the VFTs affect pupils?
    a. What level of immersion does the VFT offer the pupils?
    b. Which aspects of interaction do the VFT offers pupils?
    c. How can the VFT convey technical content?

This work will give an overview of the required steps for creating a VFT so that teachers who are interested can implement a VFT in classes. For this, four different software/tools were analyzed under selected aspects relevant to the everyday work at school to get an impression of the existing possibilities and obstacles for the creation. In this paper, a prototype of a VFT is created with different software and tools and compared afterwards concerning the research questions. The main objective of the VFT is to give an overview of the area. To research how a VFT can convey technical content, the VFT should be used to analyze biodiversity in an area with exemplary vegetation and bird voice analysis.

Methods

This chapter describes the necessary steps for creating a VFT with four different software/tools. First, creating 360° images is described as the basis for creating VFT. Then the preparatory work for conveying technical content in a VFT is described with the example of biodiversity analysis. Finally, it should be mentioned that the VFT is a prototype to demonstrate the creation of a tour with different software and tools under technical content, without requirement on correctness or completeness of the procedure of the vegetation analysis and bird voices analysis. Afterwards, the creation of VFT with software/tools of four different categories is described.

Creating 360° Images

The VFT in this paper is based on own 360° images because they provide a more realistic visual representation of the field site, a first-person experience in comparison to a fully 3D virtual environment, and the integration into different VR platforms with other sources is more easily (Greussing, 2020; Zhao et al., 2020). However, the record of 360° images requires some preparatory work; Figure 1 gives an overview of the steps for creating own 360° images. The first step is the production of the 360° images. That includes the location selection, the planning of the tour, and the image recording. These three aspects are generally described in the following and concerning our VFT.

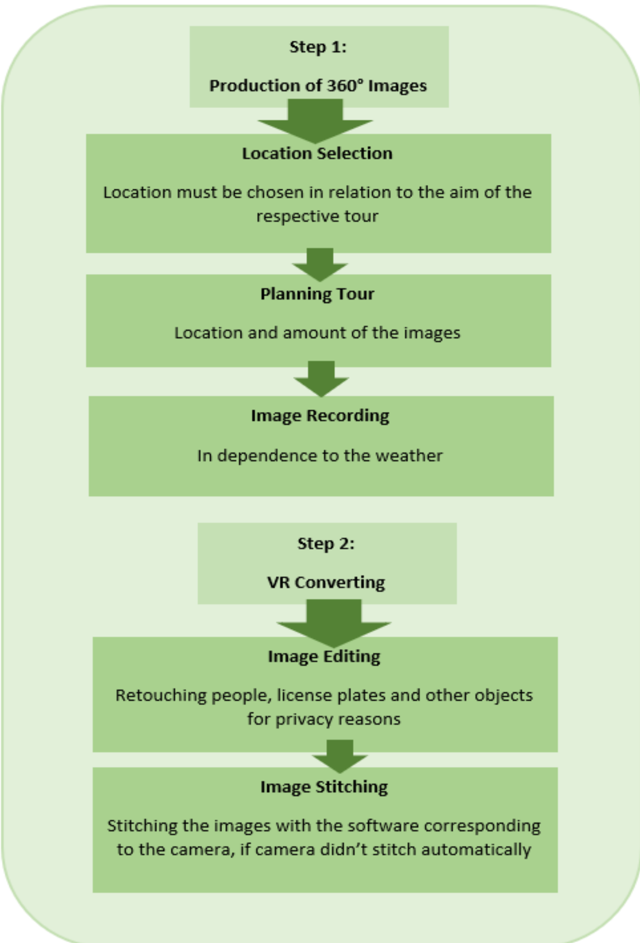

Figure 1. Process of Recording 360° Images

Location Selection: As seen in Figure 1, the first aspect of step 1 is that the location for the VFT must be chosen concerning the aim of the respective tour. We focused on the 'Eskesberg', an area in Wuppertal, Germany, with the coordinates: N51° 15´38 E7°6´14. From the years 1850 to 1956, the area was a limestone quarry. After decommissioning the quarry, it was used as a landfill until 2004. In the years 2004 and 2005, the area was renatured, and the 'Eskesberg' became a nature reserve (Wuppertal, 2021). The aim of our tour is to exemplary analyse the vegetation and the bird voices of an ecosystem. The 'Eskesberg' gives wide green spaces and predetermined ways the opportunity for both.

Planning Tour: After choosing an area, the next step is planning the Virtual Tour. It includes an inspection of the area to get an overview and to plan the different sites for the tour as to which places the images should be recorded. When the VFT is planned as a tour, as walking in this area, it is essential for the sites they are at a distance so that it is possible to see the following site from the actual one, so that the feeling is to walk to the following site. The distance between the sites can variate concerning the spatial conditions from site to site. There should be a few sites for the tour to stay manageable because cybersickness symptoms can increase with time (Singla et al., 2019). We choose 20 sites to get a wide-ranging overview of the ecosystem. The distance between the sites varies from about 20 meters to 65 meters, depending on the circumstances of the way and the viewing distance. Figure 2 gives an overview of the planned tour.

Image Recording: With the planning of the sites, the last aspect of step 1 is to record the 360° images at each site. Due to the technologies and the quality of the images, the weather conditions must be considered. It must be at least a dry day and not be too cloudy for better light. The record of the images for our VFT took place on the 23rd of July 2020, with sunny and clear weather. For the recording, the camera '*Insta 360 Pro 2*' was used, and a 360°image, a 3D image and a 360° video for each location were recorded at average eye level with a resolution of 3849x1920 pixels, a single lens resolution of 1920x1440 pixels and a framerate of 30 fps. The 'Insta 360 Pro' has six lenses and produces an image of each camera. By stitching the six images together in a separate step, the 360° is created. To compare the quality of different 360°cameras at one location, pictures with 'GoXtreme Omni 360', 'Ricoh Theta V' and 'Samsung Gear 360'were taken.

Figure 1 shows that the second step is to convert the recorded 360° images for use in VR. Therefore, the first aspect is *Image Editing:* For privacy reasons, it is necessary to edit the images to retouch people, license plates and other objects. After the editing, the last step is *Image Stitching:* Stitching is the process of putting the images from the individual lenses of the camera together into one 360° image if the camera does not do this automatically. In our case, the freeware software '*Microsoft Paint 3D*' was used to edit the images. Anonymizing was not necessary, but the tripod was retouched for the images. Finally, the six separated images recorded by the '*Insta 360 Pro 2*' were stitched with the Software '*Insta 360 Stitcher*'. The folders with the six images can easily be imported with 'drag and drop', and the software exports the 360° image. To have a better orientation about the tour, we created a map of the area with the tour locations with '*QGIS*', an open-source Geographic-Information-System. This map is shown in Figure 2. The locations, the tour and the area of the vegetation analysis are shown on the map. In the VFT, the map is placed on every site as an image on the bottom of the field of view so that it can be opened if an orientation is necessary. In the VFT, the map of Figure 2 is shown, but at every site, the appropriate location on the map is marked with a red dot.

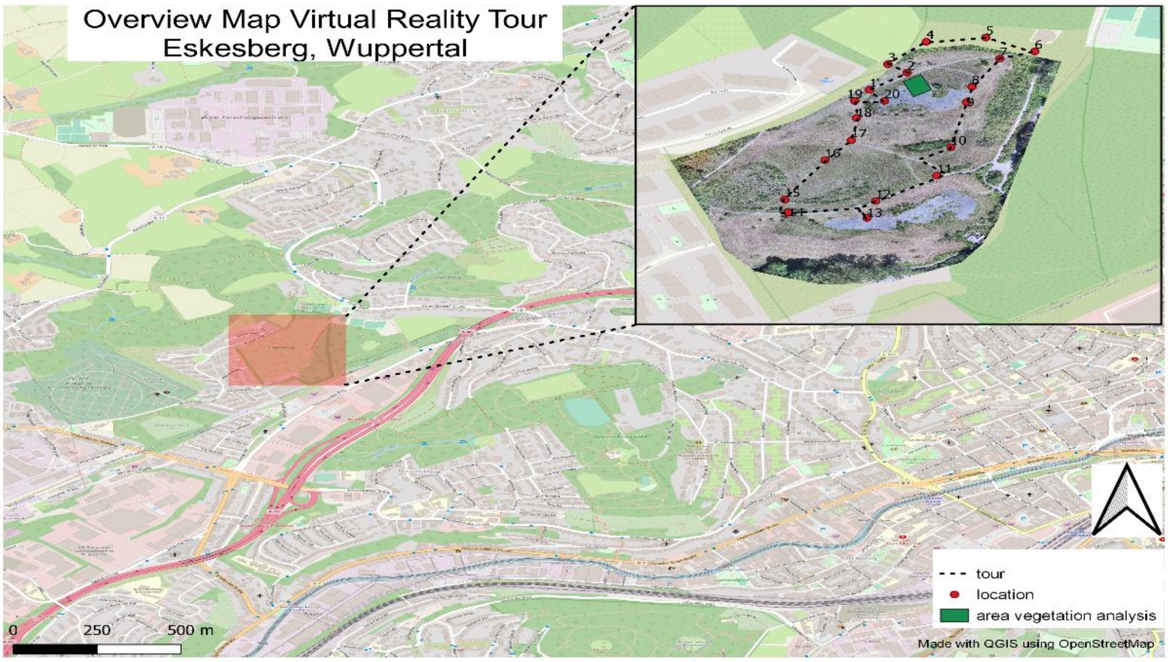

Figure 2. Overview Map of the Tour at 'Eskesberg'

Preparatory Work Technical Content in VR

Some additional preparatory work is necessary to complement a VFT with the aspects of a biodiversity analysis. For analyzing the biodiversity, the vascular plants are used for the floristic biodiversity and the birds for the faunistic biodiversity. The respective preparatory work for analyzing both (in VR) is described below. However, because of the production of a prototype, to work out the workload and the potential of different software and tools, the recording of the images and bird voices took place for only one day and not in the best season for the use case vegetation and bird voice analysis.

