Green H2VR

Guideline

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The Erasmus+ project

"Green H2VR -Promoting relevant green skills in renewable energy through innovative eXtended Reality technologies (KA210-VET-A97B97B5)"

is a project on green hydrogen and its possible applications, which was funded with the support of the European Union.

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Table of contents

List of figures 4
Introduction 4
State of the art “Extended Reality” 6
Definitions: 6
Extended Reality (XR) 6
Mixed Reality 6
Augmented Reality 6
Virtual Reality 7
New didactic methods through VR: 7
3I Characteristics of VR: 9
Immersion 9
Interaction 10
Imagination 11
Potential of VR for vocational education and training (VET): 11
Acceptance of the use of VR: 12
Teaching staff 12
Learners 13
Socio-economic considerations: 14
Pedagogical concepts 15
Technological concepts 15
Organizational and personnel development 15
Equipment: 15
Hardware 15
Software 16
Additional equipment and organizational framework conditions 17
Basics of green hydrogen 19
Areas of application 20
Production 20
The „Green H2VR“ project 21
Project description 21
Training scenario of the Green H2VR app 22
Learning questions: 25
Evaluation description and analysis of results 26
Integration of VR in education 27

Recommendations for the use and process of VR training 28
Initial tutorials 28
VR training types 29
Location and time of the VR training 29
Virtual reality at home 29
VR during the classroom session 29
Observation of usage and learning success 30
Role of the teacher 30
Recommendations for the development of VR training 31
Bibliography 32

List of figures

Figure 1: Application variables of VR technologies in education (based on Kommetter, 2019). 8
Figure 2: Technology acceptance model (TAM) of virtual learning environments (based on Pletz & Zinn, 2018: 91). 12
Figure 3: Media development plan (based on Hellriegel, 2018, 71). 14
Figure 4: Meta Quest 2 ©Facebook Technologies, LLC. 16
Figure 5: Safety note 22
Figure 6: Control system 23
Figure 7: Interactive game table 23
Figure 8: Meaning of buttons and levers 24
Figure 9: Meaning of panels 25

Introduction

The first alterations in climate change are already noticeable. When it comes to environmental and climate protection, we are still lagging far behind. The European Union has set itself ambitious goals, especially to drastically reduce CO_2 emissions in the EU. According to the EU Council, energy production and use currently accounts for around 75% of greenhouse gas emissions. The promotion of clean energy sources and the decarbonization of the energy sector is therefore being strongly promoted (Fit for 55, European Green Deal). Developments in the field of green hydrogen production could make a significant contribution to decarbonization and sustainable energy storage and use, as green hydrogen is the only energy source that has the potential to ensure a completely CO_2-free, sustainable and energy-independent society and mobility. The Green H2VR project therefore aims to raise awareness of the pioneering green hydrogen technology with the help of virtual reality (VR).

Scientists worldwide agree that hydrogen technologies will play a key role in meeting energy demand. Hydrogen technology offers promising potential, especially when it

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comes to storing environmentally friendly energy, as hydrogen does not cause any CO_2 emissions and almost no air pollutant emissions when used. Renewable energy sources, such as the sun, are often subject to fluctuations. In summer there are many hours of sunshine, in winter significantly fewer. In order to be able to meet existing energy demand all year round, it is extremely important to develop sustainable energy storage solutions. Hydrogen applications could be the crucial link in the chain of sustainable energy generation and supply. There are already initial offers of energy storage solutions with hydrogen technology for private households that enable a self-sufficient electricity storage system (such as the JOHANN energy storage system from Elements Energy GmbH and energy storage solutions from Batarow Hydrogen).

The EU Commission's hydrogen strategy (2020) sees great potential in the use of hydrogen as a fuel or energy carrier and storage to achieve climate neutrality by 2050. In order for hydrogen to contribute to climate neutrality, it is necessary to use it on a much larger scale and to use its production entirely for decarbonization. Therefore, according to the EU decision, ten million tons of hydrogen should be produced annually by 2030 and a further ten million tons should be imported into the EU.

In order to achieve climate neutrality in the EU by 2050 and to enable the smooth use of hydrogen technology, it will be crucial that the specialists in the sectors concerned are prepared for the effects and possible applications of hydrogen technology. The Green H2VR project therefore aims to integrate the diverse potential of hydrogen technology for a climate-neutral and self-sufficient energy supply into vocational training in the fields of electrical engineering, building technology and installation technology, among others. The central goal of this project is to create a universal product with which hydrogen technology can be disseminated in a wide variety of professional groups and educational levels in order to reach the widest possible group of people.

Through intensive engagement with VR technology and its use in various training areas, the project partners (WKO Steiermark (Styrian Chamber of Commerce), HyCentA Research GmbH (Austria's first hydrogen research center) and Mindconsole Berlin (VR development agency) have gained valuable insights into the implementation of VR in vocational education and training. These experiences are summarized here to support educational institutions and training companies in the decision for and actual introduction of VR. This guide is aimed at those people for whom VR is a new term, but also at those who have already considered and researched the implementation of VR or are already in the middle of the introduction phase.

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State of the art “Extended Reality”

Definitions:

Extended Reality (XR)

Virtual, computer-generated, three-dimensional learning environments or objects, in combination with appropriate end devices such as headsets or tablets, enable completely new experiences in which users can immerse themselves in a digital or digitally augmented reality. "XR" (or "Extended Reality") is the umbrella term for all types of augmented (AR), mixed (MR) and virtual (VR) realities that merge the physical and virtual worlds in the user's experience. XR does not refer to specific technologies, but to the way in which this entire field of technological developments expands and improves human experience and interaction (State of XR Outlook Report 2021: 14). This innovation is increasingly impacting the economy as well as the education sector. One reason for this is that this technology is available to an increasingly wider public. XR makes it possible to simulate almost any environment, subject, object and process. Recently, promising positive results have been observed when using XR technologies for learning soft skills, for example. People who were trained with XR learning content learned faster and had better and more sustainable results than those who were taught in a traditional classroom or via e-learning (PwC’s study into the effectiveness of VR for soft skills training).

Mixed Reality

Mixed Reality (MR) is a continuum between reality and virtuality and includes the technologies Augmented Reality (AR) and Virtual Reality (VR), both of which were developed in the late 1960s (cf. Milgram 1994: 2 cited in Thurner 2021). The current report on the future of immersive learning by the “Immersive Learning Research Network” predicts that MR Learning will soon be introduced into all areas of education and shows practical examples, potentials and fields of application that are already available (State of XR and Immersive Learning, 2021). Although mixed reality is increasingly being used in training and further education, its use is still very often experimental.

Augmented Reality

Augmented Reality (AR) is a 3D technology that merges the real and virtual worlds in real time using holographic representation by inserting computer-generated objects into the real environment using smartphones, tablets or smart glasses. These objects are usually texts, graphics or animations. Users can seamlessly interact with virtual and computer-generated images while using real objects. Companies use this technology to develop new products and designs, to provide remote support for maintenance work or assembly and sales (see Pape, 2021). AR is particularly suitable

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when training is to take place in the real environment (see Ahmad, as of June 25, 2024). Here, AR supports learners by displaying information and assistance.

Virtual Reality

Virtual Reality (VR) is an artificially generated 3D world that users can experience through specific hardware and software applications. In contrast to AR, a reality can be created that resembles reality, such as the simulation of workshops. But it is also possible to create more abstract realities, such as worlds from fantasy books, and immerse yourself in them. That is why it is called "immersion". The degree of immersion is determined, among other things, by the type and level of detail of the digital representation of objects, characters and environments. Although VR tried to conquer the market as early as the 1990s, it was not until 2014 with the acquisition of Oculus Rift by Meta and the launch of Google Cardboard that the breakthrough was achieved, at least in the gaming industry and in companies as a marketing concept (see Ebner, 2018).

The difference between VR and 3D can be explained as follows:

- **Interaction:** In contrast to 3D environments, you can interact with the virtual world. In VR, you can influence events and the world, and the course of events can be influenced by your own actions.
- **Immersion:** VR enables deeper immersion and a more intense feeling of presence in the virtual world.

