Immersive Learning in Real VR

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Abstract. Immersion is an essential factor for successful learning. Immersive learning environments put learners directly into experiences and events related to the learning content. Virtual reality (VR) experiences give us new opportunities and ways for enabling immersive learning processes. In this chapter, we review different learning environments that use (real) VR as a tool to teach in different learning settings and discuss the state-of-the-art design and evaluation techniques and analyze the benefits and limitations of the different methods.

Keywords: Immersive Learning · Virtual Reality · 360VR

1 Introduction

Over the past decades, the way we learn and how the information we need to learn is presented has fundamentally changed. Especially online videos have emerged and shown to be an essential component of educational processes [20]. Already in 1922, Edison mentioned: *"I believe the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks"* [40].

Videos can help students to visualize, mesmerize, and understand topics and are often cost-effective methods compared to present teaching elements. In recent years, studies have shown that interactive forms of videos have a high potential to support learners in the learning process. Video-based instructions were even described to be similarly realistic as face-to-face instructions, but add flexibility and accessibility to the learning process [13,26].

In recent years, the use of 360-degree videos has become increasingly popular, also for immersive educational experiences [51]. Immersion has been shown as a successful driver of enhanced learning experiences in several studies.

360-degree videos can be experienced with VR head-mounted displays (HMD) to help learners immerse themselves into the experiences. The benefits of using VR environments for teaching scenarios have been shown already very early and quite intensely. It gives students possibilities to explore environments and processes which are invisible, too expensive or complicated to reproduce for a learning process, or even impossible to perform in a traditional learning environment. As VR technologies have become relatively affordable and also portable over the past years, the integration in learning setups

such as classrooms, training environments, or even self-directed learning at home is becoming increasingly attractive. With VR technologies, entirely new learning scenarios can be designed to support and engage learning to understand even complex phenomena and processes. The learning scenarios which are used for teaching can either be entirely simulated or animated or produced using real video content (360-degree videos) for taking the learners to real learning scenarios to re-watch processes.

The goal of this chapter is to present and discuss an overview of the state-of-the-art of immersive learning experiences with a focus on experiences using video footage from real-world processes and events.

2 Capturing 360-degree Videos for Educational Purposes

With game engines such as Unity[1], we can create and design entirely virtual worlds that can visualize and simulate learning environments. However, this also requires advanced 3d-modeling, coding, and interface design skills.

In contrast, with the use of 360-degree videos, VR experiences can be created directly by educators, and realistic video-based experiences are enabled.

Feuerstein [22] describes a typical workflow for integrating 360-degree videos in higher education. The first step is the production, which involves thoughts about elements such as controlling and positioning the camera. The second step is the post-processing. This is usually done by using the proprietary software provided by the camera manufacturer. Optional steps would be to add further information points and interactions with the user. The last step is described as the delivery of the video content. 360-degree videos can be delivered either through a traditional monitor-based environment or through an immersive VR device . The delivery we are focusing on in this paper is the delivery in a fully-immersive way: through an HMD resulting in a (real) VR experience.

Many authors also described their experiences by capturing videos for the learning experience. Ardisara and Fung [10] describe how they use 360-degree cameras to capture laboratory techniques in an undergraduate organic chemistry course. Lecturers describe the video capturing process as easy. In their case study, Ardisara and Fung identified several advantages compared to the use of conventional cameras. One does not need to worry about the focus or the scope of the view. Also, no external camera personnel is needed as the lab instructor can use the camera to film while conducting the experiments.

Kavanagh et al. [34] describe in a case study how they create educational videos for HMDs with 360-degree cameras. They describe the process as easy and cost-effective; however, they also list different issues in the process. Issues include the right positioning of the camera, fish-eye lens-related distortions, the price of high-quality hardware, and the video quality of cost-effective models. One major issue the authors described was also the missing possibility to direct the attention of the views. Mainly for educational purposes, it is crucial to remove external visual distractions. In 360-degree experiences, learners can easily be distracted by the surroundings. This can be either be an unintentional loss of track of the primary educational experience (e.g., losing track where

[1] https://unity3d.com/

the lecturer is located) or distractions by other parts of the experience (e.g., elements or actions in the surroundings). Thus, strategies to guide learners are crucial to create successful learning experiences.