Vegetation Analysis

The vegetation analysis only takes place in a part of the ecosystem; an exemplary area was chosen because it just was to analyze the possibility of a vegetation analysis in VR. The vegetation survey was planned according to Braun-Blanquet, 1964. For this method, the area for the vegetation survey must be defined under the following aspects. First, the area has to be homogeneous, which means a structural-physiognomic and floristic uniform characteristic of the inventory is expected. The decision on the homogeneity of an area is primarily intuitive (Tremp, 2005). Besides the homogeneity, the area must have a defined size. The suitable size is obtained by determining the minimum areal of the plant community or by sizes; they were determined empirically for particular vegetation types. For determining the minimum-areal the plant species must be counted in an area that is doubled systematically. The number of species found in that area is entered in a species-area curve. If the minimum-areal is reached, the number of species does not increase appreciably. For the area at 'Eskesberg', the size of 25 m2 was defined by the empirically determined size for grassland as vegetation type (Tremp, 2005).

Besides the definition of the area for the vegetation analysis, another preparatory work was to take detailed images of every plant in this area. It is necessary because the recorded 360° images (resolution of 3849x1920) cannot show every plant in the necessary detail to classify the plant. So, detailed pictures of every plant's blossom, stem, leaf and ground were taken with the '*Canon EOS 5DS'*, a resolution of 5792x8688 pixels, a focal length of 50 mm and no flashlight.

Analysis of Bird Voices

It is necessary to record the bird voices in the area to analyze the birds virtually. The voices are recorded as audio, so the birds in the area can be analyzed due to their twittering. The record of the bird voices took place in the early morning hours on the 6th of August 2020. Recording the voices on different days, times, and seasons is necessary to get a representative effect from the birds in this area. Here we just recorded one day because this paper focuses on the technical implementation in VR.

Digital Book

Concerning the problems of cybersickness in VR, because symptoms of cybersickness, like nausea, headache or drowsiness, are triggered by virtual stimuli, and they increase with an increase in time (Rebenitsch & Owen, 2021; Singla et al., 2019), an alternative to integrate the technical content of vegetation analysis and bird voices analysis can be a digital book. For digital (school)books, there is a rough classification into four types, (1) static e-books, (2) static e-books with interactive supplementary material, (3) e-books with integrated multimedia content and (4) interactive e-books with integrated multimedia content (multitouch learning books) (Ulrich & Huwer, 2017). This work focuses on multitouch learning books, where additional materials, like worksheets or learning cards, can be integrated into an interactive digital book. These books offer the flexibility to adapt the content and methods. The software creates a multitouch learning book and inserts texts and images (Huwer et al., 2018). We use the '*BookCreator' (Book Creator app, 2021)*, which can be used as an app or online as a browser version. The online version is without costs; only registration is necessary.

Creating Virtual Field Trip with Different Software and Tools

This paper aims to compare different software and tools for creating immersive Virtual Field Trips with own 360° images. The four categories were formed to decide which software and tools would be compared. A) A commercial software/tool; B) A software/tool without costs and registration; C) A software/tool without costs but with registration; D) A Game Engine. So, for every category, one software/tool was exemplarily chosen A) '*VR Suite Present 4D'* (Trzaska, 2021), B) 'Marzipano' (Marzipano - a 360° Viewer for the Modern Web, 2021), *C)* '*Google Expedition Tour Creato*r' (Tour Creator, 2020) and D) '*Unity' (*Unity Technologies, 2021), where it is possible to use own 360° images, the software and tools with their handling and possibilities are described in this section. For creating the VFTs with the different software/tools, the gaming laptop '*Acer ROG STRIX G RTX 2070'* was used, costing about 1500€.

Virtual Field Trip with a Purchasable Software/tool

For the category of purchasable software/tool, we used the software '*VR Suite Present 4D'* (Trzaska, 2021)*; other* examples of software/tools in this category are '*Pano2VR*' (Garden Gnome, 2022), '*CloudPano*' (CloudPano, 2022), '*Kuula*' (Kuula, 2022) and '*3D Vista'* (3DVista, 2021). '*VR Suite Present 4D'* is a software for creating Virtual Tours, where you need a licence with costs. With this licence, it is possible to use the software with different computers HMDs. Therefore, it is possible to create a new project on the computer desktop or in VR with an HMD. The following description of creating a new project is for working on the computer desktop. For creating a new project, the Editor Mode must be started. With the Editor Mode, icons' interactivity is disabled so that they are movable. The iMenu must be opened first to add 360° images. With each 360° image, the software creates a separate tour scene and a Hotspot. The Hotspots connect to the other scenes, making the tour a walk-through VFT. The Hotspots in every scene can be moved with drag and drop with the mouse. The iMenu gives an overview of each scene, making it easy to switch between them. After importing the 360° images, it is possible to complete every scene with different media. That also works through the iMenu. These media are Images, Sounds, Points of Interest (POI) and a Quiz. After finishing the tour, it is possible to distribute the project via the Cloud of the software or a cable to other devices, like an HMD or smartphone.

For our VFT, the 20 recorded 360° images were imported into the software and connected with the hotspots. For the vegetation analysis, the recorded detailed images of the plants were added at the corresponding location in the tour. The recorded bird voices could be added as a sound in every location. To not add the sound in every location, it is possible to add it throughout the whole tour in the project's source code. There is also the possibility to change the colors of the iMenu, the icons of the media, as well as the size of the media icons in the source code.

Virtual Field Trip with a Software/tool without Costs and Registration

The online tool '*Marzipano' (*Marzipano - a 360° Viewer for the Modern Web, 2021) was chosen for the category of software/tool without costs and registration. It is a browser-based tool for creating Virtual Tours online. To start creating a tour, the 'Marzipano' Tool button must be clicked when going to the tool's homepage. After clicking the button, the first step is to add the 360° images with drag and drop or select files. Various images can be added simultaneously, and more images can be added later. The tool creates with every image a separate tour scene. The position of the scenes in the tour can be changed per drag and drop in a list of the scenes. For every scene, adding an information hotspot and a link hotspot is possible. With the information hotspots, an information text can be formulated and placed everywhere in the image. The link hotspot is connected to the next scene so that the tour can be a walk-through VFT. Also, the link hotspot can be moved with the mouse with drag and drop. It is necessary to export the project to save it. With the export of the project, the tool generates a folder with different files to download. The Javascript, HTML and CSS files must be edited for customizing the project after the export. In Javascript, adding images and sounds to the scene is also possible. However, only if an information hotspot was created before the sound or image could be connected to the information hotspot. Finally, the HTML file must be opened with a web browser to view the project. That is only possible when hosting the sources of the images on the same device. For our VFT, the 20 recorded 360° images were uploaded and connected with link hotspots to a walk-through VFT. After exporting, the images and sounds for the vegetation and bird voices analysis were added to the tour in the source code.

Virtual Field Trip with a Software/tool without Costs, but with Registration

For the category of software/tool without costs but with registration, the '*Google Expedition Tour Creato*r' (Tour Creator, 2020) was chosen. Other examples of software/tools for category C are '*Orbix 360°*' (Orbix360°, 2022), '*Theasy*' (Theasys, 2022) and '*Lapentor*' (Lapentor - Free 360° Virtual Tour Software, 2022). It is a browser-based tool for creating Virtual Tours online. For creating a tour with this tool, a google mail account is needed for registration. When creating a new tour, a cover photo can be chosen in the first step, an image can be dropped in a frame, or a file can be selected. Also, the tour can be titled, a description can be formulated, and a category for the tour, like history, art or science, can be chosen. Now it is possible to create the tour. The next step is adding a scene; here, it is possible to add an image from *Google Street View* or an own 360° image. The 360° images can be uploaded with drag and drop or by selecting a file. Just one image after the other can be uploaded to the tool. It is possible to title every scene and give a description. Also, ambient audio, a scene narration and a point of interest can be added in every scene. The created tour is automatically saved online and connected to the *Google* mail address, so it is possible to make changes later.

For our VFT, the 20 recorded 360° images were uploaded. For the vegetation analysis, it is impossible to include the recorded detailed images of the plant. However, the recorded bird voices could be added as ambient audio to every scene. Here should be mentioned that during the work for this paper and the comparison of the software/tool, *Google* announced that '*Google expedition'* will be shut down poly on June 30, 2021.

Virtual Field Trip with a Game Engine

As a fourth category, a game engine was used, where it is possible to create a VFT with 360° images. The software '*Unity'* (Unity Technologies, 2021) was chosen for this. '*Unity'* offers different products depending on if you are a private person or a team. For private persons, '*Unity'* differs between students and personal use. First, students can register to get to know the tools and workflows. The requirements are the age of 16 or older, and they must be enrolled in an accredited educational institution. Then they get the newest version of the '*Unity'* development platform, five places for the '*Unity'* team's advanced and cloud diagnosis in real-time.

For personal use, it is possible to register for the free '*Unity'* version to build the first content. The requirements are sales and donations of less than 100.000$ in the last 12 months. Then the newest version of '*Unity'* and resources for the beginning and learning '*Unity'* can be used. For teams from all industry sectors, '*Unity'* offers the products *Unity* Plus' and '*Unity* Pro'. '*Unity* Plus' requires sales of less than 200.000$ in the last 12 months.

Then it can obtain a place for 369€ per year for '*Unity'* with the extras of adjusting the splash screen, expanded cloud diagnosis, ads and in-app purchases and 25 GB Cloud storage. The '*Unity'* Pro costs 1.656€ per year with the extras of splash screen customization, expanded cloud diagnosis, technical support, available source code and ads and in-app purchases (Unity Technologies, 2021).

'*Unity'* is a game engine, so not specially developed for creating VR Tours. First, it is necessary to download and install the software. The program *Microsoft Visual Studio* must be installed to edit the source code. Next, it is necessary to download and install the '*Googles Software Development Kit'* to create a VR application for smartphones with google cardboard. The VR Tour with the cardboard is for Android-Smartphones, so some settings must be changed. The Android platform must be chosen in the editor's menu at 'file' and 'build settings'. Then, with a click on 'player settings,' it is now possible to do more settings. For example, at 'XR Settings', a checkmark can be clicked for 'Virtual Reality Supported', and with the Symbol '+', the platform 'Cardboard' can be added.