The use of VR in vocational education and training is particularly beneficial for internalizing processes and training the reflexive execution of action sequences in certain situations. VR will be discussed in more detail in the next chapters. In this work, VR is not understood as 360° video or cardboard glasses, as the possibility of actively constructing and co-creating the virtual world is not possible with these technologies. In this guide, VR has a higher claim than passive, receptive use on the part of the learner. Through VR, the learner, their learning motivation, needs and goals become the center of the learning process and the learners become acting and active subjects who can experiment and practice with virtual objects (cf. Hellriegel, 2018: 66).

New didactic methods through VR:

In order to identify possible areas of application for VR in vocational education and training as well as general education, Figure 1 provides an overview of the different application variables.

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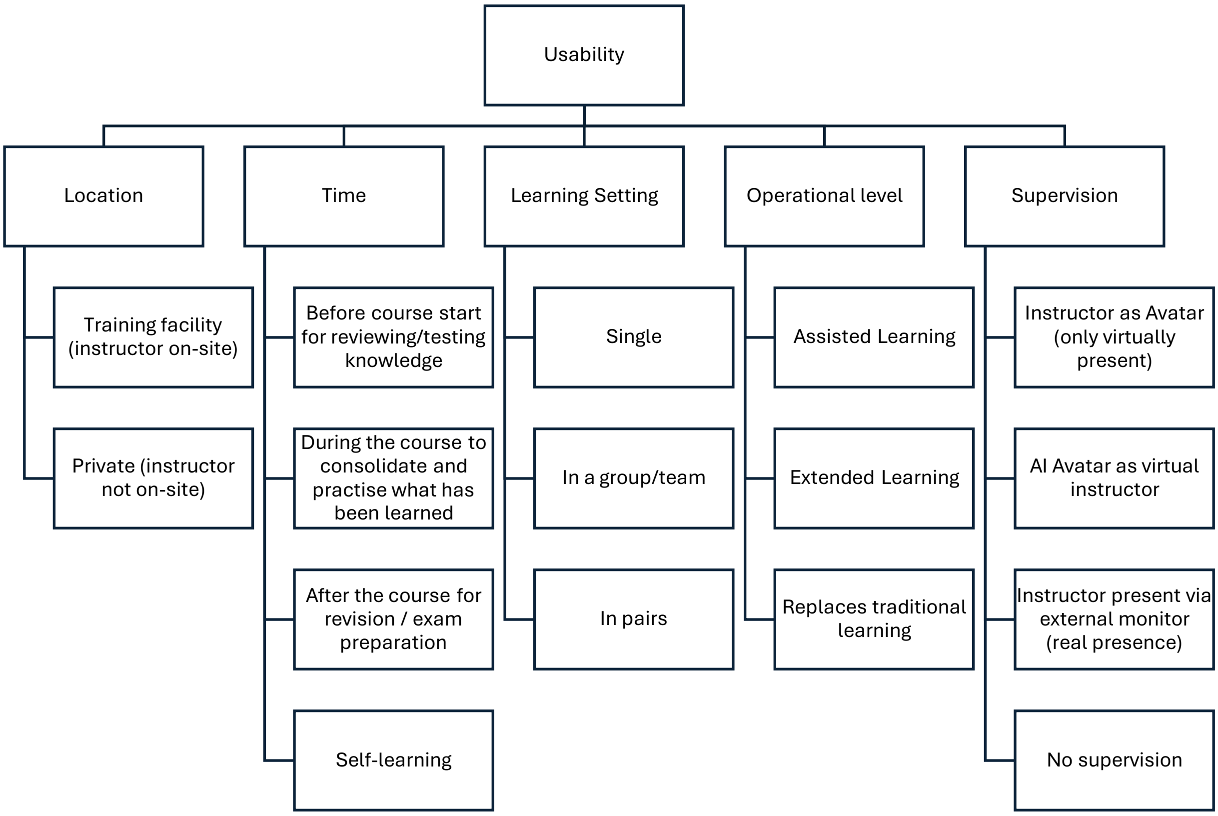

Figure 1: Application variables of VR technologies in education (based on Kommetter, 2019).

The graphic shows that there are many different ways in which VR can be used in education. It can be used on-site or in the user's private environment; before, during or after a course; as an individual or team task. These variables are described in more detail in a later section. Despite these countless possible uses, the use of VR in education is not yet widespread and therefore VR in education is still an area that has not been explored much. Nevertheless, potential can be seen due to the interactive and immersive nature of the technology. The decisive factor is not the entertainment of the learners, but the increase in learning motivation, involvement in learning activities and the sustainable success of learning outcomes through active and experience-based learning.

VR is already increasingly being used for training in military, police and medical contexts. One notable example is the EU-funded project “IRONORE”. Using VR, 1000 participants trained in the EU civil protection exercise for cross-border cooperation in the event of a crisis. VR offered the unique opportunity to realistically train a team in an unprecedented extreme situation.

However, the now affordable hardware makes it possible to integrate VR to a much greater extent in different areas and contexts. It is therefore necessary to investigate how successful learning can take place in VR using which didactic methods. From a

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didactic point of view, it can be stated that constructivism[1] provides important insights that should be taken more into account with regard to a teaching-learning process in the context of VR (cf. Hellriegel 2018: 76).

The following didactic methods can be realized with VR, which also reflect the variables in Figure 1 (cf. Federal Ministry of Education, Science and Research, 2022):

- **Open learning:** independent organization of learning
- **Distance learning:** learning is independent of time and place
- **Experience-based learning:** learning with a focus on practice can also be understood as action-based learning
- **Competency-based learning:** practical problems are addressed in real-life contexts to promote competence building
- **Problem-oriented learning:** realistic problem solving
- **Discovery learning:** also known as exploratory learning. The focus is more on the learner's activity and the path to the solution than on the solution itself
- **Situational learning:** not only the material learning environment but also the social environment of the learner is part of the learning situation
- **Collaborative learning:** several learners work together on a task
- **Individual learning:** learning can be adapted to one's own learning pace
- **Gamified learning:** interaction and storytelling as a learning method

The decisive factor for the use of these didactic methods, but also for the success in terms of learning motivation and sustainable learning outcomes of VR in education, is the "multi-perspective perception of reality" (cf. Reich, 2008 cited in Hellriegel, 2018). "The teaching-learning process can be understood less as a one-sided transfer of knowledge, but in particular as a self-directed, active-constructive, situational and social process in which the focus should be on experiencing, trying out, investigating and experimenting for oneself" (Hellriegel, 2018). An active and constructive role of the learners in an authentic situation is crucial and VR offers this possibility due to the so-called "3I" characteristics. These characteristics are described in more detail in the next section.

3I Characteristics of VR:

Immersion

The Latin word “immergere” means “to immerse”. According to a definition from the Dictionary of Psychology, immersion means “the extent to which the technology used

[1] Constructivism is a theory of knowledge that assumes that there is no absolute truth that is equally perceptible to all people, but only individual constructs of reality. Put simply, every person constructs his or her own reality with the help of his or her own sensory perceptions and cognitive processes. In this sense, learning understood in constructivist terms is always a highly individual, active process in which personal, self-directed experiences are important.

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is capable of providing an inclusive, intense, comprehensive and vivid illusion of reality" (Wirtz, 2022). The more senses are addressed, the more intense the immersion.

Immersion is achieved through four technical aspects:

1. the users should be isolated from the real environment, i.e. sensory impressions should be generated primarily by the VR system (inclusive)
2. as many senses as possible should be addressed (extensive)
3. the output devices should completely surround the users and not offer a narrow field of vision (surrounding) and
4. the output devices should enable a "lively" representation, for example through high resolution and color quality (vivid)" (Slater and Wilburg, 1997 cited in Pletz, 2012: 15).

When it comes to immersion, a distinction is also made between mental and physical immersion. Real movements of the body lead to reactions of visual, auditory and haptic parameters in the virtual environment. This phenomenon describes physical immersion. Mental immersion refers to the feeling of immersion or being present in the virtual world (cf. Mulders, 2020: 4).

Another distinction is the degree of illusion, distinguishing between the illusion of place and the illusion of plausibility. Feelings and reactions in the virtual environment are identical or similar to those in the real world (cf. Mulders, 2020: 5). Users can feel present in a virtual body, perceive it as their own body. In this way, learners can view facts from the ego perspective and thus establish concrete references to a physical presence, which is an important feature of successful learning (cf. Hellriegler, 2018: 67).