2.1 Guiding Learners in 360-degree Videos

In the traditional 2D education media, many techniques have been refined and are regarded as incontrovertible methods to guide the eye and attention of the viewer. The methods developed by Block [12] which are also usable in 360-degree media and VR are:

Surface division: By using the lines and edges occurring in the environment as image splitting or even as extra ”picture frames”, the attention of the users can be directed thereby.
Color and brightness: Highly saturated colors or bright image areas can also be used well for attention steering. Note that brightness always attracts attention first, followed by saturation of a color.
Movement: The rhythm of a picture is strongly related to the equipment of the scene. This, too can affect the attention of the user. A rhythmically calm image can make viewers concentrate on certain content or objects, while a rhythmically irregular image can quickly become a hidden object.

2.2 Cone of Focus

One important tool to guide the learners' attention is the 360-degree content sharing diagram (as depicted in Figure 1) called Cone of Focus, which was developed by Soap Collectives[2].

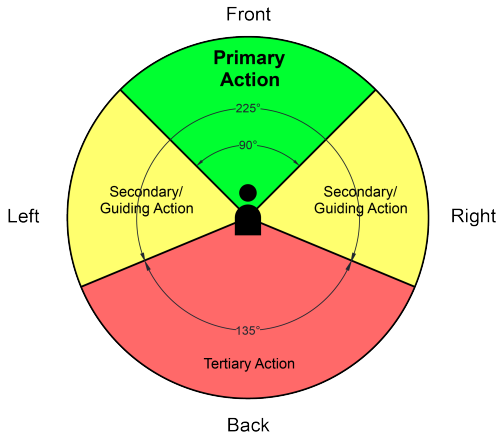

Fig. 1: Cone of Focus: In order to draw the attention of the users in VR to the learning content, the focus of the 360-degree recording should be in the front area.

[2] https://www.thesoapcollective.com/

It is assumed that the majority of users are on a non-rotatable chair (e.g., classroom, training environments). From this position, now the focus of the user can be planned. One mistake is placing the events around the camera; this is often confusing, loud, and overwhelming. Instead, the place should be set with care and reason.

Therefore, the 360-degree scenes are divided into three areas. The ”Primary Action” lies in the range of 90-degree in front of the observer. It is advisable that the content of the training begins here. The ”Secondary Action” areas are approximately as far to the left and to the right of the user as they can be, without requiring user effort to turn their heads. This area is meant to support the teaching content, it is not essential for the understanding of the matter itself, but it does help with the context. Finally, the area of the ”Tertiary Action” is behind the observer and serves the elements on which no consideration must be taken. Compared to traditional educational videos, this would be things that are out of the frame and, therefore, not attracting the attention of users. However, in 360-degree media, this area serves to immerse the observers. If the observers turn around once this ensures that they are not thrown out of the environment and realize that they only have a HMD on.

The principle of ”Cone of Focus” is supported by the ”Guiding Action”(see Figure 2). This can be a series of events that are supposed to take the user to a specific location in the 360-degree range. Rough leaps in light, sound, or events are perceived by the observer, even if they are in the area of secondary action since this is still in the peripheral field of vision. As a result, attention is then directed in this direction.

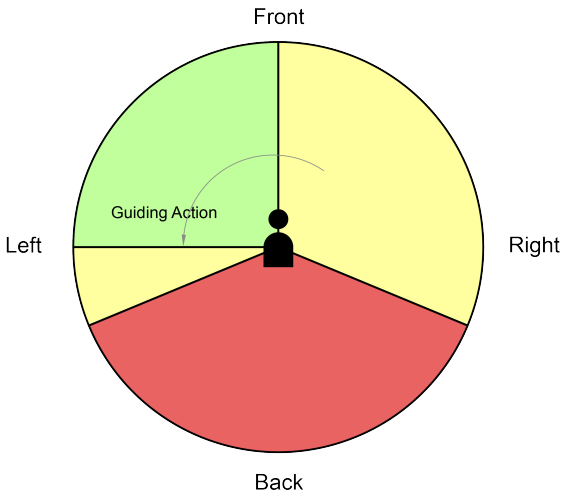

Fig. 2: The Guiding Action can steer the viewer’s focus into new areas.

3 Application Domains and Examples

VR enables learners to be immersed in learning scenarios. They can train in environments by immersing themselves in lifelike situations which are otherwise too dangerous

(e.g. chemistry experiments), which would result in terrible consequences (e.g. simulation of a surgery), which are too expensive (e.g. complex laboratory setup), or which are hard or even impossible to reproduce [16].