To implement 360° content in '*Unity',* spherical mapping is an option, where all pixels of a video or picture are pictured to the inner side of a hollow sphere. For creating a sphere in '*Unity',* the 3D Object sphere can be created, which size can be scaled, and position can be changed. For rendering the sphere from within and not like generally from the outside, a shader must be created, and the source code of this shader must be changed. To the shader, new material must be created and assigned to the sphere with drag and drop. The corresponding picture must be imported to 'Unity' to picture images and videos within the sphere. A folder can be created, and the images or videos can be imported with drag and drop to the folder. The image or video can be dragged and dropped into the sphere by opening the folder. A new material with the shader 'FlipNormals' should be created automatically. The image or video is now within the sphere but dark and mirrored. The scale must be changed from (50,50,50) to (50,50, -50) to change the mirrored representation. The directional light is created automatically by starting a new '*Unity'* project. This one must be deleted, and a point light must be created with a right click to the main camera in the hierarchy window. The light still is not that bright, so the range and the intensity of the point light must be changed. Now with this sphere, one scene of the VFT is created. For creating more scenes for the tour, it is now possible to duplicate the created sphere and change the image or video. Navigation between the scenes is possible through a hotspot, so they must be created for a walk-through VFT. For this, a sphere into the sphere is necessary. So, a new sphere must be created, and the size must be scaled from (1,1,1) to (0.1,0.1,0.1) so that it is smaller than the sphere from the scene.

With the navigation in the scene view, the hotspot can be placed in the correct position. However, the view in the scene view is not like the game view, so the position of the hotspot must be checked with a switch to the game view. A hotspot like this has no function, so it must be interactive and touchable. For this, the hotspot needs the components 'GVR Pointer Physics Raycaster' and 'EventTrigger'. With these two components, the hotspot is interactive but still without the needed function. For this, a new script for the hotspot must be written, where it gets the command to change positions. When saving the script, the variables' Player' and 'Room' are now in the Inspector in '*Unity'*.

For the variable ‘Room’, the next sphere can be placed with drag and drop into the field next to ‘Room’. Next, a new object must be created for the ’Player’, and the main camera must be placed on the ‘Player’. The ‘Player’ now has to be placed in the field next to ‘Player’ in the Hierarchy window. Now action can be assigned to the component ‘EventTrigger’ in the Inspector. With clicking ‘Add New Event Type’ and choosing ‘PointerClick’, an action is created exactly as when a hotspot is clicked or when it is in the focus of a touch. In the new row, clicking the ‘+’ Symbol and adding an action to the pointer click is now possible. There the hotspot must be dragged into the field. Next to this is a new drop-down menu, where the options’ HotspotController’ and then ‘ChangeRoom()’ must be chosen. Like this, all hotspots between the scenes can be created. The smartphone must be connected to the computer, and then in the ‘*Unity’* menu ‘File’ and then ‘Build and Run’ must be clicked to test it (BesoBerlin, 2021).

To the scenes, it is possible to add audio over the ‘*Unity’* menu ‘component’, then ‘audio’ and ‘audio source’. Now it is possible to add the source into the field with drag and drop. With the relevant coding knowledge, it is possible to create nearly everything with *Unity; the* three scripting languages JavaScript, C# and Boo, are supported by ‘*Unity’*. For this project, the scripting language C# was used.

For our VFT, 20 spheres for the 20 recorded images were created and connected with hotspots for a walk-through VFT. The sounds for the bird voices analyses were added as an audio source to the spheres. With the coding knowledge, adding images to the matching plants was possible, but they were too small. A bigger size for images of about 20 plants is not possible in one scene. So, the images must be interactive, so they change size when clicking or touching the image. For this, the coding knowledge needed to be sufficiently high. Before creating the VFT, the creator practiced scripting and the work with ‘*Unity*’, so the specifications for the work with this software in the following captions are based on this experience level.

Results and Discussion

The comparison of the software/tools is based on the research questions and analyses the four software/tools under the following aspects: technical equipment for creating a VFT, time effort for creating a VFT, computer skills for creating a VFT, immersion of the created VFT, the interaction of the created VFT and the convey of technical content through the VFT. So, the main categories are based on the steps of creating a VFT and immersion and interaction as the main advantages of VFT emerging from the literature (Makransky et al., 2021; Nalluri et al., 2021). Therefore, for every main category presented as a table in this chapter, subcategories were formed on the material (software/tool).

Requirements for Creating a VFT

Technical Equipment for Creating a VFT

It is necessary to have a 360° camera, a software/tool to create a VFT and an output device to use the VFT for creating and using a VFT with its own 360° images. That is technical equipment where the price range is wide, and the quality varies because there are different options for every category, as shown in Table 1. So, from a teacher's perspective, it is essential to determine which equipment is necessary to create a VFT and what costs are involved because it cannot be assumed that schools have this technical equipment.

Table 1 shows the technical equipment camera, software/tool and output devices for creating and using a VFT. For each category, different ones were tested for different user categories, for beginners, advanced and professionals with different equipment prices. Most equipment's system requirements are low, so all newer *macOS* and *windows* 10/11 computers can be used. The division into beginners, advanced and professionals is based on the prices, handling and technical requirement for using the equipment.

The first category is 360° cameras with the four examples that were available for us, of '*GoXtreme Omni 360*', '*Ricoh Theta V*', '*Samsung Gear 360*' and '*Insta 360 Pro2*', for every camera the approximate price, the resolution of the images and the control technology is listed in the table. The '*GoXtreme Omni 360*' is a camera for 'Beginners', costing approximately 60€. The camera has two lenses and a resolution of 2048x1024 pixels. To control the camera, a smartphone with an Android operating system and an installed App is necessary; this App can only be used with Android. The camera is attached to the device to connect the camera to the smartphone. The images will be saved in the App on the smartphone (GoXtreme® Action Cams, 2018).

For the user category 'Advanced', we could test the two cameras, '*Ricoh Theta V*' and '*Samsung Gear 360'*. The '*Ricoh Theta V*' price is approximately 400€; the camera has two lenses and a resolution of 5376x2688 pixels. A smartphone with iOS 13-14.6, iPhone 6s or higher, iPadOS 13-14.6, and iPadAir2 or higher is needed as technology to control the camera. Also, smartphones with Android OS 8-11 can be used, but the operation is not guaranteed on all devices. The use of an App is necessary, and the images are saved on the camera and can be transferred with the App on the smartphone (Ricoh company, 2022).

With a price of about 220€ the '*Samsung Gear 360*' is in a price range between the '*GoXtreme Omni 360'* and the '*Ricoh Tetha V'*. The camera has two lenses and a resolution of 4094x2048. It is necessary to install an App on the Smartphone: Galaxy S8, Galaxy S8+, S7, S7 edge, S6 edge+, S6, S6 edge, A5 (2017), A7 (2017) with Android 5.0 or higher or iPhone 7, 7 Plus, 6S, 6s Plus, SE, with iOS 10.0 or higher to control the technology. The images are saved on a memory card in the camera and can be downloaded on the smartphone when connected to the camera (Samsung, 2017).

The '*Insta 360 Pro2*' with an approximate price of 5600€ is assigned to the user category 'Professionals'. With six lenses, the camera has a resolution of 7680x3840 for 360°-images, 7680x3840 for 360°-videos, 7680x7680 for 360°-3D-images and 64000x6400 for 360°-3D-videos. A smartphone with Android 7.0 or higher, iOS 10.3 or higher, and an App are necessary to control the camera. The images are saved on six micro SD cards and one SD card in the camera and can be exported to a computer (Insta360, 2022).

To compare the quality of the different 360° cameras concerning the resolution, Figure 3 shows images recorded with each camera at the same place and time so that all influencing factors are equal. The images are represented as panoramas with a zoom on an image section and are not included in VR Software with a 360° view. The colour in the images varies concerning the camera. The sky on that day was clear and blue, which is not shown in the image taken with the camera of the ‘Beginner’ category, where the color of the sky seems greyer. The other cameras’ images show the sky’s color as similar and realistic. The color of the grass is also not so intense in the image of the `Beginner’ category as in the other images. About the resolution, a difference is discernible from the image taken with the category `Beginner’ camera compared to the other three cameras. The grass and the building are blurred. Whereas in the other pictures, it is focused. Between the images taken by the cameras of the categories’ Advanced’ and Professional’, a difference is shown when looking at the trees at the top of the image. The tree branches are distorted in the images taken with the category ‘Advanced’ cameras. That could be because of the representation as a panoramic. However, on the image from the ‘Professional’ camera, it is not distorted.

Figure 3. Images with a Zoom Factor recorded with the **a** ‘GoXtreme Omni 360’, **b** ‘Ricoh Tetha V’, **c** ‘Samsung Gear 360’ and **d** ‘Insta 360 Pro 2’ to compare resolution

The next category for the equipment is the software/tools to create a VFT out of the recorded 360° images. The four software/tools ‘*VR Suite Present 4D’*, ‘*Marzipano*’ and ‘*Google Expeditions Tour Creator’* and ‘*Unity*’ with the approximate price are assigned to the user categories. The three software/tools ‘*VR Suite Present 4D’*, '*Marzipano*' and '*Google Expeditions Tour Creator'* are for beginners/advanced concerning the necessary skills for using, which are shown in detail in Table 1. '*VR Suite Present 4D'* is a software and is associated with costs, the price range for an education version is 150-500€. '*Marzipano*' and '*Google Expeditions Tour Creator'* are online browsers free of cost. For the use of '*Google Expeditions Tour Creator,'* a registration with a google mail address is necessary.

The software 'Unity' is associated with professional users. Therefore, registration is necessary for the user but is free of cost for non-commercial use. The last category for the technical equipment in the table is the output devices. For the user category beginners, smartphones mounted on headsets, like cardboard, can be used for approximately 14€. That is a VR glass made of cardboard for putting the smartphone in as the output device.