Interaction

An immersive virtual environment is created when the user can interact with and in this environment (cf. Hellriegel, 2018: 65). This allows the approach of "learning through experience" according to Dewey or "learning by doing" to be followed. This follows the principle of embodied cognition; that is, physical interactions with the environment influence cognitive processes (cf. Pelz, 2021). By moving their bodies during an action, users create mental schemas of the manipulated objects, which can have a positive influence on the learning process.

VR offers more interaction and construction services than conventional media. Users can not only move freely in the virtual worlds, but also create objects, content or even virtual worlds themselves. Furthermore, freely selectable options for action can be made available so that self-directed decisions can be made (cf. Martín-Gutiérrez et al. 2017 cited in Hellriegel, 2018: 67). In this way, people receive direct feedback on their actions through real-time visualizations and reactions from the system (cf. Zinn & Ariali, 2020 cited in Pelz, 2021). According to Martín-Gutiérrez (2017), high learning success occurs particularly when learners can make their own decisions based on the results

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of their own actions and serve to achieve the goals, they have set for themselves (cf. Hellriegel, 2018: 66).

Imagination

Imagination describes the fantasy of the human mind to perceive non-existent things (cf. Mulders, 2020). This cognitive ability plays an important role, especially in immersive learning, as it gives learners the opportunity to interact in virtual learning environments and generate real learning processes and results.

Potential of VR for vocational education and training (VET):

Traditional procedures and methods of imparting knowledge, such as frontal teaching or "memorization", often do not result in sustainable and effective learning success. Modern learning methods must take into account other factors in addition to the pure imparting of content in order to ensure a successful learning process. "The teaching-learning process must rather be understood as an active, constructive, social, situated, practice-related process that takes into account the individual world of the learners" (Arnold, 2012 quoted in Hellriegel, 2019: 71). According to Pletz (2021), VR offers the following potential for vocational education and training and safety-related training, which meets the demands of learning according to Arnold (cf. Pletz, 2021: 23):

- **Authentic simulation:** In VR, expensive machines, dangerous and risky situations or difficult-to-reach environments can be simulated without real training objects such as machines or equipment being present in physical form.
- **Spatial and temporal flexibility:** Education can take place regardless of place and time. Training units can be adapted to the individual learning pace and repeated countless times until the learning goal is achieved.
- **Cost savings:** By saving on real training objects and reducing machine downtime and damage, costs can be significantly reduced.
- **Safety:** Dangers can be experienced safely without fear of personal injury or damage to machines. In contrast to real training, mistakes are allowed and desired and do not pose any risk of accidents.
- **Visualization:** Complex issues can be visualized in order to achieve a higher and quicker understanding among the learners and subsequently increase self-confidence.
- **Deepening of teaching content:** Virtual environments offer the potential for interaction and collaboration between learners and teachers and promote discussion and feedback processes (cf. Martín-Gutiérrez 2017 cited in Hellriegel, 2018: 68). Precise data can be collected during the implementation of the virtual content, such as eye tracking, timing of reactions, etc., so that the learner's learning development can be addressed specifically.
- **Minimizing external disruptive factors:** By immersing yourself in the virtual world, external disruptive factors such as smartphones or immediate activities in the real environment are reduced and learners can focus better on the task.

- **Gamification:** Learning in VR can be designed in a playful way with the setting of different levels of difficulty, personalized content and reward systems to increase learning motivation.
- **Individualization:** The overarching term for the potential of VR listed is respect for the heterogeneity or individuality of the learners. VR learning environments enable highly individual learning experiences.

Acceptance of the use of VR:

When introducing VR or a new technology in general, it is important to pay attention to the "Technology Acceptance Model" (TAM) for the successful and sustainable use of this technology. The use depends on several factors, as shown in Figure 2. Worth mentioning are, on the one hand, the "perceived usefulness", the expected added value, and, on the other hand, the "perceived user-friendliness", i.e. the expected effort to operate this technology. "Technologies whose application is perceived as useful, and which are easy to use without great effort are therefore more likely to be accepted than technologies for which this is not the case. External factors, such as the socio-demographic characteristics of the user, but also support from management, the organization and characteristics of the system, in turn affect the usefulness and user-friendliness" (cf. Pletz & Zinn, 2018, 90). Furthermore, previous experience with the technology has a positive effect on the intention to use it. Since these are rarely present in VR, greater emphasis must be placed on perceived usefulness and user-friendliness (cf. Pletz & Zinn, 2018: 93ff).

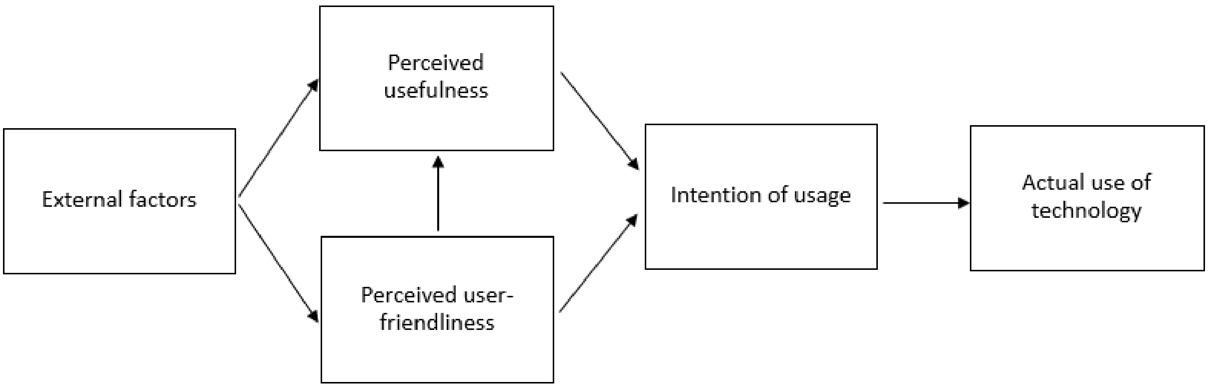

Figure 2: Technology acceptance model (TAM) of virtual learning environments (based on Pletz & Zinn, 2018: 91).

Ideally, acceptance studies of technological innovations should be carried out before the time of introduction in the educational institution in order to be able to act accordingly and achieve acceptance among all those involved (cf. Pletz, 2021: 2).

Teaching staff

Above all, the recognizable benefits and added value of using this new technology as a supplementary teaching method must be clear to teaching staff. In Pletz's study, the added value mentioned was faster progress in lessons with better results, as well as

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assistance with difficulties in conveying certain learning content (cf. Pletz 2021, 259). In order to increase the teaching staff's acceptance of VR and to reduce certain fears, additional criteria are added in addition to the TAM variables listed above. "For example, Kohnke and Bungard (2009) assume that managers can positively influence technology acceptance by clearly supporting the technology and ensuring that the necessary prerequisites for meaningful use are met" (Pletz 2021, 78). Other intra-organizational measures, such as regular information about changes in the technology, instructions on how to use it, the reliability of the technology or the provision of user training and immediate support options if usage problems arise during their course, have a beneficial effect on acceptance (cf. Pletz 2021, 78).

It is also crucial that teaching staff are aware of their possible role change in the classroom and accept it. Based on a study from the 1990s, Youngblut (1998) found that the use of VR changes the role of the teacher from that of mediator to that of facilitator and learning supporter (cf. Hellriegel, 2018, 66). However, this does not arise solely from the unreflective use of VR applications but must be framed by the teachers in a didactic setting (cf. Hellriegel, 2018: 68).

Teaching staff must be given the time they need, not only to familiarize themselves with the technology, but also to rethink the course design and concept and plan the meaningful integration of VR. The participatory involvement of teaching staff in the implementation and development phase is crucial for rapid and sustainable acceptance of VR.

Learners

The most important acceptance factors for VR learning content are also repeated among learners according to the TAM concept. The benefits must be clearly visible to users, such as that learning is less physically demanding, safer, faster and easier or that there is the possibility of practicing certain work steps as often as desired. Information about playful aspects, but also the possibility of automated learning through virtual experience, can motivate learners. After using VR several times and after the initial wow effect, which is often responsible for a successful application when VR is introduced, has worn off, this recognizable added value must act as a motivation for use.