Several studies have shown the potential of immersion in digital learning scenarios. The added values of immersion are, for instance, the support of multiple perspectives, situated learning, and transfer [18]. The additional dimension of immersion provided by fully immersive VR environments with HMDs has been shown to support the knowledge structure. Coulter, Saland, Caudell, Goldsmith, & Alverson [16] have shown in a study that learners show a significant knowledge gain when using VR learning scenarios compared to computer-screen based (partially immersed) learning settings.

In this section, we describe different application scenarios found in the literature for different learning activities.

3.1 Virtual Tours

With proper equipment like omni-spherical cameras, people can create 360-degree content on their own. As a result of this, platforms like YouTube or Facebook already allow the sharing and playing of 360-degree videos. This easy creation and accessibility led to a huge amount of 360-degree content on the web, which includes virtual tours of museums, malls, and buildings. The use of additional software like the Skybox VR Player[3] allows users to watch 360-degree YouTube videos with HMDs like the HTC Vive. In comparison to traditional videos, 360-degree virtual tours enable viewers to focus their view on their point of interest. Especially, virtual tours through museums, iconic buildings, or cities show great potential in terms of immersive learning. Also, they allow individuals to travel to places that would be inaccessible otherwise [35]. Reyna [48] describes virtual tools in education *"as a way to showcase complex scenarios that are difficult to explain with images, words, or event conventional videos"*.

These tours can be used to learn about all different subjects and topics such as science, history, architecture, construction industry or geography. Examples of 360-degree virtual tours found on Youtube include a virtual tour through the Royal Tyrrell Museum [6] to learn about dinosaurs, a virtual tour through a space shuttle [4], a tour through the Buckingham Palace [3].

3.2 Recorded processes and procedures

In many areas, the learning and training of a particular process or procedure is an essential element. Examples are the construction and execution of an experiment, the construction of a complex machine, or the execution of a medical procedure. This form of learning is currently often supported by video training. A teacher, trainer, or expert conducts the process, and the viewers learn by watching and re-watching the process steps in the video. 360-degree videos can help prevent information from being lost, for example, by setting the camera focus incorrectly. It also puts learners in a realistic environment and helps them understand the processes as a whole through situational learning.

[3] https://store.steampowered.com/app/721090/SKYBOX_VR_Video_Player/

Medical Training Medical students usually have the opportunity to watch real surgeries during their education. However, the number of spectators in an operating room is strictly limited. Therefore, the students only have a few chances to get familiar with the actions and procedures in an immersive and realistic environment. VR as a tool for training students in the medical field might be the solution. Different approaches use 360-degree pre-recorded images or videos of operating rooms during surgeries to create educational learning environments in VR [7]. As a result of this, the spherical recording of the operating room allows for better observation compared to traditional video recordings because the view of the user is not limited to a specific camera angle. Some approaches go even further and enable the interaction of the user with the environment. In these cases, computer-generated components are often inserted into the environments which were created with 360-degree photorealistic content [31,32,47].

Laboratory Courses Videos also have been an essential tool for demonstrating the use of laboratory equipment or experimental procedures. Ardisara and Man Fung [10] demonstrate how to record and integrate 360-degree videos in an undergraduate chemistry laboratory course.

Sports Training An excellent opportunity for 360-degree videos is to use them for learning and training sports-related behaviours and skills. They are an effective medium for learning experiences in areas like sport climbing [25] or sports in general [29].

Craftsman Training VR using 360-degree photorealistic content could especially be helpful for an artisan to learn specific procedures like the steps for building a kitchen or laying tiles. Such learning environments have the advantage that they are independent of space and time and allow for individual learning progress. One approach is to perform different steps of a procedure in different parts of a room and record the whole environment using an omni-spherical camera. This enables the apprentice to focus on the steps which are still unclear [24].

Enjoyment Training Quality of life, health and well-being, as well as the creative potential that results from positive experiences and interaction with VR environments, are crucial human factors underlying a vibrant and productive social context. VR technologies have recently come up with tools to predict the affordability of future scenarios. Applications that relate in particular to visual stimuli that allow the induction of imagined sensory experiences (e.g. urban environments). In particular, dementia patients, are motivated, in a positive attitude, with pleasant and conscious sensory experiences, to react to their daily environment in order to improve their cognitive reserve [44] [37].

3.3 Recorded situations

Often, it is necessary to expose learners to situations, which are hard to train in real-life scenarios and need to be simulated in a safe environment. This, for instance, includes the simulations of catastrophic situations and how to train these scenarios in a realistic but safe way. These situations are often recorded with professional actors.