For the user category advanced/professionals, we used two Head-Mounted-Displays. We had the '*Oculus Go'* as a stand-alone HMD and the '*Oculus Rift S'* as a computer-based HMD available. During the work of this paper, '*Oculus*' (now *Meta*) stopped the production of both HMDs. Therefore the '*Meta Quest 2*' (approx. 500€) can be named as an alternative to the HMDs we used (Meta, 2022). The '*Oculus Go'* is a stand-alone HMD, an independent HMD without a connection to a computer. The resolution from the '*Oculus Go'* Display is 1280x1440 per eye, with a refresh rate of 60-72 hertz (Grover Deutschland GmbH, 2022a). The '*Oculus Rift S'* is a computer-based HMD, so it is powered by a computer. The display's resolution per eye is 1280x1440, with a refresh rate of 80 hertz (Grover Deutschland GmbH, 2022b). As the '*Oculus Rift S'* is a computer-powered HMD, higher system requirements of a computer are necessary. These and the requirements for the '*Meta Quest 2'* as an alternative to the '*Oculus Rift'* are included in a table in the appendix.

Table 1. Comparison of Technical Equipment (360° camera, software/tool and output device) for creating a VFT (Google, 2022; GoXtreme® Action Cams, 2018; Grover Deutschland GmbH, 2022a, 2022b; Insta360, 2022; Meta, 2022; Ricoh company, 2022; Samsung, 2017)

Category		**Price**	**Information**	
360°Camera			Resolution	Control technology
Beginners	GoXtreme Omni 360°	approx.60€	2048x1024 2 lenses	Smartphone: Android operating system; With App; Image saves on smartphone
Advanced	Ricoh Tetha V	approx.400€	5376×2688 2 lenses	Smartphone: iOS 13-14.6, iPhone 6s or higher, iPadOS 13-14.6, iPadAir2 or higher; Android OS 8-11 (operation is not guaranteed on all devices); With App; Image saves on the smartphone
	Samsung Gear 360	approx.220€	5792x2896 2 lenses	Smartphone: Galaxy S8, Galaxy S8+, S7, S7 edge, S6 edge+, S6,

Category		Price	Information	
360°Camera			Resolution	Control technology
				S6 edge, A5 (2017), A7 (2017) with Android 5.0 or higher; iPhone 7, 7 Plus, 6S, 6s Plus, SE, with iOS 10.0 or higher; With App; Image saves on a memory card in the camera
Professional	Insta 360 Pro 2	approx.5600€	360°-image: 7680x3840; 360°-video: 7680x3840; 360°-3D-image: 7680x7680; 360°-3D-video: 64000x6400 6 lenses	Smartphone: Android 7.0 +; iOS 10.3+; With App; Image saves on six micro SD cards and one SD card in the camera
VR Software/Tool				
Beginners/ Advanced	VR Suite Present 4D	150-500 € (Education version)	VR Software	
	Marzipano	free	Online Browser	
	Google Expeditions Tour Creator	free	Online Browser	
Professionals	Unity	free	Software/Game Engine	
Output Device				
Beginners	Smartphones mounted on headsets (Cardboard)	approx.14€	VR glasses out of a cardboard for putting the smartphone in as an output device.	
Advanced/ Professionals	Stand-alone HMD (Oculus Go)**	699-999€*	Independent VR Headset without connection to a computer. Resolution of 1280x1440 per eye. A refresh rate of 60-72 Hz	
	Computer-based HMD (Oculus Rift S)**	699-999€*	VR headset powered by computer Resolution of 1280x1440 per eye. A refresh rate of 80 Hz	

*prices from a German price comparison website, 2022-01-21

** production stopped, alternative ‘*Meta Quest 2’* (500€)

Time Effort for Creating a VFT

Creating a VFT includes preparatory work, which takes time and varies concerning the used software/tool. Table 2 shows the time effort of preparatory work for a VFT, which is separated by the time for creating the 360° images and for preparatory work for the VFT. For the creation of the 360°- images, different steps with different time efforts are necessary. First, the location must be chosen; this can take several days. Inspecting the chosen location can also take several days, it depends on the size of the area. Then, the recording of the 360° images takes per image less than ten minutes (with the '*Insta 360 Pro*'). After recording the images, it is necessary to edit and stitch them. The editing takes less than ten minutes per image, and the stitching takes less than ten minutes (with the '*Insta 360 Stitcher*'). Finally, the creation of a map to integrate into the VFT for an orientation of the tour and the area takes approximately 3 hours when having GIS skills. Without GIS skills, more time must be considered for this aspect. So, for the preparatory work for a VFT with 20 sites, there is, in total, a time effort of approximately ten hours, excluding the additional time of the location choosing and inspection, which took, in our case, a total time of several days.

Table 2. Time Effort Preparatory Work for Creating a VFT

Working step	**Approximate time**
360° images	
Choose location	(Several days)
Inspection location	(Several days)
360° images Recording	< 10 minutes per image
Image editing	< 10 minutes per image
Image stitching	< 10 minutes
Preparatory work VFT	
Map for orientation (with GIS skills)	< 3 hours
Time in total (with 20 sites)	approx. 10 hours

Table 3 shows the time effort to create the different aspects of a VFT for the four tested software/tools. The first line shows that only using category D requires a training period, which also means an expenditure of time. So, when a time effort for category D is named in the following, this did not include the time for a training period when they have yet to get programming skills. With the categories A, B and C, creating a scene takes less than five minutes, and with D less than 15 minutes. The time effort to create a hotspot with A and B is less than five minutes, category C does not offer the opportunity to create a hotspot, and creating a hotspot D takes less than 30 minutes.

For the time effort when adding optional aspects to the VFT, we chose 'interactable images', 'sound' and 'quiz' as an example concerning our VFT with vegetation and bird voices analysis content. The following time effort can be expected when the software/tools offer the aspects. Only category A allows integrating an interactable image, which takes less than five minutes per image. The integration of a sound is offered by A, C and D, which takes less than five minutes. The software of category A offers the opportunity to integrate a quiz, which takes less than 30 minutes. This time indication refers only to the technical implementation; more time must be considered to create the content for the quiz.

With B and D, it is possible to add interactable images with scripting; with B, it takes less than 30 minutes, and with D more than 60 minutes. Likewise, a sound can be added with scripting when using the tool of category B, which takes less than 30 minutes. Only with category D can a quiz be added with scripting; this takes more than 60 minutes; here, the time indication also refers to the technical implementation. So, creating a VFT with 20 sites, without optional aspects, takes approximately three hours with the tested software/tool of categories A and B, approximately two hours with C and about 15 hours with D. With approximately ten hours of preparatory work, it takes about 13 hours to create a VFT with 20 sites with the tested software/tool of categories A and B, 12 hours with C and approximately 25 hours with D.

Table 3. Time Effort for Creating a VFT with the Software/tools of Category A, B, C and D

Working step	**A**	**B**	**C**	**D**
Training period	×	×	×	✓
Creation of a scene	< 5 minutes	< 5 minutes	< 5 minutes	< 15 minutes
Creation of a Hotspot in a scene	< 5 minutes	< 5 minutes	--	< 30 minutes
Optional aspects offered from the software/tool				
interactable Image (orientation map)	< 5 minutes	--	--	--
Sound	< 5 minutes	--	< 5 minutes	< 5 minutes
Quiz*	< 30 minutes	--	--	--
Optional aspects created with scripting				
interactable Image	--	< 30 minutes	--	>60 minutes
Sound	--	< 30 minutes	--	--
Quiz*	--	--	--	>60 minutes
Time in total (for a VFT with 20 sites, **without** optional aspects)	approx. 3 hours	approx. 3 hours	approx. 2 hours	approx. 15 hours
Time in total with Preparatory work (10 hours; 20 sites; without optional aspects)	approx.13 hours	approx.13 hours	approx.12 hours	approx.25 hours

* technical implementation, without the creation of the content

Computer Skills for Creating a VFT with Exemplary Software/tool

The software/tools require some creator skills; this varies concerning the software/tool. Table 4 compares the software/tools on a scale from zero to five. Zero means a low level of skills is necessary, and five means a high level of skills is necessary. The four software/tools were compared for each category to evaluate the level of skills, and the points were awarded concerning the tested software. A low level of skills means that the creation through the software is intuitive, whereas, for a high level of skills, the creation is not intuitive or given by the software and requires scripting skills.

Table 4. Computer Skills for Creating a VFT with the Software/tools of Category A, B, C and D with a Scale from 0-5, 0 = low level of skills and 5 = high level of skills

Working step	**A**	**B**	**C**	**D**
Graphical user Interface	● ● ○ ○ ○	● ○ ○ ○ ○	● ○ ○ ○ ○	● ● ● ● ●
Creation of a tour scene	● ○ ○ ○ ○	● ○ ○ ○ ○	● ○ ○ ○ ○	● ● ● ● ●
Creation of optional aspects	○ ○ ○ ○ ○	○ ○ ○ ○ ○	○ ○ ○ ○ ○	○ ○ ○ ○ ○
Interact-able Image	● ○ ○ ○ ○	● ● ● ● ○	○ ○ ○ ○ ○	● ● ● ● ●
Sound	● ○ ○ ○ ○	● ● ● ● ○	● ○ ○ ○ ○	● ○ ○ ○ ○
Quiz	● ● ○ ○ ○	○ ○ ○ ○ ○	○ ○ ○ ○ ○	● ● ● ● ●

The three software/tools of categories A, B and C have a graphical user interface, which means the creation of the VFT is intuitive just by clicking through it. The tested software of category D has a graphical user interface for essential aspects, but primarily additional scripting is necessary. The skills necessary to operate the graphical user interface of the software/tool are shown in the first line. With two of five points, the operation of the graphical user interface in category A and one of five points in categories B and C requires a low level of skills from the creator. In contrast, the software in category D requires five of five points high skills. When the 360° images are uploaded to the software/tool, categories, A, B, and C automatically create a scene for each image. D does not create a scene automatically with 360° images. It is necessary to create a sphere for each image as a scene of the VFT, requiring scripting skills. So, for creating a tour scene, Category A, B and C have, with one of five points, a low level of needed skills, shown in the table's second line. Moreover, concerning the necessary scripting skills, D requires, with five of five points, a high level of skills for creating a tour scene.

