Whitepaper

Creating VR content for teaching operations management

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Summary

This whitepaper guides practitioners and academics in creating Virtual Reality (VR) teaching content for operations management education and training. The focus is on creating non-real-time VR content from manufacturing sites. At ETH Zurich, the Chair of Production and Operations Management led by Prof. Torbjørn Netland has taught operations management with such VR technologies since 2017. In this whitepaper, we first briefly introduce VR's potential for teaching operations management. Second, we provide advice for the selection of appropriate hardware and software. Third, we propose a systematic method for deciding locations for shooting VR content in manufacturing facilities and give tips for effective on-site filming. A case study of the Hilti Corporation provides an illustrative example of a VR teaching app developed at ETH Zurich using commercial VR software. This app is used both (1) for teaching at the university and (2) for training in the company. Finally, possible use cases for VR-based teaching in manufacturing are elaborated. We see great opportunities for VR in the future of business education.

Acknowledgements

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innovedum

Photo credits

Table of contents

Summary *2*
Virtual Reality in teaching *4*
Roadmap for creating VR content *6*
Choosing the right VR hardware 7
Choosing the right VR software 10
Location selection 14
Filming 15
Creating the VR app 16
Cost and time estimates 17
Use case example *18*
VR app for teaching at ETH Zurich 18
Using the VR app for training at Hilti 20
References *21*

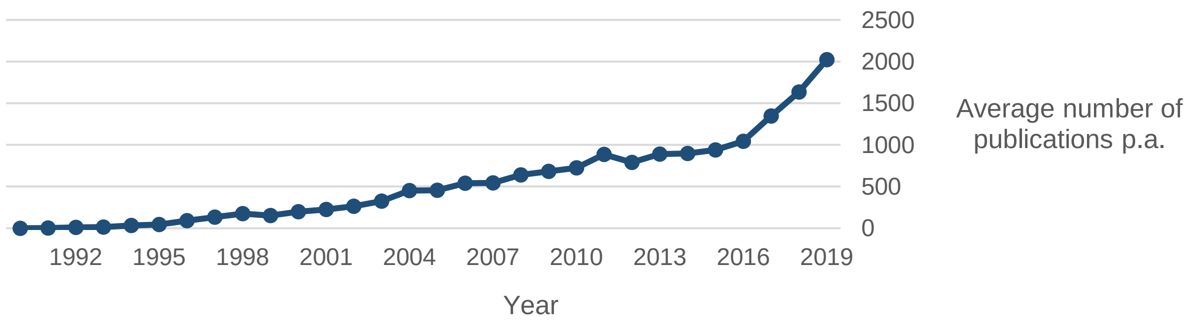
Virtual Reality in teaching

VR is an artificially simulated, three-dimensional, visual experience with which a user can interact. This experience can be realized in many different ways and forms. VR is an entirely virtually simulated experience, whereas Augmented Reality (AR) combines virtual and real-world objects. This whitepaper focuses on VR in the form of 360-degree photo and video footage that is combined with other elements into a learning environment.

The first forms of VR can be traced back to the late 1950s. However, it was first in 2012—when Oculus Rift created a Kickstarter campaign—the hype for this technology started. Initially fostered by the multi-billion-dollar gaming industry, this mind-boggling technology found application in many other fields. One of these fields is teaching. Studies found VR to be enhancing learning experiences (e.g., Lee et al., 2010). Today, some types of VR represent immersive, low-cost, readily available, and scalable technology that is well suited for providing students with fun and innovative ways of learning and for companies seeking new ways of training employees.

Interest in VR technology is growing exponentially.

We believe many topics related to operations management (OM) are best taught "hands-on." Therefore, factory visits are often an important part of OM education. But such visits are difficult to organize and administer. Besides, the recent Corona pandemic has made factory visits impossible in many places. VR provides an effective and efficient solution. Interest in VR technology is growing exponentially. Figure 1 shows the growth of research articles concerning VR in teaching since 1990.



Notes: Search on Scopus and Web of Knowledge with search string: "VIRTUAL REALITY" and "TEACHING" or "LEARNING" or "EDUCATION," 09.09.2020.

Figure 1 *– Growth of publications related to VR in teaching*

VR offers multiple advantages. Freina and Ott (2015) reveal four main reasons for using VR in an educational environment, as summarized in Table 1.