Nurse Education Different forms of simulations for nurse education have evolved over the last five decades. With this, earlier training models like role-playing have been extended or replaced by new forms of simulations that make use of games, computer-aided instructions, or VR [42]. In some countries like Sweden, extreme catastrophic situations are rare. Still, it is crucial to prepare emergency personnel for different catastrophic situations to maintain their competence. To address this challenge, 360-degree video can be used to expose nursing students or trauma teams to immersive learning environments showing simulated scenes in different conditions and places [30]. Another approach is to let nursing students experience different disabilities in VR to become aware of the patient's situation. One disability known as macular degeneration can, for example, be visualized by darkening areas of the user's view in the virtual environment [14].

Safety Training The usage of VR is not only possible for areas where the cost is surpassing the average by far, but also for fields that bring along hazardous working conditions and where the effort to conduct training is immense. VR safety training allows areas like the mining industry [23,45,46,54] or the construction industry [52] to lower their expense while being more effective and improving safety. Another possible domain of application is for earthquake safety training, where users are made aware of potentially dangerous situations and how to handle them [36]. Training like this can also be applied in terms of schools, where road or pedestrian safety is a significant factor in order to improve street crossing behavior [38].

3.4 Recorded experiences

VR is also often called the *"Ultimate Empathy Machine"*. VR helps learners to experience situations in someone else's shoes. This is also referred to as learning through perceptual illusion (embodiment) or the body ownership illusion [11]. Learners learn by experiencing other perspectives. Examples include an experience developed by The Guardian explaining a party situation from the perspective of a 16-year-old autistic narrator [5]. Another short 360-degree film places the viewers firsthand in the place of a prison inmate who lives in solitary confinement [2]. One of the most famous examples is the 360-degree film "Clouds Over Sidra", which lets viewers experience life as part of the Zaatari Refugee Camp, home to 130,000 Syrian refugees, most of them children [1]. Recorded experiences also become increasingly popular as a part of virtual news coverage and reporting strategies. Archer and Finger [9] found as part of a study with 180 people watching 360-degree videos that VR formats prompted a higher empathetic response than static photos or text treatments and that viewers would also be more likely to take political or social actions after viewing the videos.

3.5 Recording processes for learning through replay (self-reflection)

One approach is to use a 360-degree camera and let learners record their learning acts and to reflect upon the video afterward. Recent studies have explored the impact on the students and concluded that this yields high realistic sensations and inspires the students to observe and revise their behavior [53].

Teacher Education Videos can help teachers to facilitate reflection on their teaching style and practice [55]. VR in combination with 360-degree content is a powerful tool for teacher education as well. 360-degree recordings of classrooms can be used by pre-service teachers to learn about the classroom situation and analyze the students' behavior. Also, it enables them to learn how to reflect on specific teaching situations. Such enhanced observations are not possible with standard videos as the view is limited by the angle of the camera, and exploring the whole situation is therefore often not possible [48,49].

Sports Training Watching recorded processes of the own performance is not only used in the classroom but also, for instance, in professional sports training. Immersive learning has also been shown to be successful for training quarterbacks and helping them to immerse themselves in their past games and rethink decisions they have made during the game [8].

4 Benefits and Potential

In literature, we can find a long list of various benefits of 360-degree VR learning experiences:

- Easy accessibility by users through different devices [39]
- The whole environment and situation is accessible [50,43]
- Efficient presentation form of the content [32]
- Experience of situations in a secure setting [32]
- Feeling of presence [33]
- Enhanced empathy [33,48]
- Enhanced student engagement with the content [14,27,28]
- Enhanced student interest [51]
- Enhanced motivation towards learning goal [29,24]
- Improved learning speed [14]
- Improved learning results and skill acquisition [56,51]
- Less material required [14]
- Barrier between learners, teachers, and machines are removed [27]
- Enhanced reflection possibilities from different perspectives [29]
- Learning process independent of space and time [24]
- Learning content available to large audience [24]

The benefits of using real-world VR lie in faster, simpler, and more affordable content creation, as well as a more realistic and personalized watching experience. Several studies have also shown the effectiveness of 360-degree content in improving learning outcomes [53] and minimizing simulator sickness [51].