A well-balanced level of difficulty of the training experience also plays a role as a criterion for user-friendliness and acceptance among learners. The virtual handling should be realistic and intuitive in order to be able to move quickly and easily in the new environment. As few buttons as possible should be necessary for operation and the introduction to handling the controllers should only take a few minutes. The faulty and sensitive haptics are one of the biggest criticisms of users (cf. Pletz 2021, 264f).

As with teaching staff, a detailed introduction to the technology is crucial for learners' acceptance. Pletz's study shows that having a teacher present to support students with any questions was very helpful for both the use and acceptance of the technology.

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The factor of the learners' age should be briefly discussed. Older learners usually need to be given a little more time to become familiar with the technology, and attention should also be paid to the language used during induction training. More attention must be paid to user-friendliness and the communication of added value for older people (cf. Pletz 2021, 262f).

Previous experience with VR can lead to faster acceptance of VR in education but can also have negative effects. VR is particularly well-known in the gaming industry. The budget in this industry is much higher than in the education sector, and this results in differences in the graphic and haptic qualities of VR apps. The qualitatively different VR experiences, gaming vs. learning tool, can lead to rejections in the education sector. If the problem of so-called "motion" or "VR sickness", such as nausea, dizziness or heart palpitations, occurred during a previous application, it is difficult to persuade learners to use it again.

Another positive or negative factor for the acceptance of VR is group dynamics or social factors. The fear of exposing oneself to other course participants through failure or embarrassing movements can influence usage and should be addressed at the beginning. To increase acceptance in the group, generated result or learning progress data should not be published in the group (cf. Pletz 2021, 266). The group has a positive influence on acceptance if the group motivates and encourages use or if the gamification approaches of the VR app create a sense of competition.

Socio-economic considerations:

Despite numerous potentials, the successful use of VR requires the development of concepts on the following three levels with equal importance:

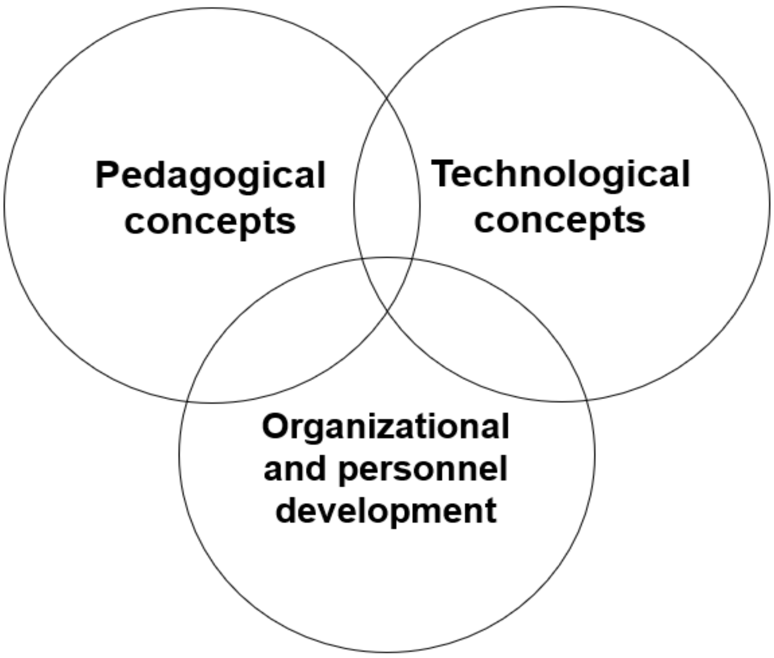

Figure 3: Media development plan (based on Hellriegel, 2018, 71).

Pedagogical concepts

In order to use VR as a successful educational concept, a learning goal should always be clearly defined at the beginning of each development or purchase of virtual learning content and anchored in the teaching-learning concept, as VR offerings should be seen as a supplement to lessons (Hellriegel 2018, 72). "Due to the variety of different options for action on the part of the learners with regard to the VR offerings, it is necessary for the teacher not only to consciously help shape the content selection of the offerings, but also to consciously control the didactic potential with regard to the learners' options for action and participation" (Hellriegel 2018, 72). Rethinking educational models requires more than just the involvement of the teacher. Close cooperation between all actors, especially with the VR developers, who are familiar with the possibilities of the technology and its effects, should be sought.

Technological concepts

Which VR hardware should be purchased must be determined at several levels of the educational institution. Sustainable solutions for maintenance, retrofitting, modernization, etc. must be in place before expensive media are purchased (Hellriegel 2018, 73). The technical infrastructure of the educational institution should be examined and, if necessary, improved in advance, such as setting up broadband internet access and appropriate precautions and regulations on data protection and IT security. Just a basic set of hardware (VR glasses) is not sufficient for successful use in education.

Organizational and personnel development

Before introducing any new (learning) technology, it is important to involve those responsible and those affected in the change process at an early stage and in a participatory manner. Previous experiences, attitudes, reservations and fears should be identified and taken seriously. It is an advantage if managers and especially teaching staff are open to the use of innovative media technologies and recognize the added value. Sufficient time must be ensured to familiarize themselves with the VR glasses in order to be able to efficiently develop and plan their use in teaching. Furthermore, it is "necessary to offer teachers opportunities for further training that contribute to the development of media competence, methodological competence and media pedagogical competence" (Hellriegel 2018, 73f). Staff for quick problem solving, maintenance, cleaning, servicing, etc. should be available.

Equipment:

Hardware

In the course of the Green H2VR project, only the Meta Quest 2 glasses were used. The Quest 2 from Meta, also known as Oculus Quest, does not depend on a PC for game calculations, but works autonomously with a Snapdragon processor. It is a wireless, high-resolution pair of glasses with good tracking through integrated cameras and sensors. The price for the 128 GB model is currently around €250. The Meta Quest 2 is a so-called head-mounted display (HMD). Features of an HMD are the closed housing, which does not allow any light effects from the real environment to enter, as well as lenses that are attached in front of an OLED screen. The HMD not only follows "the head movements of the users, who perceive the virtual environment from an egocentric perspective", but also allows "six-level motion tracking" (6DOF) using pre-spatially defined areas and infrared LEDs (Pletz 2021, 20f). 6DOF means that in addition to tilting, panning and rotating, movements forward and backward, right and left as well as up and down are also recorded (see Erl, 2022). A distinction is also made between wireless (standalone hardware) and HMDs connected to a PC (PC hardware). The resolution and image quality are higher with the wired HMDs, but this limits the spatial flexibility.

Figure 4: Meta Quest 2 ©Facebook Technologies, LLC.

Software

In order to be able to develop VR applications according to your own wishes, you need a development environment. There are currently two top dogs on the market that offer their game engines for the development of all kinds of applications - Unity3D and Unreal. Depending on the learning content/goal and the necessary functions, you can choose one or the other game engine. Both offer free use in the "low tier" area, and only when a certain sales level is reached you do have to pay for a license. Your own preference and skills in the coding language can and should also be considered; here, for example, Unreal uses C++, while Unity uses JavaScript or C#. In addition, both companies serve the market with asset stores, where you can access ready-made 3D models, characters, sounds and particle systems, among other things. Both engines are suitable tools for application development for virtual reality and depending on your own requirements or origin, you will make your selection for the development environment based on these and other parameters.

In order to use VR sustainably in VET institutions, organizational and administrative tools are helpful. This software is intended to facilitate the organization of the rental of VR glasses to teachers and learners, as well as the associated bureaucracy and administration of data protection documents or rental contracts. If tracking data or result data from VR exercises, tests or games from the glasses are to be used to check the learning progress for the teachers, an appropriate system or platform must be available for evaluating the VR glasses and making the data available. Software to support teachers, but also users, in order to be able to quickly clarify and resolve any technical questions that arise, is an advantage. Furthermore, a communication channel can be helpful not only for service technology, but also between teaching staff and users, and between users for exchanging information with each other.

Additional equipment and organizational framework conditions

In addition to the hardware and software, further equipment and framework conditions must be taken into account, which are listed in this section.

Facilities

If the VR goggles are used during lessons in the educational institution, sufficient space must be provided in order to be able to move freely in the virtual world and ensure immersion. The size of the required space may vary depending on the VR headset and virtual learning environment. The recommended playing area is between 3.5m x 3.5m and 5m x 5m. Virtual teaching content is often designed for stationary use, so that not much real movement is required. However, care should be taken to ensure that there are no objects such as tables or chairs directly next to the users, as arm movements or a few steps may still be involved during use.