Creating optional aspects for the VFT requires different skills, depending on the software/tool and the possibility of creating it, either with the graphical user interface or scripting. For the optional aspect, we chose the exemplary ones we needed for the VFT, so interactable images, sound and quizzes are listed in the table. Creating interactable images with the software of category A requires one of five points, and with B, four of five points of skills. On the other hand, the tested tool of category C does not offer the opportunity, and with D, high skills are necessary with five of five points.

Adding a sound to the VFT with the software of category A, just a low level of skills is necessary (one of five points). The tool of category B requires higher skills with four of five points, and the software/tool of categories B and C requires one of five points, just a low level of skills. Only categories A and D allow integrating a quiz into the VFT. Therefore, with two of five points, lower skills are necessary when using the software of category A than the one of category D, where a high level of skills (five of five) is necessary.

Effect of the VFT on Pupils

Immersion of the VFT Created with Exemplary Software/tool

Immersion is an essential aspect of VR because it means the feeling of being physically present in a virtual world (Nalluri et al., 2021). Table 5 compares the software/tools in different aspects of immersion using the VFT with a scale from zero to five. The more black points in the scale, the more immersive it is. Immersion is based on the technical features of output devices (Dörner et al., 2019); that is why the first line compares the immersion of the software/tool regarding the display that can be used as an output device. Because of the possibility of using an HMD as an output device when creating a VFT with the tested software, category A has five of five points for the immersion. A VFT created with the tested tool of category B can just be watched on the computer as an output device and display, so it is not so immersive and has just one of five points. On the other hand, the tested software/tool of categories C and D are also immersive regarding the display because an HMD can be used, so they both have five of five points.

'*For a complete immersion in a virtual world, all our five senses should be involved*' (Freina & Ott, 2015). So, the second line compares the software/tool concerning the involved senses. The senses of sight and hearing are involved in the created VFT of all software/tools. However, the three other senses of touch, smell and taste are not involved in the VFTs created by all four tested software/tools. So, all four software/tools have two of five points for immersion regarding the involved senses. Spatial immersion means a person feels '*being physically present in a non-physically world*' (Freina & Ott, 2015); navigation through the virtual world is essential, so the user feels like walking through the tour. That is why the third line compares the possibilities for navigation in the VFTs with the different software/tools.

Category A is with four of five points immersive regarding the navigation. This VFT has hotspots to navigate from one scene to the other, so it is a walk-through tour because it is possible to 'walk' from one scene to the next. The navigation is with eye tracking, so the scene changes when watching on the hotspot for a few seconds. The navigation in a VFT created with the tested tool of category B takes place with the computer mouse and hotspots, so it gets two of five points for the immersion. The tested tool of category C is less immersive than the other because it is not a walk-through tour. After all, it is not possible to add hotspots. With the tested software of category D, it is possible to create a walk-through-tour with hotspots, so it has four of five points for the immersion regarding the navigation.

Table 5. Level of Immersion from the VFT Created with the Software/tools of Category A, B, C and D with a Scale from 0-5, 0 = low level of skills and 5 = high level of skills

Aspect of immersion	**A**	**B**	**C**	**D**
Display for 360° images	●●●●●	●○○○○	●●●●●	●●●●●
Senses involved in the VFT	●●○○○	●●○○○	●●○○○	●●○○○
Navigation through the VFT	●●●●○	●●○○○	●○○○○	●●●●○

Interaction of the VFT Created with Exemplary Software/tool

Like immersion, interactivity is also a distinguishing element of VR. ‘Interactivity is a technical feature of the virtual learning tool related to the learner’s sense of user control and agency’ (Makransky et al., 2021). The level of interactivity and the learner’s sense of user control and agency can vary. The interactivity in VFT, for example, moving in the simulated world or interacting with objects, can facilitate and, in the same way, impede learning (Makransky et al., 2021). The VFT designed with the different software/tools offer different levels of interaction with objects. A comparison of exemplary objects is shown in Table 6.

Table 6. Level of Interaction from the VFT Created with the Software/tools of Category A, B, C and D with a Scale from 0-5, 0 = low level of skills and 5 = high level of skills

Interactable Object	**A**	**B**	**C**	**D**
Images	●●○○○	●●○○○	○○○○○	●●○○○
Point of Interest/Information hotspot	●●○○○	●●○○○	●●○○○	●●○○○
3D Objects	●●●●○	○○○○○	○○○○○	●●●●○
Quiz	●●●●○	○○○○○	○○○○○	●●●●○

On a scale from one to five, the level of interaction is shown, zero means a low level, and five is a high level of interaction. With the tested software of category A, it is possible to add an image. This image is small and just with an icon, but when looking at it with the HMD or clicking on it on the desktop, so after an interaction, the size changes, and the image appears over the whole screen. This kind of interaction has two of five points and is also possible with the tested software/tool of categories B and D, so they have two of five points. With the tested category C tool, it is impossible to add images.

The second line shows the interactivity of the Point of Interest/information hotspot, which can be added in the tested software/tool of categories A, B, C and D. All of them have two of five points because the interaction is the same as the images, so it is possible to point/click on it, and then the information is shown. It is possible to integrate 3D objects in the VFT of categories A and D. In both software, these objects can be rotated in all directions, so the interaction has four of five points. Also, it is possible to integrate a quiz with A and D. Here, it is possible to interact by clicking on the correct answer to a question. So, with four of five points, there is a higher level of interaction.

Convey of Technical Content through VFT Created with Different Software/tool

For conveying technical content in a VFT, optional aspects are necessary to not only have the tour based on the 360° images, which give an overview of the environment. Nevertheless, VR can be integrated efficiently into education when embedded in pedagogical and technical concepts (Hellriegel & Čubela, 2018). The option given by the software/tool to integrate expertise can also be seen in Table 6. These aspects will be discussed in the following with the example of the vegetation and bird voices analysis.

For the vegetation analysis, it is necessary to integrate detailed images of the plants because the 360° images are not sufficiently detailed to show the identification characteristics of every plant. Adding an image is not possible with the tested software/tool of category C with the tested tool of category B, it is theoretically possible to include images in the source code, but in practice, it does not work with just a lower level of programming skills. So, these tools are useless for creating a VFT for vegetation analysis. Images can be added with the tested software of category D, but they are not intractable. So, if there is an image, it must be at a size so that details are recognizable. That is not possible for a floristic analysis because the number of detailed images of plants would cover up the environment. A high level of programming skills is needed to make the images interactable, so they change size when pointing at them. So, D is also not useful for creating a VFT for a vegetation analysis for teachers with just a lower level of programming skills. With the tested software of category A, adding interactable images that change size is possible when pointing at it to the VFT. So, at the corresponding location, an image of the area for the vegetation analysis and the images with the detail of the plant can be added and placed next to the plant in the 360° image. Also, it is possible to add a 360° image where the area for the vegetation analysis is staked out. With the images, the basics for a vegetation analysis can be integrated into the VFT with A. For the analysis of the plants, an identification key is necessary. This identification key must be included in VR. With A, one possibility to add a plant identification key is with the option of a quiz.

It is necessary to add the audio with the recorded bird voices for the bird voices analysis. With the tested software of categories A and D, it is possible to add a sound played during the whole VFT or when walking to one scene. The tool of category C offers the opportunity of a scene narration, so a sound can be played by clicking on it. The tested tool of category B also offers the opportunity to add a sound to the tour, but this also does not work in practice with low programming skills. That is the basis for the bird voices analysis in VR; the actual analysis must take part in reality because a separate App should be used for it.

Of the four tested software/tools, one of category A is most suitable for creating a VFT to analyze biodiversity. That can be justified because a sound for analyzing the bird voices can be added to the software for each scene, and interactable images can be added.

Digression: Digital Book

The basics for the biodiversity analysis can be integrated into the VFT in the tested software of category A, but these are just the basics, not the analysis. For the analysis of the plants, an identification key is necessary. This identification key must be included in VR. With the tested software of category A, one possibility to add a plant identification key is with the option of a quiz.

However, the plant analysis takes time, which can be a problem concerning cybersickness. When adjusting the identification key to the plant and didactically reducing it with this simultaneously, the analysis of one plant takes approximately 5 minutes. So, when having an area for the plant analysis in grassland with 25 square meters and, for example, ten plants, only identifying the plants in VR can take 50 minutes. The experience of the ecosystem and the theoretical instruction in vegetation analysis are added to this time. Symptoms of cybersickness, like nausea, headache or drowsiness, are triggered by virtual stimuli, increasing with time (Rebenitsch & Owen, 2021; Singla et al., 2019). That also shows the study of Martirosov et al., 2021, where they researched in an experiment what the average time for the experience of some level of cybersickness in different virtual reality immersions is. This experiment shows that the Virtual Environments (VEs) on stereoscopic screens (CAVE and Oculus) cause simulator sickness, and the participants had to stop the simulation. More than half of the participants of the Oculus group had to stop before ten minutes due to a feeling of cybersickness. The average time for the simulation exit in this group was 7.25 minutes. On the other hand, when using a VE with a low level of immersion on a monoscopic PC screen, all participants could finish the simulation without problems (Martirosov et al., 2021). So, including vegetation analysis in VR means students must spend a long time in the VE. Also, the quiz can include the identification key but no explanation for the biodiversity and plant analysis. So, to reduce the time in VR to reduce the probability of cybersickness and to expand possibilities for the identification key, another digital option for the plant analysis must be found. Also, as described in the Introduction, Minocha et al., 2018 found that VR will be most effective when combined with other technologies.