In contrast to simulated or computer-generated VR experiences, the creation of 360-degree content in Real VR is more accessible to a wide range of users as it does not

require special modeling or programming skills. Instead, students and teachers can produce their own content autonomously using 360-degree cameras (which are becoming more affordable) like the Ricoh Theta[4] to shoot panoramic photos or record omnidirectional videos. This accelerates and simplifies the content creation process for 360-degree VR experiences [22]. For example, shooting 360-degree video of the experiment being performed in real life takes a few hours, whereas creating a simulated version of the experiment in 3D requires several weeks of programming and modeling.

In the context of learning, especially the use of 360-degree videos can lead to a better learning experience. A recent study evaluated the use of 360-degree immersive video recordings of practical lessons with veterinary surgery on horses [27]. A sample of 100 veterinary science students watched the recordings with a mobile VR headset, out of which 79% rated their quality of experience as excellent or good, and they were satisfied with the educational use of VR to improve the learning process. In another study, 40 participants (foundation year doctors) were equally assigned to either 360-degree VR video or 2D video teaching. As a result of this, they had to watch their allocated video about instructions of tying a single-handed reef knot for 15 minutes. Afterward, the two groups competed against each other. The results showed that the 360-degree VR video teaching group performed significantly better compared to the 2D video teaching group [56].

Using VR headsets instead of flat screens to display 360-degree content is beneficial for immersion. Compared to flat screens, VR headsets enable isolation from real-world distractions and directly translate users' head movement into navigation in the video, which feels more intuitive than having to navigate through a conventional interface such as mouse and keyboard or phone display. A study in the medical field [28] has demonstrated that watching operative procedures in the 360-degree format can lead to more attentiveness and engagement among students, compared to watching these videos on traditional 2D screens.

Video content recorded with 360-degree cameras also has the potential to enable a broader audience to experience something they otherwise would not be able to experience in a very realistic way. One example of bringing world-class education to the masses is Harvard university's online version of their popular introductory Computer Science course called "CS50". In fall of 2016, the course team recorded all course lectures in 360-degree stereoscopic VR. They uploaded these videos on YouTube[5]. Watching the recorded 360-degree lectures with a VR headset allows users to turn their head around and see different perspectives of the Harvard lecture theatre, just as if they were sitting there in real life.

360-degree content does not only have the advantage to represent multiple perspectives of real-life moments but additionally also offers an individual and personalized watching experience as users can choose which segment of the image or video to look at [29]. Unlike traditional learning videos with a fixed perspective, 360-degree videos offer a unique way of storytelling, as viewers themselves are in control of their view direction at any point in time [22]. Using VR headsets like Google Cardboard to view

[4] https://theta360.com/en/

[5] https://www.youtube.com/watch?v=0C8a6GBF8Bg&list=PLhQjrBD2T381yQVAOzT-PHcGMgvjFX2V6

this content, enables viewers to adjust their view direction through head movements, which further contributes to the feeling of immersion and presence.

The measurement of human stimuli through affective teaching methods and perceptions is an essential component of computing for learning applications. The increasing use of VR results in more possibilities to capture data and to adapt the application to the target group via a feedback loop (Figure 3).

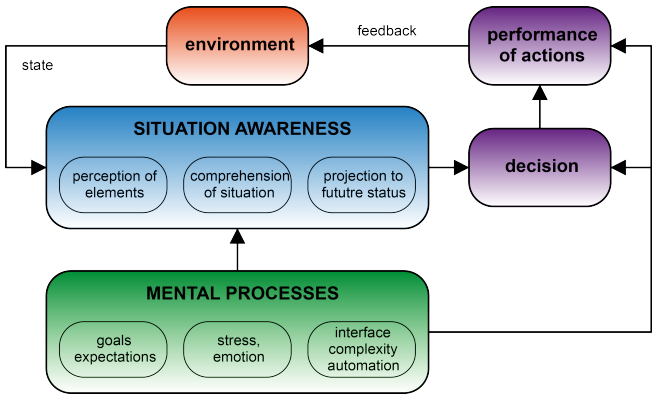

Fig. 3: Schematic sketch of Endsley's [21] theory of situation awareness in dynamic situations and its interdependency on human decision making, action performance and mental processes.

In learning VR environments, attention behaviors can be analyzed. By using the central Head-Gaze, it is possible to record head movements. The trajectories of the movement give feedback on whether the user could focus on the task or whether the teaching method should be different. Using temporal head movements, so-called Turn Rates (TR) [19], the level of attention can be determined. Quick head movements over time give feedback about whether the user is focused on the task (low TR) or trying to remember on his task (high TR).