Safe storage of the VR glasses must also be organized. The size of the room or cupboard depends on the number of VR glasses to be stored. However, care must be taken to ensure that charging stations or power connections are available for charging the VR glasses.

Hygiene

As VR goggles are worn on the face and the controllers are held in the hand, they must be adequately cleaned after each use, whether VR goggles are used during a course or privately. Commercially available disinfectant wipes or disinfectants in spray bottles with paper rolls can be used to quickly disinfect sweat, make-up or sun cream during lessons. Disinfectants containing alcohol should be avoided. Rubbing alcohol should only be used if the manufacturer specifies it as a cleaning agent. The lenses must not be cleaned with disinfectants containing alcohol, but only with special agents for screen cleaning or cleaning agents for sensitive surfaces.

Additional hygiene products are also available on the market, for example to cover the foam face cushion with silicone or leather to ensure easier and more thorough cleaning. The most intensive cleaning is provided by UV-C cleaning cabinets, which remove germs, viruses and bacteria using high radiation energy. Depending on the

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cabinet, there is space for one or more pairs of glasses and the cleaning process takes approx. 60 to 300 seconds. A lens protector should be fitted before cleaning. Experience values for long-term use are not yet known, as the UV-C radiation could possibly attack the plastic (see DTHG, 2022).

Transportation

VR glasses include several components such as controllers and charging cables. Small storage cases, carrying bags or rucksacks are available for easy transportation of the individual glasses and accessories. If several VR glasses are to be transported to a specific location at the same time, a basket or trolley should be considered. Labeling: For inventory purposes, but above all for the purpose of allocation, it is essential to label the VR glasses with accessories such as controllers, charging cables and storage boxes. Standard labeling devices for label printing have proven themselves for this purpose.

Time

Once the decision has been made to introduce VR into the curriculum, time is of the essence - both for implementation and for use. Learning objectives should be precisely defined in collaboration with developers and teachers and suitable didactic models should be applied or considered. Sufficient time should be allowed for this preparatory work before the actual apps are developed.

Teaching staff need time to familiarize themselves with these new media and to recognize the potential and possibilities. As they will later usually also act as support staff for the users, they must feel comfortable using the learning technology and be able to solve any problems or questions that may arise themselves.

Time should also be reserved for the introduction of VR goggles during the course. In vocational education and training, the course curriculum is very tightly planned, so there is little time to spare. However, sufficient time should be allowed for training on the VR goggles and the VR learning content, as well as for organizational matters.

Costs

As with any purchase of new technologies or devices, the costs are variable and depend on the time of purchase as well as the requirements and use.
However, it is not only the initial costs that need to be considered, but also the subsequent running costs such as maintenance, service and personnel.

In-house developments of VR apps are cost-intensive, but it should be noted that numerous VR learning apps are already available and in-house development is not always necessary. On the other hand, the ROI[2] of the self-developed app increases with more areas of application. How much does the purchase of a new training device

[2] Return on investment literally means: The return on investment, i.e. the capital. ROI is therefore a calculation figure or an entrepreneurial indicator that provides information on when an investment has paid off or whether it is profitable.

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(e.g. CNC machine) cost and how many learners can be trained with it in a certain period of time compared to the purchase of VR glasses and virtual training?

Basics of green hydrogen

The element hydrogen is the lightest atom and occupies the first place in the periodic table of elements (PTE). It is mainly found in chemical substances such as water, acids and hydrocarbons and hydrogen does not occur in its pure form in nature. Due to the need to separate hydrogen from molecules, it is considered a secondary energy. Hydrogen has no color, no smell and no taste. One kilogram of (compressible) hydrogen contains 33 kWh of electricity. In comparison: One liter of diesel corresponds to 10 kWh of energy.

Hydrogen makes it possible to store large amounts of energy in the long term and also enables safe and cost-effective transportation over long distances. The use of hydrogen can help make industry and the transportation sector climate-neutral and eliminate the need for fossil fuels. In the future, hydrogen can make an important contribution to the stability and security of the energy supply and to securing the prosperity of the industrial location, as the share of fluctuating renewable energies is continuously increasing.

Due to the dynamic growth of the global market for innovative hydrogen technologies, new jobs and sales markets are opening. At the same time, it contributes to global economic growth. Clean hydrogen is a universal energy carrier and makes a significant contribution to reducing greenhouse gas emissions in industries that cannot be converted to renewable electricity sources, nor easily.

Although hydrogen is a colorless gas, there are different “colors” of the gas. These are used to identify differences in production and their impact on the environment. The most common colors are hydrogen in the colors **grey**, **blue** and **green**:

- Fossil fuels such as coal or natural gas are used in the production of grey hydrogen, for example through the so-called “reforming”, i.e. steam reforming. This process leads to the formation of carbon dioxide (CO_2), which means that grey hydrogen is considered carbon intensive and therefore not climate neutral. It is currently the most commonly used hydrogen production method, but also the most environmentally damaging. However, hydrogen produced with electricity from the general power grid in electrolyzers is also sometimes referred to as grey hydrogen because fossil energy sources are still used to generate electricity.
- Blue hydrogen, just like grey hydrogen, is produced from fossil fuels. However, the resulting CO_2 is collected and stored underground (carbon capture and storage, or CCS for short) instead of being released into the atmosphere. This makes this version more environmentally friendly than grey hydrogen, as it has no CO_2 emissions. However, this storage is extremely energy-intensive, and no evidence has yet been found for the safety of potential “CO_2 repositories”.

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- **Electrolysis** is the method for producing green hydrogen. In this process, water is split into its components hydrogen and oxygen using only renewable energies such as wind or solar energy. This makes green hydrogen the cleanest form of hydrogen, as it does not cause any CO_2 emissions. It has the potential to be a sustainable alternative to other energy sources and make a significant contribution to the decarbonization of various (economic) sectors. However, the expansion of renewable energies in Europe is currently not sufficient to meet the demand for green hydrogen.

However, hydrogen is assigned other colors depending on the underlying production process and the energy sources used. When coal is used as an energy source, it is referred to as brown hydrogen. In contrast, pink hydrogen is produced by electrolysis using electrical energy from nuclear power. Fossil and renewable energy sources are used in the production of yellow hydrogen. Hydrogen that is produced as a “waste product” of chemical processes is referred to as white hydrogen.

Areas of application

Hydrogen is currently used in various areas, but its share of the total energy supply is still relatively small compared to other energy sources. Hydrogen is used in industry both as a raw material and as a chemical component in various processes such as refinery production. Hydrogen is also used in the steel industry to replace coal. In the mobility sector, H_2 is to be used wherever electric drives are not practical or not possible. Aircraft, ships and trucks are also to be powered in this way in the future.

Production

The process of electrolysis consists of producing hydrogen by splitting water (H_2O) into its components hydrogen (H_2) and oxygen (O_2) using electricity. **Alkaline electrolysis** and **PEM electrolysis** (PEM = Proton Exchange Membrane) are two common electrolysis methods:

- In alkaline electrolysis, either caustic soda (sodium hydroxide, NaOH) or potassium hydroxide (potassium hydroxide, KOH) is used as the electrolyte. The method involves an electrolytic cell with a positive pole anode and a negative pole cathode, which are immersed in the electrolyte solution. When an electrical voltage is applied, the water is split and oxygen molecules (O_2) are released at the anode, while hydrogen molecules (H_2) are formed at the cathode. Alkaline electrolysis has a long tradition and uses inexpensive materials. However, it requires a high operating temperature and is less efficient than PEM electrolysis.
- PEM electrolysis uses a proton exchange membrane as the electrolyte. The membrane allows protons (H^+) to pass from the anode compartment into the cathode compartment while preventing the passage of electrons. The electrolysis cell consists of an anode on the hydrogen side and a cathode on

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the oxygen side and the PEM membrane is located between them. The water is split by applying an electric current, so that protons and electrons are created at the anode. The electrons move through an external electrical circuit, while the protons pass through the membrane to the cathode. Hydrogen is produced by the combination of protons, electrons and oxygen molecules at the cathode. PEM electrolysis is more efficient, reaction times are faster, and the operating temperature is lower. Fuel cell technology uses the opposite principle for instance. The chemically stored energy in the hydrogen is converted into electrical energy (see IHK: Hydrogen - the basics).