***Table 1** – Advantages of using VR in teaching according to Freina and Ott (2015)*

VR allows you to experience…	as in, for example…
past or future times	historical period of the past
physically inaccessible places	tour of the inner workings of a machine
training in dangerous situations	virtual emergency airplane landing
ethically questionable situations	heart surgery as a new medical student

VR offers the possibility to experience inaccessible places or situations, getting useful information from them and learning how to cope with your emotions while being far away from any real danger (Freina and Ott, 2015). Furthermore, by integrating the learning experience into a VR, the experience transforms from passive to active. This effect is achieved by shifting the experience from simple consumption of information to an experience, which learners must actively navigate (Netland et al., 2020; Mantovani et al., 2001). There is evidence that students with access to VR resources outperform those who only have access to written material (Mahrer, 2014). Two concepts that are essential for the transformation from passive learning to active learning are *Immersion* and *Interactivity* (illustrated in Figure 2).

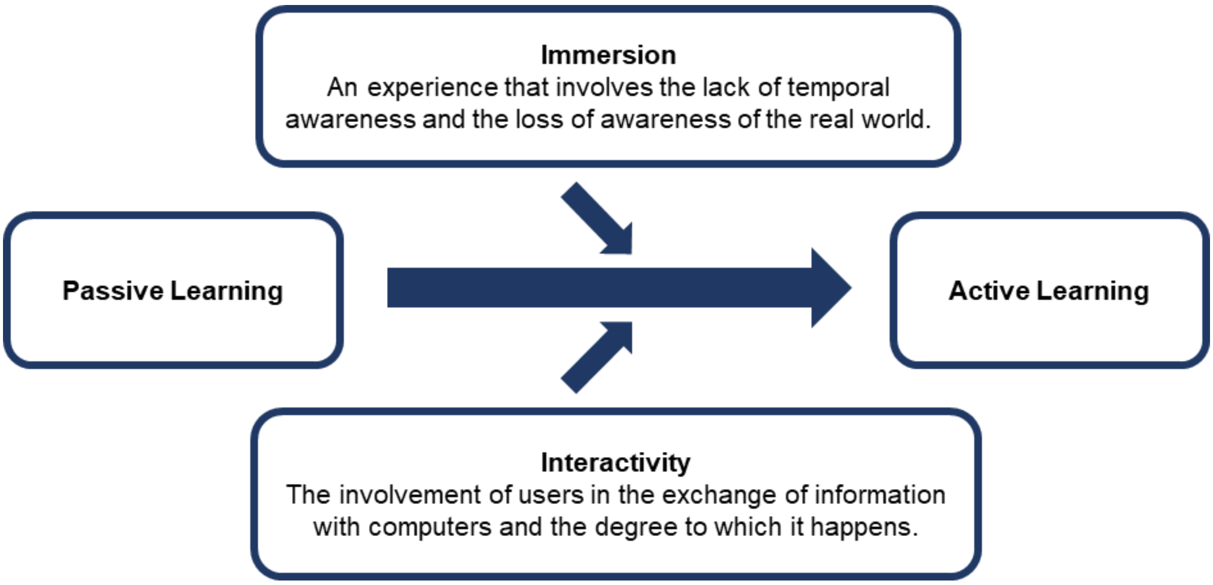


***Figure 2** – Path from passive to active learning with VR*

Roadmap for creating VR content

It’s easy to get started using VR for teaching. In the following, we propose a procedure that requires no previous knowledge. It guides the reader step-by-step to create her/his own virtual experience tailored to her/his needs.

At every decision point, we provide multiple options, each having its own strengths and weaknesses. We also offer the decisions we have taken ourselves for the case example provided in a later section. The idea is to enable the reader to create VR experiences that suit her/his needs and purposes. Figure 3 shows the four-step roadmap we set forward.

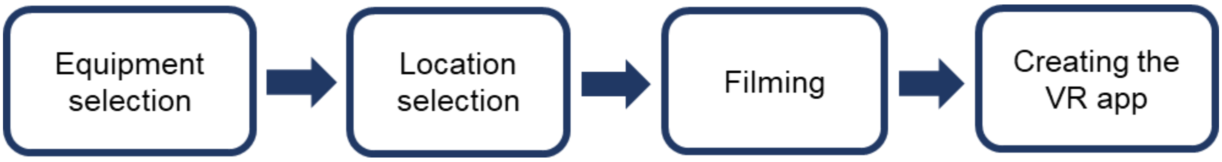


Figure 3 *– A roadmap for creating VR teaching content*

Choosing the right VR hardware

VR content can be created with some basic and cost-efficient hardware. The five essential devices needed are shown in Figure 4 and will be discussed in the following.