While the list of benefits is long, the authors also identified several limitations and challenges for the future. These will be discussed in the next section.

5 Limitations and Challenges

In literature, we can find the following main limitations of 360-degree VR learning experiences authors have described:

- Inability to interact with the environment or objects in the video [27,39,48]
- Low resolution [29]
- Possible Cybersickness resulting from camera movement [29,33,51]
- Expensive setup for professional recordings [28]

- Novelty factor might influence current results on the improved learners' engagement [24,28]
- Missing options for user-friendly authoring for adding information and data [43]
- Distractions, missing focus points, and factors such as cybersickness can result in decreased learning outcomes [51]

Even though the creation and delivery of content in 360-degree has been advancing in the past years, there are currently still several challenges and limitations that both content creators and consumers are faced with. Apart from limited user interaction possibilities, it is challenging to integrate efficient assessment methods into real VR. Moreover, real VR is less flexible than computer-generated VR in terms of user exploration, as every possible exploration path needs to be pre-recorded.

With a 360-degree recording, viewers sometimes miss essential impressions as the camera is placed too far away from the action. On the other hand, viewers may steer their own chosen perspective into an overall "wrong" direction and thereby miss the essential action.

Depending on the type of camera and software, problems often arise when merging the images. These cameras use two lenses to capture a 360-degree video or photo. Professional models use even more. The 190-degree - 220-degree videos recorded by each camera lens (depending on the model) are stitched together in the process of stitching.

For this purpose, exact calculations must be carried out at the edges, so that one can no longer see the so-called stitching seam afterward. There is a significant difference between the quality of the various camera models and manufacturers. With many cameras, one immediately sees the seam that connects both images. Color transitions, brightness, and also stitching errors are frequent.

5.1 Interactivity

One major limiting factor for providing a realistic user experience is the fact that user movement within 360-degree content is not possible. Users cannot just "walk into" a panoramic picture of a building or navigate freely by deviating from the pre-recorded camera path in a 360-degree video. In contrast, virtual models and artificial virtual worlds allow for individual, free exploration - users can indeed walk into a virtual model of the building, follow their path, and create individual storylines. Also, user interaction with the raw, unedited pre-recorded video is not possible as the video itself can hardly react to any user input without special enhancements, such as adding extra layers with animations, deformable objects, 3D audio and moving backgrounds in post-production[15].

5.2 Flexibility

The possibility for self-directed choosing of the viewing direction is a benefit that also comes with drawbacks in specific application domains. In movies with a storytelling plot, viewers could miss essential parts of the storyline or scene elements if they choose to look in the "wrong" direction, as described in [41].

Staying flexible while experiencing content in VR is crucial for exploratory learning [17]. In a static 360-degree image, users are not flexible in exploring their environment as they cannot freely navigate like they would be able to do in a computer-generated VR environment.

6 Conclusion

Immersion is an essential factor in improving learning experiences and enables learners to experience scenarios that are usually hard or impossible to experience. VR experiences can help learners to focus on the learning elements entirely, they keep them engaged, and their understanding can be improved by being virtually present in learning scenarios. In this chapter, we have discussed different immersive learning experiences and applications with a focus on real VR experiences. The main application domains for educational scenarios include virtual tours, which are often expensive or impossible to make, such as tour through a museum, a historical landmark, or the space. Further scenarios can be the recording of processes and procedures to help learners understand the single steps of the procedures. Typical areas of application include surgeries, laboratory setups, or also assembly tasks. The recording of complex simulated situations is also a domain that can help learners to train extreme catastrophic situations. These situations are usually recorded with actors. Another domain we discussed is learning through self-reflection. This can be important for speaker training, teachers' education, or sports training to support learners by helping them to reflect on the situation and the decisions they made, so they are able to revise their own behavior. The last domain we described in this chapter is the use of VR to create empathy. Viewers learn by experiencing situations through the shoes of others.

Benefits can be summarized as fast and simple content creation, an engaging experience, a better learning experience, and the possibility to bring content to the masses in a realistic and affordable way. However, challenges specifically for the educational purpose remain: learners' assessment strategies for educational processes are hard to integrate, interactive content is challenging to integrate, and the flexibility and personalization of the experience is not given. Even with these challenges remaining, VR (real VR and also simulated experiences) have a high potential to change the way we will learn in the future, either in a self-directed way or also in classroom settings.

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