So, for our VFT, an additional digital book was created to analyse the plants and bird voices in combination with the VFT. The area for the vegetation analysis is marked out in the 360° image so that a spatial assignment is possible. The tool '*Book Creator' (Book Creator app, 2021)* was used to create the digital book. The tool allows the creation of a digital book by combining text, images, audio and video. So, for the plant analysis, a digital book was created where first, in a theoretical part, the basics of vegetation analysis, like the identification characters of the plants, were described. The book's second part is the vegetation analysis of the location 'Eskesberg'. For this, the location 'Eskesberg' is described, and then the function of the vegetation analysis with a dichotomous identification key is explained. An interactive identification key for each plant follows for the analysis. The identification key had to be created for each plant because it had to be adjusted to the characteristics that could be recorded with the detailed images. The identification key is based on the one of Rothmaler & Jäger, 2017. The plants should be noticed, and at the end, there is a control in the form of an App where the images of the plants are shown, and the correct name must be written to this. So, there is self-control of the vegetation analysis. After the vegetation analysis, the analysis of the bird voices is thematized in the digital book. First, the basics are described, and afterwards, the recorded bird voices are integrated into the book with audio. The analysis takes place with an App. So, the audio can be played in the book and analyzed with the App. The biodiversity analysis takes place in a second book, listing the correct plant and bird names to guarantee a correct biodiversity analysis. Then in the first part, the basics are described, and in the second part, a formula to calculate biodiversity is integrated into the book. So, at the end of the second book, the result is the biodiversity index to the location 'Eskesberg', which was explored before in the VFT.

Discussion

The focus of our work was that teachers could create their VFT with 360° images, for this, different software and tools were compared. It is necessary to have the technical equipment to create a VFT, the possibilities for the equipment are diverse, and we just gave an example of available equipment. In Germany, the nationwide availability of digital educational infrastructure should be supported by the 'DigitalPakt Schule'. So, 5 billion euros are available to implement digital training in schools. Especially high-speed internet and stationary terminals like interactable boards are eligible (Bundesministerium für Bildung und Forschung, 2021). However, in Germany, not all schools have a working and fast internet connection. So, it cannot be expected that schools have technical equipment for creating a VFT by recording their own 360° images, and the teachers must buy it by themselves when they want to integrate it into their lessons.

Consequently, if teachers want to integrate their VFT into their lessons, the costs for the technical equipment must be low. Additionally, in the following, some studies are used with the equipment they used for VFT in schools. For example, Jitmahantakul & Chenrai, 2019 created 360° VR environments for geoscience classrooms with 360° images made with a 360° camera, they did not name a concrete model in their work, and with *'Google Expeditions Tour Creator'*. As output devices, the students in their study used their smartphones and cardboards. The VR environment is created to give the students and teachers access to geological outcrops with geological information for each. They describe 'Google Tour Creator' as 'one of the most effective and easy-to-use tools for viewing, observing and analyzing geological features, processes, and events (Jitmahantakul & Chenrai, 2019).

For their year-long research program on the use of mobile VR in primary and secondary schools, Minocha et al., 2018 used guided field trips from 'Google Expeditions' with cardboards in geography and science lessons. Riemer & Nowotny, 2020 aimed to create a VFT with a low technical, financial, and time expenditure for use in schools. They used 360° images for the tour, made with the 'Garmin-VIRB-360', which can be compared with our category 'Advanced'. To create the tour, they used 'Unity 3D' and designed it for cardboards. They conclude that creating this VFT with this combination of equipment is low-cost when using cardboard and excludes the camera as basic equipment (Riemer & Nowotny, 2020).

Based on our experience with the quality of the equipment and relating to the studies, a camera of the category

'Advanced' in combination with a 'Beginner/Advanced' software/tool and a 'Beginner' HMD can be recommended. For the camera, it is also possible to use the category 'Beginner', it depends on the aim of the VFT. Comparing the cameras shows the most significant difference in quality between the category 'Beginner' and 'Advanced' cameras. The' Beginner' camera can be a solution for private use without the aim of inducing learning gains, but the quality of 360° images in the educational sector should be better. Because they are more immersive and *'[...], immersive media can indeed initiate a deeper processing of information [...]'* (Greussing, 2020). However, the difference in the quality from the camera of the category 'Advanced' to 'Professional' is not so great, so the 'Professional' cannot be recommended for use in schools because of the price.

The recommendation concerns research question 1a, but the used software/tools were considered under further aspects. The time effort of creating VFTs with own 360° images, 20 sites and fundamental optional aspects is at least 12 hours when using category C and can be up to 25 hours when creating the VFT with category D, and that is the time effort with programming skills. Furthermore, this time does not consider the time for choosing and inspecting the location. The time to produce the 360° images is independent of the used software/tool. That is shown in the work of Riemer & Nowotny, 2020, where they created a VFT with '*Unity*', so our tested software of category D, in total, needed 168 hours to create this trip with their own 360° images. In their work, they describe that this time effort reduces with increasing experiences (Riemer & Nowotny, 2020). However, for teachers in everyday work, this means a time effort that is not concerning using the VFT for perhaps a few lessons. The VFT can be used in different classes but must be adjusted to the especially learning group because learning is situational and must be matched to the students and their prior knowledge (Hellriegel & Čubela, 2018), which includes some time again.

Regarding teachers' time effort to create a VFT, the working hours of their everyday work must be considered. Higton et al., 2017 reported that teachers' workload is high, with mean hours working of more than 50 hours a week, of those, about 17 hours were spent working during the weekend outside the school. Due to this working time, nearly all teachers do individual planning or preparation of lessons, and 79% of primary teachers and 56% of secondary teachers felt that this is too much time. The working hours are an issue in teachers' working lives, as shown in the teachers' answers, where 52 % consider that the workload in their school is a very serious problem and 41% that it is a fairly serious problem. The majority of the teachers in the study, 86%, cannot complete the assigned workload during the contracted working hours (Higton et al., 2017). That shows that teachers have a very high workload during their everyday work in school and that lesson preparation takes too much time. So, the time for creating an own VFT is limited when this is considered.

The creation of a VFT requires some skills of the creator. When the software/tool has a graphical user interface, it is much easier to create a VFT because it is intuitive to click through. With the tested software/tool of categories A and C, everything can be created with the graphical user interface, so for all aspects, just a low level of skills of the creator is necessary. The tested tool of category B also offers the opportunity of creating a VFT with a graphical user interface, but this includes just the creation of a scene. Adding an image or sound is possible in the source code after the export of the project, so a higher level of skills is necessary. Nearly everything requires high skills when creating a VFT with the tested software of category D. These results for the need for high skills for creating a VFT with D correspond with the results in the work of Bucher & Grafe, 2018. They designed the seminar '*Teaching and Learning with Augmented and Virtual* Reality', where they planned, implemented and evaluated a VR or AR application and paid attention to the pedagogical and technical/usability perspective of pre-service teachers. When the participants had their first contact with '*Unity*', it was difficult for them to become familiar with the program, which was very frustrating. The program experience was frustrating and complex, especially because of the perceived limitations of their skills (Bucher & Grafe, 2018). So, creating a VFT with '*Unity*' requires skills and can also be frustrating because of the program's complexity, but it can be a mature product for technology-minded educators (Klippel et al., 2019). The work of Bucher & Grafe, 2018 also points out that most teachers need preparation to use technology in their later careers in schools. That is an aspect that influences the skills of the teachers for creating a VFT. It is not essential that all teachers learn in their studies and training, so it cannot be expected. This limits the software/tools that can be used to create a VFT.

So, when regarding the aspects of the needed technical equipment with the problems of the limited budget of schools for digital infrastructure, the time effort for creating a VFT and the needed skills for the handling of the software/tool, the tested software of category C can be recommended for the lowest price for the equipment, the lowest time effort and skills for the creator. However, does this also offer the highest benefit for pupils concerning the immersion, interaction and convey of technical content?

The level of immersion of the VFT varies concerning the used software/tool. For an affordable immersive feeling, just a smartphone and a cardboard are needed additional hardware. For a more immersive experience, HMDs can be used (Martín-Gutiérrez et al., 2017). However, why is it important to focus on the level of immersion the VFT offers the students? An immersive VR can scaffold situated learning due to the possibilities of adding an authentic context and situated activities to a learning process that is tactic and unstructured. Immersive VR may lead to deeper cognitive processing because of an embodied and egocentric perspective when experiencing it. So, knowledge understanding and transfer can be enhanced (Zhao et al., 2020). Klippel et al., 2019 developed a taxonomy for different levels of VFTs. The levels distinguish in aspects of VR and how immersive they are. '*Immersion into VR can be viewed as physically being present in an imaginary world*' (Nalluri et al., 2021). The first taxonomy is the basic VFTs, where the actual physical reality is replicated using technologies like 360° images, high-resolution photographs, and three-dimensional models. The offer of information and perspectives that cannot be provided in physical reality is characteristic of the following taxonomy, the plus VFTs.

The manipulation of models and simulations to create immersive experiences is characteristic of advanced VFTs. Basic VFTs can be created with minimal training, but advanced VFTs demand substantial design and programming skills (Klippel et al., 2019). The study by Klippel et al., 2019 shows that students who took part in immersive VFT (iVFT) assessed their learning experiences better than students who took part in an actual Field Trip (AFT) with the same content. Also, the students from the VFT received significantly better lab grades. Even for the basic iVFT that were created, the participants performed better on a laboratory assignment than the participants of the AFT (Klippel et al., 2019). However, the work from Makransky et al., 2021, with an experiment to investigate the effectiveness of an interactive and immersive virtual reality (IVR) simulation compared to a video for teaching scientific knowledge, shows that immersion not only has good results concerning learning.

Because even though the IVR groups had a higher enjoyment and presence than the video group, it did not result in better procedural knowledge (Makransky et al., 2021). An immersive VFT can enhance deeper learning or at least create a higher enjoyment of the learning situation, meaning a high immersion level is desirable. Concerning the research question, what level of immersion does the VFT offers the students, it can be mentioned that the tested software of category A and D offer the highest level of immersion. Here the use of the software/tool may be changed concerning the age of the students, the VFT is created for and the aim of the VFT. When the students are younger, and the VFT aims to motivate them for a theme, and the further work will not be in VR, the creation with the tool of category C can be immersive enough.