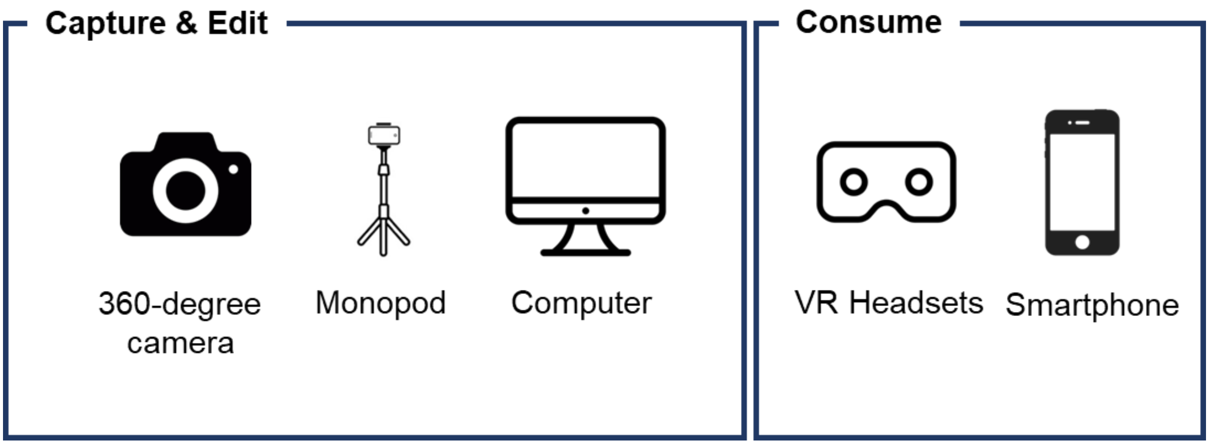


***Figure 4** – Five essential hardware for creating VR teaching material*

360-degree camera
To capture VR content, a specialized 360-degree camera is required since traditional cameras are not capable of capturing 360-degree VR footage. Below is a brief comparison of three well-known 360-degree camera manufactures and their flagship models.

For the industrial case presented later, the Insta360 ONE X was used (predecessor of the Insta360 ONE X2). However, the market for 360 cameras is developing rapidly, so we advise always to check availability and online test reports. When filming in difficult light conditions, further aspects like resolution and aperture should be considered as well.

***Table 2** – 360-degree camera manufacturer comparison*

Manufacturer	Flagship Model	Price	Batteries	Memory
Insta360	ONE X2	~600 USD	removable	removable Micro SD
Ricoh	Theta Z1	~900 USD	internal	internal 19 GB
GoPro	Max	~500 USD	removable	removable Micro SD

Monopod

In a VR experience, 360-degrees of the captured scene are visible. Therefore, the creator should not film by holding the camera in the hands (the person would then appear in the video). A monopod makes it possible to capture VR footage without visual disturbances. Additionally, it holds the camera steady.

There are various types of monopods available on the market. A monopod that is used for filming 360-degree content should have certain properties, namely (i) length, (ii) stability, and (iii) size. First, its length should be around 1.60m-1.80m as VR footage should be filmed at the natural height of a person's point of view. Second, the monopod needs to be very stable even if fully extended. Third, the tripod "foot" that supports the monopod should be small. Most VR cameras have the ability to stitch the 360-degree footage together in a way that the tripod is not visible. However, in case the tripod is too big, this is difficult.

We used the Bushman Monopod V2—a monopod for 360-degree filming (~150 USD) but any monopod made for VR should work well.

VR Headsets

To experience the VR content in the most immersive way, VR headsets are required. VR content can also be consumed two-dimensionally on computers, but the degree of immersion will be much lower. VR headsets come in different quality and price ranges. Generally, they can be divided into three categories: Cardboard, plastic, and high-end VR headsets (Table 3).

***Table 3** – Three different categories of VR headsets*

	Cardboard Headsets	Plastic Headsets	High-End Headsets
Look			
Price	~3-10 USD	~10-30 USD	~300-600 USD
Scalability	✓	✓	✕
Comfort	✕	✓	✓
Immersion	✕	✓	✓

If the price has a priority, *cardboard headsets* are the most attractive. Some more quality can be achieved with *plastic headsets*. If the objective were to provide the highest quality and opportunity to interact with more than the eyes, the *high-end VR headsets* such as the Oculus Rift and Oculus Quest would be the go-to-choice. The latter also enables real-time interaction in VR with other actors, but this feature is outside the scope of the teaching app we discuss here.