The „Green H2VR“ project

Project description

The Green H2VR project aims to support those professional groups in particular, whose working environment is most affected by developments in hydrogen technology, in building up skills in the field of hydrogen technology and sustainable energy generation and storage so that skilled workers have the necessary know-how, and the energy transition can succeed. The Green H2VR project is therefore primarily aimed at apprentices and workers in the fields of installation, plant engineering, gas technology, electrical engineering, solar technology, home automation, civil engineering and safety engineering. The importance of hydrogen will continue to increase in the coming years in order to meet energy requirements. It will therefore be particularly important for employees in the above-mentioned professional fields to expand their skills with regard to the use of hydrogen technology. The aim of the Green H2VR project is to create a universally applicable product that can be used in a variety of occupational groups and can be used in both initial and continuing vocational training.

Another target group addressed by the project is vocational education and training institutions, as Green H2VR not only enables them to expand their vocational training in the area of green skills, but also to make their courses more innovative, digital and inclusive. As a result, Green H2VR also supports vocational education and training institutions in increasing the flexibility and attractiveness of their training programs. The project thus also contributes to increasing innovation in the VET sector.

The app, which was developed in the project, is designed to familiarize learners with the basic principles of green hydrogen production and various usage paths for green hydrogen in a playful way in a virtual learning environment. The VR technology makes it possible to visualize elements and processes easily and thus makes the interaction of the individual trades easier to understand.

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Training scenario of the Green H2VR app

When you start the app, you are immediately faced with the interactive "game table" and you can get started straight away after reading the safety instructions (see Figure 5) and pressing "Einverstanden (Agree)".

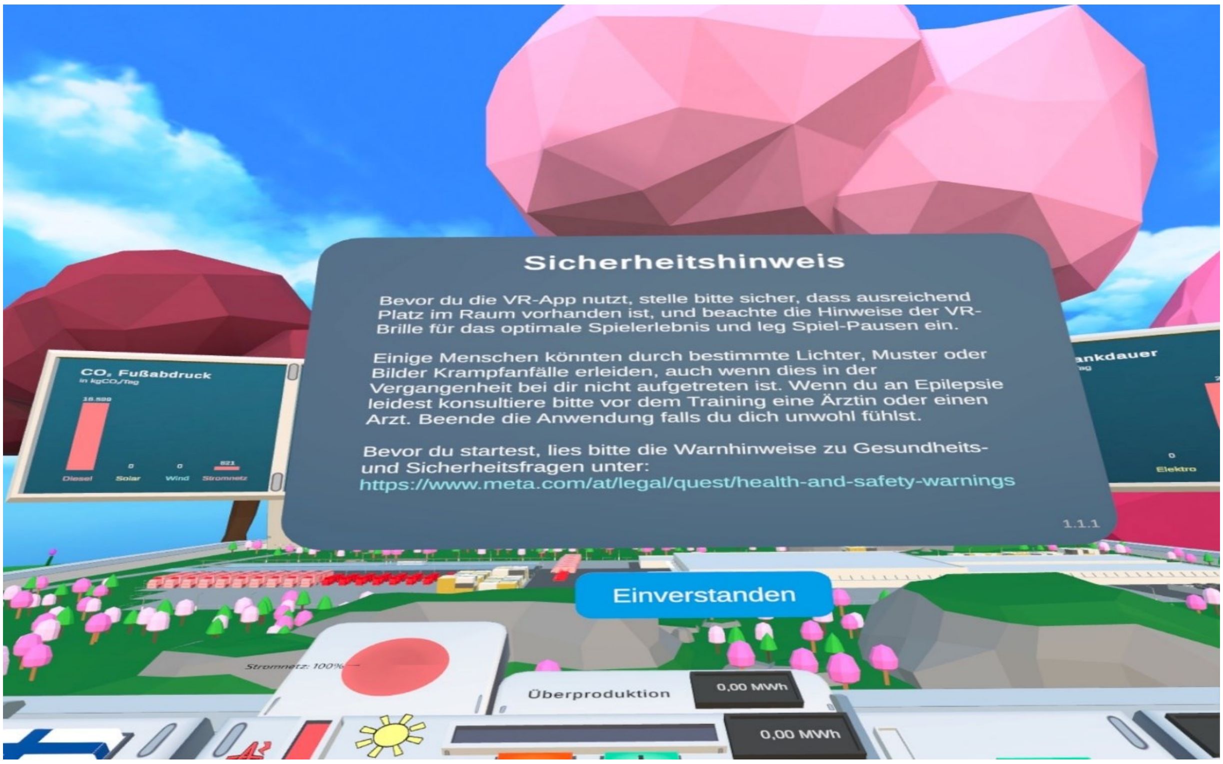

Figure 5: Safety note

If you pan a little to the right in the VR app, you can see the description of the controls in the app on a panel (see Figure 6).

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Figure 6: Control system

In the following illustration (see Figure 7) you can see the interactive “game table” in front of which you find yourself when you open the VR app.

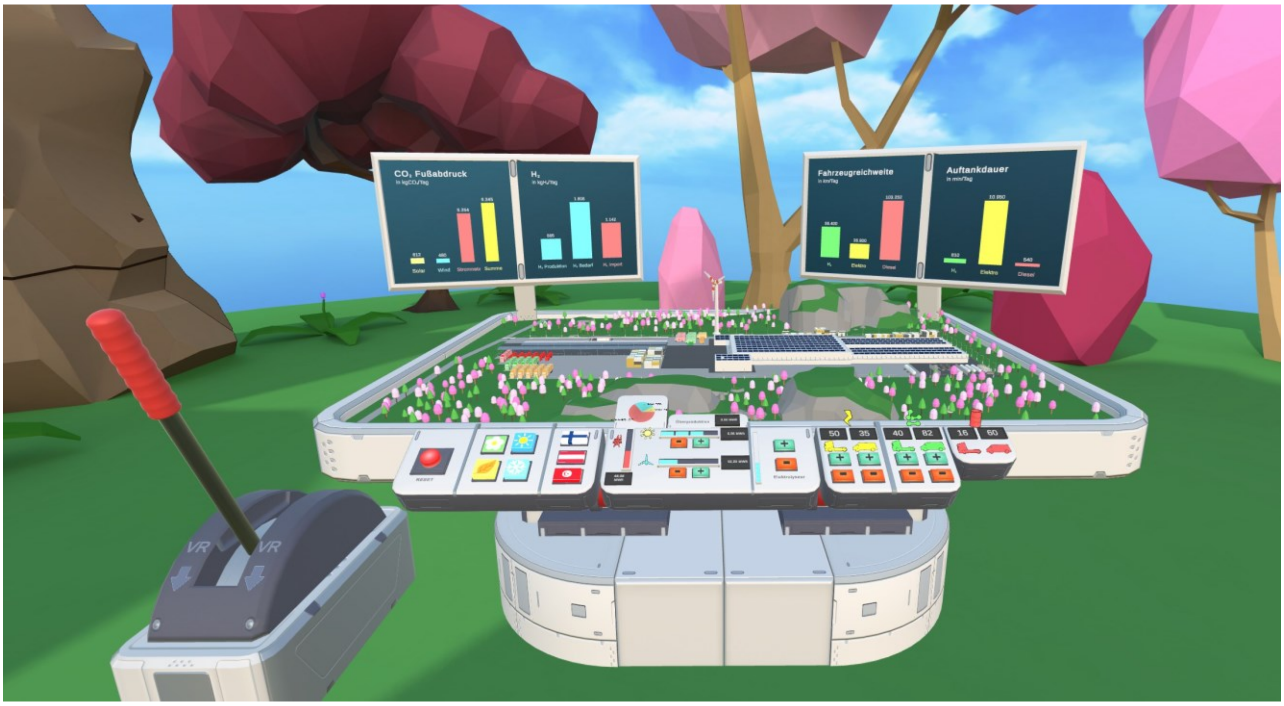

Figure 7: Interactive game table

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In the following figures, the various buttons and levers (see Figure 8) in the app will be briefly discussed and it is also explained what can be changed or adjusted with them, as well as what can be read on the four panels (see Figure 9) in the background.