The study from Makransky et al., 2021 can also be referred to concerning the interactivity of VFTs. That it is desirable to create a higher level of interactivity and immersion for a higher enjoyment in the learning situation is confirmed by the experiment of Zhang et al., 2019, where they investigate '*[…] how the level of interactivity affects learning performance, especially in the context of interactive VR storytelling for complex science concept learning*' (Zhang et al., 2019). They did a pre-and post-test between VR experiences with different levels of interactivity to students' learning gains. The pre-and post-test results show no significant difference in the learning gains with different levels of interactivity, but '*[…] the students reported significantly more engagement, concentration, and efficiency in learning*' (Zhang et al., 2019) with an increased level of interactivity. So, a high level of interactivity is not necessary for significantly better learning gains. However, it is useful and positive in a learning context, as the participants of this experiment reported (Zhang et al., 2019).

The VFTs created with the different software/tools offer the pupils different aspects of interaction. The highest level of interaction offers the VFTs created with the tested software of categories A and D, especially with the interaction with 3D objects and the possibility of adding a Quiz. The VFTs created with these four tested software/tools cannot offer interaction with objects like in reality. Nevertheless, as the cited papers show, this is irrelevant to learning gain. So, the level of interactivity is mainly important for enjoyment and motivation and may be viewed concerning the learning group.

In our case, conveying technical content is problematic because it is specific. However, it works the most effectively with the software of category A in combination with a digital book as supplementary media. Implementing images and sound in the VFT for the technical content also means interactivity, so it can also be used for this in the VFT and can motivate the students. From a teacher's perspective, the software/tool of categories C and D can also be an option for conveying technical content if it can be sensibly implemented in audio and a few images that can be integrated into the 360 images.

When referring only to the price of the software/tool concerning the digital infrastructure and school budget, the categories without costs, B, C and D, can be recommended. However, the time effort for creating a VFT with the software of category D is, in our example, twelve hours more than with category B and thirteen more than with category C. Concerning the price and the time effort for creating a VFT, the tested online tools of categories B and C can be recommended, this can be confirmed regarding the needed skills of the creator for using the tools. Whereby category C requires lower skills than B. So, the tested software of category C can be recommended for the lowest price for the equipment, the lowest time effort and the creator's skills. However does this also offer the highest benefit for pupils concerning the immersion, interaction and convey of technical content?

Regarding the level of immersion and interactivity of the VFT created with the different software/tools, categories A and D can be recommended because they offer the highest level of immersion and interactivity. Also, these two offer the most possibilities to add additional aspects, so conveying technical content can be better implemented. However, category A is associated with costs, so for most teachers no option when the school has no budget. Furthermore, creating a VFT with category D requires much time and high skills of the creator. A higher level of immersion requires higher enjoyment and presence but only sometimes better procedural knowledge (Makransky et al., 2021). Lower immersive VFTs can result in deeper learning, so the creator's time, effort, and skills must be put into effect on the students, which is why category C can also be recommended. This tool is without cost and requires a low level of skills to create, and offers a medium level of immersion and a low level of interaction.

Conclusion

This paper compared four different software/tools to create a VFT with own 360° images. The creation and use of a VFT include technical equipment, which amounts at least to software for creating it, and a smartphone mounted on headset for the use, which requires financial capacities. For using VFTs in schools, the costs should be low, which can be realized with software without costs and a ‘Beginner’ HMD. In addition to limited financial capacities, the time capacities of teachers are also limited but required for creating a VFT. The workload for creating a VFT with the software with the lowest workload is still high regarding the teachers’ workload. Here our work can give an orientation for teachers to weigh if it is worth it to create a VFT that can be used for different classes when having the option to vary the VFT regarding the learning group. Replacing own-created 360° images with existing 360° images can reduce costs and time, but this still offers the option to create a VFT adapted to a learning group or technical content. Only one of the tested software/tools requires a high level of computer skills for creating a VFT, so this aspect does not pose an obstacle to creating a VFT. The level of immersion and interactivity varies regarding the software/tool, but for use in schools, this is not essential for learning gains. A higher level of immersion and interactivity mainly results in higher enjoyment and engagement. The study shows that conveying unique technical content can be challenging, like in our case. However, most software/tools offer the opportunity to add optional aspects to a basic tour, giving opportunities to convey technical content.

In total, the comparison of the four exemplary software/tools results under the aspects of the needed technical equipment, time effort, needed skills, level of immersion and interaction, and the convey of technical content the tool of category C can be recommended for teachers to create a VFT out of 360° images. Nevertheless, this still takes much time and includes costs, so the possibility for teachers to use VFT in their classes is still limited. A way to exploit the advantages of VR for the learning process can be the replacement of own 360° images with existing ones or the use of existing VFT and the combination with other digital media to adapt it to the learning group. Therefore, our comparison results can be used to find a category of software/tool that corresponds with the creator’s circumstances.

This study gives an overview of the creation of VFT with selected software/tools, and the analysis of some aspects. That is based on the literature and experience of the authors with the software/tools, so this study is not representative. One possibility to continue this study could be to analyze the categories, time effort, and skills with future teachers and teachers in an experiment where different creator requirements can be considered and analyzed. In further studies, it is also interesting to analyze these aspects and software/tools with teachers in their daily work and measure the learning gains and motivation of lessons based on a VFT. It could also be interesting to analyze the willingness of teachers to use VFT and to create it by themselves. In our case, a further study can also measure the effect of students analyzing the vegetation in a VFT in combination with a digital book.

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References

3DVista. (2021, December 21). *Professionelle Virtual Tour Software*. https://www.3dvista.com/de/

Abhijit, J., Mallikarjuna, R., & Manish, S. (2017). *HoloLens Blueprints*. Packt Publishing.

Alsaqqaf, A., Li, F., Beck, D., Peña-Rios, A., Ogle, T., Economou, D., & et al. (2019). Conceptual Framework for Virtual Field Trip Games. *Immersive Learning Research Network: 5th International Conference, ILRN 2019, London, UK, June 23–27.* Advance online publication. https://doi.org/10.1007/978-3-030-23089-0_4

Arthurs, L. A. (2021). Bringing the Field to Students during COVID-19 and Beyond. *GSA Today*, *31*(3/4), 28–29. https://doi.org/10.1130/gsatg478gw.1

Attallah, B. (2020). *Post COVID-19 Higher Education Empowered by Virtual Worlds and Applications*. Booklet. IEEE. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=9320772 https://doi.org/10.1109/ITT51279.2020.9320772

BesoBerlin. (2021, September 10). *Google Cardboard Apps mit Unity erstellen für Einsteiger*. https://www.besoberlin.com/google-cardboard-apps-mit-unity-erstellen-fur-einsteiger/

Bheda, R., Bhimani, D., Dharamshi, F., Sheth, S., Menon, R., Somra, R., & et al. (2021). *Educational Advancements in the Field of Augmented Reality and Virtual Reality*. Booklet. IEEE. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=9509941 https://doi.org/10.1109/ICCICT50803.2021.9509941

Book Creator app. (2021, October 26). *Book Creator - bring creativity to your classroom - Book Creator app*. https://bookcreator.com/

Braun-Blanquet, J. (1964). *Pflanzensoziologie: Grundzüge der Vegetationskunde* (3., neubearb. und wesentl. verm. Aufl.). Springer. http://digitale-objekte.hbz-nrw.de/storage/2008/10/18/file_25/2613612.pdf

Bucher, K., & Grafe, S. (2018). Designing Augmented and Virtual Reality Applications with Pre-Service Teachers. *2474-0489*, 1–8. https://doi.org/10.1109/VS-Games.2018.8493415 (Booklet).

Bundesministerium für Bildung und Forschung. (2021). *BMBF DigitalPakt Schule*. https://www.digitalpaktschule.de/de/was-ist-der-digitalpakt-schule-1701.html

Bürki, R., & Buchner, J. (2020). *Immersive Virtuelle Realität mit VR-Brillen im Geographieunterricht: Potentiale und Herausforderungen*. 49-53 Pages / Progress in Science Education (PriSE), Vol. 3 No. 2 (2020): Special Issue: Proceedings of the DiNat Forum 2020 (K. Kampourakis and A. Müller Eds.) (Vol. 3). Progress in Science Education (PriSE). https://www.researchgate.net/publication/344283475_Immersive_Virtuelle_Realitat_mit_VR-Brillen_im_Geographieunterricht_Potentiale_und_Herausforderungen https://doi.org/10.25321/prise.2020.1001

Chua, Y., Sridhar, P. K., Zhang, H., Dissanayake, V., & Nanayakkara, S. (2019). *Evaluating IVR in Primary School Classrooms*. Booklet. IEEE. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=8951929 https://doi.org/10.1109/ISMAR-Adjunct.2019.00-53

CloudPano. (2022, August 12). *The standard in 360° virtual tour software | CloudPano*. https://www.cloudpano.com/

Dörner, R., Broll, W., Grimm, P., & Jung, B. (2019). *Virtual und Augmented Reality (VR/AR): Grundlagen und Methoden der Virtuellen und Augmentierten Realität*. Springer Berlin Heidelberg, Imprint: Springer Vieweg.

Erl, J. (2021, November 29). VR-Systemanforderungen: Ist dein PC fit für Virtual Reality? *MIXED*. https://mixed.de/vr-systemanforderungen/

Freina, L., & Ott, M. (2015). A Literature Review On Immersive Virtual Reality In Education: State Of The Art And Perspectives. *ELearning & Software for Education*, (1), 133–141. https://doi.org/10.12753/2066-026X-15-020

Garden Gnome. (2022, July 12). *Pano2VR - Virtual Tour Software.* https://fb.com/ggnomes. https://ggnome.com/pano2vr/

Google. (2022, July 6). *Dein eigenes Cardboard – Google VR*. https://arvr.google.com/intl/de_de/cardboard/get-cardboard/

GoXtreme® Action Cams. (2018). *GoXtreme® Omni 360° | GoXtreme® Action Cams*. https://www.goxtreme-action-cams.com/de/goxtreme-omni-360/

Greussing, E. (2020). Powered by Immersion? Examining Effects of 360-Degree Photography on Knowledge Acquisition and Perceived Message Credibility of Climate Change News. *Environmental Communication*, *14*(3), 316–331. https://doi.org/10.1080/17524032.2019.1664607

Grover Deutschland GmbH. (2022a, February 16). *Oculus Go 64GB - Grover*. https://www.grover.com/de-de/products/vr-headset-oculus-go-64gb

Grover Deutschland GmbH. (2022b, February 16). *Oculus Rift S VR - Grover*. https://www.grover.com/de-de/products/oculus-rift-s-vr

Hellriegel, J., & Čubela, D. (2018). Das Potenzial von Virtual Reality für den schulischen Unterricht - Eine konstruktivistische Sicht. *MedienPädagogik: Zeitschrift Für Theorie Und Praxis Der Medienbildung*, 58–80. https://doi.org/10.21240/mpaed/00/2018.12.11.X

Higton, J., Leonardi, S., Richards, N., Choudhoury, A., Sofroniou, Nicholas,Dr., & Owen, David, Dr. (2017). Teacher Workload Survey 2016: Research report. https://warwick.ac.uk/fac/soc/ier/people/dowen/publications/tws_2016_final_research_report_feb_2017.pdf

Hou, Y., & Fang, A. (2012). *Analysis and design on virtual field trips system*. Booklet. IEEE. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6295387 https://doi.org/10.1109/ICCSE.2012.6295387

Huwer, J., Bock, A., & Seibert, J. (2018). The School Book 4.0: The Multitouch Learning Book as a Learning Companion. *American Journal of Educational Research*, *6*(6), 763–772. https://doi.org/10.12691/education-6-6-27

Insta360. (2022, December 22). *Insta360 Pro 2 | Professionelle 8K VR Panoramakamera | Dynamisches 360°-Stitching in Echtzeit | FlowState Stabilisierung*. https://www.insta360.com/de/product/insta360-pro2/?utm_medium=pro1&utm_source=website

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies: The Official Journal of the IFIP Technical Committee on Education*, *23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

Jerald, J. (2016). *The VR Book: Human-Centered Design for Virtual Reality*. *ACM Books Vol. 8: Vol. 00008*. First edition [New York]: ACM Books.

Jitmahantakul, S., & Chenrai, P. (2019). Applying Virtual Reality Technology to Geoscience Classrooms. *Review of International Geographical Education Online*, *9*(3), 577–590.

Keller, T., Glauser, P., Ebert, N., & Brucker-Kley, E. (2018). Virtual Reality at Secondary School -- First Results. *International Association for Development of the Information Society*. https://eric.ed.gov/?id=ed600587

Klippel, A., Zhao, J., Jackson, K. L., La Femina, P., Stubbs, C., Wetzel, R., & et al. (2019). Transforming Earth Science Education through Immersive Experiences: Delivering on a Long Held Promise. *Journal of Educational Computing Research*, *57*(7), 1745–1771. https://doi.org/10.1177/0735633119854025

Kuula. (2022, August 12). *Virtual Tours made easy. Create. Edit. Share => Kuula*. https://kuula.co/?ref=benclaremont

Lapentor - Free 360° Virtual Tour Software. (2022, May 25). *Home - Lapentor - Free 360° Virtual Tour Software*. https://lapentor.com/

Lin, Y.-J., & Wang, H. (2021). Using virtual reality to facilitate learners' creative self-efficacy and intrinsic motivation in an EFL classroom. *Education and Information Technologies: The Official Journal of the IFIP Technical Committee on Education*, *26*(4), 4487–4505. https://doi.org/10.1007/s10639-021-10472-9

Makransky, G., Andreasen, N. K., Baceviciute, S., & Mayer, R. E. (2021, May). Immersive virtual reality increases liking but not learning with a science simulation and generative learning strategies promote learning in immersive virtual reality. *Journal of Educational Psychology*, *113*(4), 719–735. https://doi.org/10.1037/edu0000473

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017, February). Virtual Technologies Trends in Education. *EURASIA Journal of Mathematics, Science & Technology Education*, *13*(2), 469–486. http://www.ejmste.com;

http://www.iserjournals.com/journals/eurasia/articles/10.12973/eurasia.2017.00625a

Martirosov, S., Bureš, M., & Zítka, T. (2021, May). Cyber sickness in low-immersive, semi-immersive, and fully immersive virtual reality. *Virtual Reality*, 1–18. https://doi.org/10.1007/s10055-021-00507-4

Marzipano - a 360° viewer for the modern web. (2021, March 18). https://www.marzipano.net/

Meta. (2022, December 22). *Meta Quest 2: Immersives all-in-one VR-Headset | Meta Store*. https://www.meta.com/de/quest/products/quest-2/?utm_source=rakuten&utm_medium=affiliate&utm_campaign=PPkX79_c.b0-E_aVR2ArMsV7dEzWlomxXQ

Minocha, S., Tilling, S., & Tudor, A.-D. (2018). *Role of Virtual Reality in Geography and Science Fieldwork Education*. Booklet. http://oro.open.ac.uk/55876/; https://kess.org.uk/2018/05/02/prof-shailey-minocha-dr-ana-despina-tudor-ou-role-virtual-reality-geography-science-fieldwork-education/; http://oro.open.ac.uk/55876/1/ORO-KESS-Paper-in-Template-25April2018-FINAL-Submitted.pdf

Nalluri, S. P., L, R., & Munavalli, J. R. (2021). *Evaluation of Virtual Reality opportunities during Pandemic*. Booklet. IEEE. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=9418003 https://doi.org/10.1109/I2CT51068.2021.9418003

Orbix360°. (2022, June 14). *Orbix360º Empowers Metaverse Creators*. https://orbix360.com/home

Rebenitsch, L., & Owen, C. (2021). Estimating cybersickness from virtual reality applications. *Virtual Reality*, *25*(1), 165–174. https://doi.org/10.1007/s10055-020-00446-6

Ricoh company. (2022, January 25). *RICOH THETA V*. https://theta360.com/de/about/theta/v.html

Riemer, N., & Nowotny, F. (2020). Entwicklung von VR-Anwendungen für kulturwissenschaftliche Schulfächer. https://mediarep.org/bitstream/handle/doc/15851/beinsteiner_ea_2020_augmentierte-virtuelle-wirklichkeiten_medien-wissen-bildung.pdf?sequence=1#page=136

Rothmaler, W., & Jäger, E. J. (2017). *Exkursionsflora von Deutschland, 2: Gefäßpflanzen: Grundband* (21., durchgesehene Auflage). *Exkursionsflora von Deutschland*. Springer, Spektrum, Akad. Verl.

Samsung. (2017). *Gear 360 (2017). Samsung Electronics Österreich*. https://www.samsung.com/at/wearables/gear-360-r210/

Singla, A., Robitza, W., & Raake, A. (2019). Comparison of Subjective Quality Test Methods for Omnidirectional Video Quality Evaluation. *2473-3628.* Advance online publication. https://doi.org/10.1109/MMSP.2019.8901719

Theasys. (2022, August 12). *Theasys - 360 VR Online Virtual Tour Creator*. https://www.theasys.io/

Thürkow, D., & Gläßer, C. (2004). Virtuelle Landschaften und Exkursionen – innovative Tools in der geowissenschaftlichen Aus- und Weiterbildung. *Photogrammetrie - Fernerkundung - Geoinformation*, *5*, 391–398.

Tour Creator. (2020, December 7). *Tour Creator*. https://arvr.google.com/tourcreator/

Tremp, H. (2005). *Aufnahme und Analyse vegetationsökologischer Daten: 41 Tabellen*. *UTB: 8299: Biologie, Agrarwissenschaften, Ökologie, Geowissenschaften*. Ulmer. http://digitale-objekte.hbz-nrw.de/storage/2010/07/18/file_4/3837940.pdf

Trzaska, T. (2021, May 14). *Virtual Reality Suite (v.2.1.0) [software] – present4D GmbH*. https://present4d.com/de/

Ulrich, N., & Huwer, J. (2017). *Digitale (Schul-) Bücher–Vom E-Book zum Multitouch Learning Book*.

https://www.joachim-herz-stiftung.de/fileadmin/redaktion/04_lernprozesse_mit_dig_werkz_unterst.pdf#page=63

Unity Technologies. (2021, May 17). *Unity (v.2019.4.15f1) [software]- Unity*. https://unity.com/de

Wuppertal. (2021, May 14). *Deponie und Naturschutzgebiet Eskesberg*. https://www.wuppertal.de/rathaus-buergerservice/umweltschutz/boden/102370100000191710.php

Zhang, L., Bowman, D. A., & Jones, C. N. (2019). Exploring Effects of Interactivity on Learning with Interactive Storytelling in Immersive Virtual Reality. *2474-0489.* Advance online publication. https://doi.org/10.1109/VS-Games.2019.8864531

Zhao, J., LaFemina, P., Carr, J., Sajjadi, P., Wallgrun, J. O., Klippel, A., & et al. (2020, March). Learning in the Field: Comparison of Desktop, Immersive Virtual Reality, and Actual Field Trips for Place-Based STEM Education. *2642-5254.* Advance online publication. https://doi.org/10.1109/VR46266.2020.00012

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Appendix.

System Requirement Head-Mounted-Display

Table. System Requirements for a Computer for Oculus Rift S and Meta Quest (Erl, 2021)

System requirement	Oculus Rift S	Meta Quest+Oculus Link
GPU (recommended)	NVIDIA GTX 1060 / AMD Radeon RX 480 or better	NVIDIA Titan X | GeForce GTX 970 | GeForce GTX 1060 6 GB (Desktop) | GeForce GTX 1070 (Serie) | NVIDIA GeForce GTX 1080 (Serie) | NVIDIA GeForce GTX 1650 Super, 1660, 1660 Ti | NVIDIA GeForce RTX 20-Serie (all) / AMD 400 (Serie) | AMD 500 (Serie) | AMD 5000 (Serie) | AMD Vega (Serie)
CPU (recommended)	Intel i5-4590 / AMD Ryzen 5 1500X or better	Intel i5-4590 / AMD Ryzen 5 1500X or better
Random access memory RAM (recommended)	at least 8GB RAM	8 GB RAM or more
Video output	DisplayPort 1.2 (Mini DisplayPort to DisplayPort Adapter enclosed)	-
USB-Ports	1x USB 3.0	1x USB 3.0
Operating system	Windows 10	Windows 10