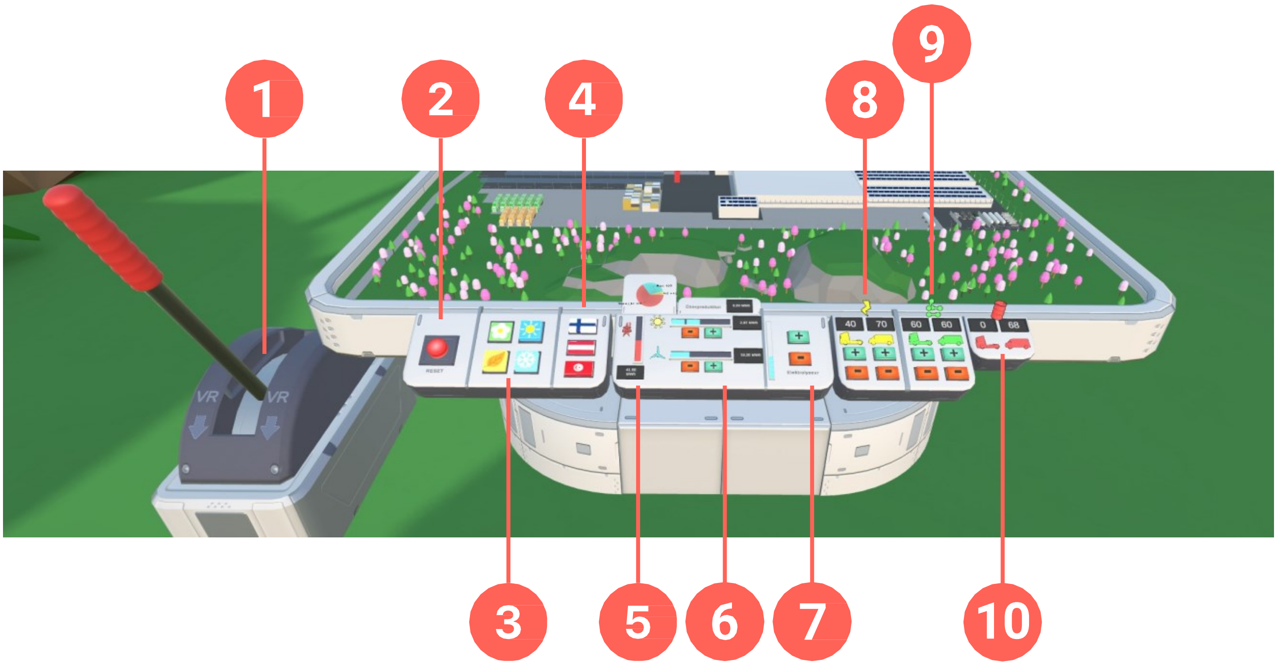

Figure 8: Meaning of buttons and levers

1. By pulling or pushing the lever, you can switch between full virtual reality and mixed reality.
2. Pressing this button will reset all your settings and allow you to start over.
3. By pressing the different buttons in this group you can switch between the four seasons, spring, summer, autumn and winter.
4. By pressing the three buttons in this group you can change the location of the logistics center between the countries Finland, Austria and Tunisia.
5. Here you can see the additional megawatt hours that your logistics center requires from the power grid.
6. By pressing the "+" or "-" button in this group you can change the solar radiation in four levels or the wind strength in three levels.
7. By pressing the "+" or "-" button you can change the electrical energy supplied to the electrolyzer.
8. By pressing the "+" or "-" button in this group you can change the number of electric trucks and delivery vehicles. To simplify things, a power of ten is used.
9. By pressing the "+" or "-" button in this group you can change the number of hydrogen trucks and delivery vehicles. To simplify things, a power of ten is used.
10. In this group you can see how many vehicles are currently on the road. To reduce the number, you can add electric (8) or hydrogen (9) trucks and delivery vehicles.

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Figure 9: Meaning of panels

1. Here you can see the CO_2 footprint of your logistics center in $kgCO_2$/day, composed of solar energy, wind energy, power grid and the sum of these.
2. Here you can see an overview of hydrogen production, demand and import in kgH_2/day.
3. Here you can see the range of the vehicles used in km/day, divided into hydrogen vehicles (H_2), electric vehicles (electric) and diesel vehicles (diesel).
4. Here you can see the required refueling time in minutes/day of your vehicles, divided into hydrogen vehicles (H_2), electric vehicles (electric) and diesel vehicles (diesel).

Learning questions:

The aim of the Green H2VR app is to carry out and answer various tasks and learning questions in a playful way. The questions created by the project consortium include the following:

- Find the maximum fleet range with a minimal carbon footprint!
- What share of generation is provided by wind power and what share by PV power?
- In which region and at what season of the year can the highest yield be achieved from renewable energies?
- What is the maximum range that can be achieved with a hydrogen vehicle fleet without drawing electricity from the grid?
- How long is the refueling time?
- What is the maximum range that can be achieved with electric vehicles without drawing electricity from the grid?
- How long is the charging time?
- What is the maximum amount of hydrogen that can be generated without drawing electricity from the grid (i.e. purely from renewable energies)?

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Evaluation description and analysis of results

In order to investigate the acceptance, user-friendliness and presence of the developed VR training and to derive guidelines for the integration of VR training into vocational training curricula, an evaluation of the VR app was carried out together with stakeholders from vocational education and training (apprentices & students) and some teachers. Both qualitative and quantitative methods were used to collect and evaluate the data.

The study started at the beginning of the project with a stakeholder workshop at the premises of HyCentA Research GmbH to determine the needs and requirements of the stakeholders involved so that they could be taken into account in the development of the VR app. In this stakeholder workshop, not only the appearance of the user interface was discussed, but also the possible content of the application, as well as various myths surrounding hydrogen production and use.

In order to test the VR application developed in this project in the best possible way and with the appropriate target group (apprentices and workers working in the fields of installation, plant engineering, gas technology, electrical engineering, solar technology, home automation, civil and security engineering), testing was carried out at the following facilities:

- Voitsberg State Vocational School: The Voitsberg State Vocational School trains apprentices in the electrical building technology apprenticeship, which developed from the classic apprenticeship as an electrician. Training is also offered in the additional modules of building control technology, renewable energies and building technology service.
- Eibiswald State Vocational School: State Vocational School for Electrical Installation Technology and Radio Mechanics.
- HTL BULME: The training focuses on electronics and technical computer science, e-technologies, mechanical engineering and industrial engineering.

These three schools are of particular interest for the evaluation of the VR app not only because of their individual focuses and vocational training, but also because of various projects in the areas of **green energy and sustainability**.

The survey consisted of three different parts:

- quantitative part: This part of the survey consisted mainly of questions from the standardized IPQ (Igroup Presence Questionnaire) scale, which is mainly used to measure the feeling of presence in a virtual environment. This standardized scale was supplemented with our own questions.
- qualitative part: This section of the survey consisted of an open question: “What can you take away from the VR training?”
- socio-demographic information

In total, almost 100 apprentices, students and teachers from the three previously mentioned (vocational) schools took part in the survey.

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The quantitatively collected data shows that there is a high level of acceptance for the use of a VR learning environment as part of apprenticeship training. It was easy for the test subjects to learn how to use the VR training solution. The evaluation results also show consistently positive results in terms of learning quality.

The majority of the answers to the qualitative question were very positive. Many of the people tested said that they would have liked to try it for longer and would be happy to do it again. Many of the test subjects also said that they had a lot of fun, that they were able to learn something new and that this type of learning is much better and more effective than a classic frontal teaching style with slides or similar. Some of the testers said that it is a very interesting way of learning and provides a good basis for creating further applications for other subject areas.

In summary, the Green H2VR evaluation was able to demonstrate a clear added value that results from the use of a VR learning environment for the learning experience and learning success in VET. In addition to individual design optimizations, the further development of the content, but above all aspects of embedding the system in everyday teaching, as well as appropriate financing, are the most important challenges for follow-up activities of the Green H2VR project.

The complete evaluation report can be requested from the author of this document at room466@wkstmk.at.

Integration of VR in education

In the course of implementing the Green H2VR project, the project partners have gained experience with the integration of VR in educational systems. These findings are listed here in order to facilitate and successfully design future implementations.

In general, VR or XR-based learning should be seen as a supplement to traditional teaching and learning methods. They should not be used to reduce or replace the exchange between teachers and learners; rather, the use of these new technologies should be seen as an enhanced learning method. A learning method that can overcome real obstacles and limitations to practice, training and learning.

Despite the view that VR should be integrated into training as a complementary learning method, the roles and course structures in general need to be reconsidered and changed.

The teaching staff should take an active role in the implementation and development phase to ensure sustainable use. The teachers involved are asked to rethink common learning methods, consider how to use them correctly and, when developing their own methods, to look at the learning material or the knowledge to be passed on from a new perspective and to redesign the course structure and knowledge assessment.

An important recommendation is to involve the various stakeholders in the implementation of VR as a teaching method, as this is a change management process.

Furthermore, as already mentioned in a previous section of this guideline, acceptance increases when the development is stakeholder-centered and the added value is quickly recognized for them. Stakeholders also refer to the users who should be involved in certain development phases, such as testing, etc.

Recommendations for the use and process of VR training

In this guideline, the numerous possibilities for using VR in education were already discussed earlier (see Figure 1). Before looking at the various possible uses for virtual training and practice in this section, the necessary training of users in how to use the VR goggles should be considered.

Initial tutorials

The time required for the initial training is a key factor in the use of VR training. One way to reduce the support effort involved in this context is to develop interactive tutorials through which learners can access basic information on how to use the hardware and software, but also learn the basic process of VR training. Initial virtual tutorials are recommended in order to be able to offer VR regardless of location and time. The introduction to the goggles and the virtual training do not necessarily have to take place during a face-to-face session with the teacher. In addition to the flexibility for independent training, a virtual tutorial also offers the advantage of being able to accommodate the individual learning pace and familiarization with the new learning technology. Although the time required for the initial training may initially seem time-consuming, it should be noted that the complexity of the interaction decreases with the length of use and that VR-based learning, even if it takes place during face-to-face time, saves time in terms of conveying teaching content. In contrast to traditional, sequential learning, the advantage of using VR is that all learners can train at the same time. One example is practicing how to switch on an expensive machine, such as a CNC milling machine. In training workshops, there are usually only one or two of these machines. Each learner should be able to practice how to operate the machine at least once. While training on this machine takes around 10 minutes per person, the rest of the learners do not have the opportunity to use the machine. A lot of time has passed by the time all individual learners have "completed" their 10 minutes on the machine. With the help of VR, this time can be reduced or made more interesting. For example, a virtual CNC training scenario can act as pre-training, so that learners can practice correctly switching on the virtual CNC machine at home beforehand. This reduces the time each learner spends in front of the real machine because they have already practiced switching on and operating the virtual machine x times. However, VR goggles can also be distributed to the remaining learners during the course unit so that they have the opportunity to practice and train virtually while they are waiting.

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VR training types

The example of the CNC machine in the previous section has already hinted at various usage scenarios for VR in education or types of VR training.

VR can be used for training in the following ways, among others:

- **Practical training:** to transfer abstract knowledge into action sequences, to practice in a team and with different action or environmental variables.
- **Pre-learning:** to refresh or learn skills and knowledge before the actual course, in order to start the training with a uniform level of knowledge.
- **Exploration of environments:** to make them more tangible.
- **Learning complex technical terms:** to learn them more easily and sustainably in a playful way.

Location and time of the VR training

Virtual reality at home

One way to integrate VR into the curriculum is for users to complete VR training privately. Each learner is given a pair of VR goggles to take home and to do the training in their own home as often as they like and at flexible times. When using them, certain measures must be taken, such as drawing up rental contracts, etc. The rental of VR goggles must be organized and administered by appropriate, trained staff. Technical support with the appropriate communication channel and software should be available to clarify any problems or questions VR users may have. In this case, the software for device management must enable remote access, as offered by ArborXR, for example. A possible desired exchange and communication channel between teacher and learner during the virtual self-training period should be considered.

If the training is to take place at home as pre-learning, i.e. before the course starts, a lead time to the actual start of the course must be planned and communicated in order to give the learners enough time to reach the same level of knowledge before the course. If learners refuse to use VR (e.g. refusal due to responsibility for the VR goggles) or do not have the appropriate capacity (e.g. lack of internet connection if necessary), alternatives such as a room at the educational institute or other learning materials must be provided in order to give these learners the opportunity to prepare for the course.

The shipping or rental of the VR glasses must be organized in terms of timing and personnel. The tasks and responsibilities between the teacher and the support team must be clearly defined.

VR during the classroom session

VR in the classroom can make waiting times more productive, be used for team training and/or for demonstration purposes, etc. Depending on the application, additional hardware such as a projector must be available, a strong internet connection must be available, or the software must be suitable for simultaneous use by several users. If the VR training takes place during the classroom session, the time factor of distributing and becoming familiar with the VR glasses must be taken into account. Personal support for the teacher is an advantage, who has of course already been familiarized with the technology beforehand.

An important tip for planning VR during the classroom session is to have the appropriate space available. VR use requires a lot of free space and is multiplied by the number of users who are to train with VR at the same time. Even if the training scenario involves stationary operation, such as the CNC machine example above or the Green H2VR app, larger hand movements or a few steps are usually involved. Tables and chairs in the room are therefore not an advantage. It is best to design a separate VR room to save the time and effort involved in adapting the room. Or it is possible to use free corridors, for example.

As already mentioned above, learners can refuse to use VR for various reasons. Often, feelings of discomfort (so-called motion sickness) are given as the main reason, but a certain feeling of embarrassment, i.e. moving "funny" in front of the group, is also often mentioned. Use is sometimes prevented by optical glasses or glasses that are too large, although it should be noted that the newer models take this problem into account and make use with optical glasses much easier. When using the system in a course and therefore in front of other learners, it is important to talk to the learners beforehand about certain inhibitions and possibly demonstrate the VR training via a projector beforehand.

Although motion sickness can be reduced with the quality of the graphics and design, care should be taken to ensure that the time spent in virtual reality is not too long at a time. VR training is mentally demanding, and learners start to feel tired or dizzy after about 20 minutes. Experience has shown, however, that these "side effects" diminish with more frequent use and the associated habituation effect.

Observation of usage and learning success

An important point to consider is whether the use or learning success should be monitored, or whether VR should simply serve as an incentive to learn and as an alternative learning method for users. This applies to use at home, but also to use in face-to-face lessons. In order to still get feedback on the use or learning results as a teacher without carrying out a classic knowledge query, gamification elements are a good option. For example, an integrated game with score ranking between users can be offered. If the teacher requires a review of the use based on data from the VR glasses, this should be considered when developing or purchasing the VR learning scenario. A trainer dashboard should generally be considered as additional software.

Role of the teacher

As already mentioned, several times, the aim is to involve teachers from the beginning of the implementation so that they not only become familiar with the technology as early as possible, but also recognize the added value as soon as possible. Only when the potential of VR is clear the versatile applications and countless possibilities and that VR can make the impossible possible can be understood. However, not only does VR training need to be developed or given attention, but consideration must also be given to how it can be optimally integrated into the course and how the course structure changes as a result.

VR unfolds its full potential when this technology is not just seen as another learning tool for individual use. VR can give the teacher insights into where difficulties or problems with understanding exist among the learners and the teachers can then address these in the course and repeat the relevant learning content.

For the smooth operation of a VR training solution in the educational institute, it is important that the teacher's responsibilities with regard to the VR goggles are clearly defined. Responsibilities for the ongoing maintenance of the hardware should be clearly distributed among the staff and not taken for granted. This applies both to VR use during the classroom session and at home.

Recommendations for the development of VR training

As has been shown in various research projects on VR applications, both learners and teachers felt it was very important that the subject-related aspects of the training content reflect the real world as closely as possible. In order to achieve the necessary realism, it is therefore important that VR learning content is created in close cooperation with subject matter experts.

One question that learners have repeatedly asked is whether a high level of realism that has no consequences in the event of operating errors in the virtual space could not also lead to people working more carelessly in real environments in the medium term. This point should be addressed when designing VR training by explicitly pointing out the consequences of errors using clear feedback mechanisms.

Another key aspect in the development of VR learning content is that it is well coordinated with the content of the curricula, so that learners always have exactly the practice options they need to deepen the current learning content. In addition, a VR learning environment should also respond to the individual learning progress of individual users by means of variable difficulty levels, so that both over- and under-challenge is avoided.

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