For the cardboard and plastic headsets, a smartphone (assumably already owned by students or other users) has to be mounted at the front side of the headsets to display the VR footage. The high-end headsets have a screen integrated into the headsets, and the VR content has to be downloaded on the storage that is included in the headsets as well.

We used mainly the plastic and the cardboard headset, which allowed scalability to hundreds of students. The cardboard viewers can be used as giveaways and can also be ordered with tailored printing (e.g., company logo). The plastic viewers could be reused. The high-end VR headsets require much more administration as the software must be installed on the viewer instead of users' phones. However, we also tried the developed apps on Oculus Quest, and it worked effortlessly.

Smartphone

When using cardboard or plastic headsets, a smartphone is required to display the VR content either in a specific application or via the web browser app. The better the smartphone, the smoother the experience. Especially a good screen resolution can improve the quality of the VR footage a lot. However, almost all smartphones of today's generations possess enough computational power for displaying basic VR experiences.

At this point, it should be mentioned that phone system software updates might make VR material dysfunctional. We, unfortunately, experienced such an occasion with a recent iOS software update. However, in most cases, such bugs are fixed quickly and should get even rarer in the future as the technology rapidly finds its way into the mainstream.

Computer

A computer is needed to stitch the VR footage together and edit the scenes. High computational power speeds up certain steps in the editing process. In most cases, modern laptops deliver more than enough performance to ensure a satisfying workflow.

Choosing the right VR software

The VR footage needs to be edited, patched together, and published for the users. Those steps are performed on a VR platform that specializes in processing and sharing VR content. There are several VR platforms on the market, all differing in their strengths and weaknesses. For the differentiation, the following ten requirements are used:

1. **Price** – Advanced VR platforms with a great variety of functions usually charge higher prices. To create a highly individualized tour, with a corporate identity and interactive features, an investment in an advanced VR platform is required. However, cheaper platforms are suitable for simpler apps.
2. **Payment** – Most of the platforms operate with a subscription-based paying system. Only three out of 18 platforms are downloadable computer programs with a one-off payment. For companies that only seek to build a virtual tour once, without future use for the development platform, it can be advantageous to have a one-off payment. Of course, this is moot if the platform offers to keep access to already created content after ending the subscription.
3. **Compatibility** – Consuming VR content with VR headsets is the most immersive way. Therefore, headset compatibility is key. To be compatible, a function to split the screen is needed.
4. **Web access** – Going through a VR tour on the web browser of a computer is an alternative to VR headsets. Especially for people reporting motion sickness using VR headsets or vision impaired people wearing glasses, computer access to the experience is beneficial.
5. **Functions** – With a wider variety of functions, it is possible to reach a higher degree of customization and tailor VR tours to specific needs. In this context, "functions" refer to features that can be integrated into the VR or an in-program photo editor to bring the best colors out of the 360-degree footage.
6. **Game experience** – Gamification not only adds fun for the users but also motivates them to engage longer in the VR environment. Some platforms show greater possibilities to gamify a VR experience than others.
7. **Workflow** – To build VR tours fast and easily, the platform should provide an intuitive workflow and require low effort to learn.
8. **Simplicity** – This requirement estimates the simplicity of the overall content distribution and content consumption using the respective platform. Content distribution refers to making the content accessible for consumers, and content consumption refers to the actual user interaction with the VR environment.
9. **Security & privacy** – When shooting any kind of footage, privacy and data security are important. Especially when filming in factories where certain processes should be kept secret from competitors, it is important for the platform to have security and privacy regulations in place.
10. **Customer support** – Since VR is still an emerging technology and professional platforms are constantly updating their features, it is helpful to get technical support from the platform on a regular basis. This category also includes the time needed to fix bugs.

Based on these requirements, we have evaluated 18 of the most popular platforms. Table 4 provides an overview of the 4 common platforms across different price ranges and unique profiles. The list of all compared 18 platforms can be found in Box 1. Note that this area is under rapid development, and new providers, functionalities, and terms emerge and change fast.

***Table 4** – Platform comparison*

	Theasys	Kuula	3DVista	Uptale
Platform				
Price[1]	20 USD/month	36 USD/month	499 EUR	3000 EUR/year[1]
One-off Payment	✕	✕	✓	✕
Goggle Distribution	✓	✓	✓	✓
Web App Distribution	✓	✓	✓	✓
Variety of Functions	low	medium	high	medium
Game Experience	medium	medium	medium	high
Intuitive Workflow	high	high	high	high
Simplicity of Solution	high	high	high	high
Security & Privacy	✓	✓	✓	✓
Customer Support	✓	✓	✓	✓

[1]3000 EUR / year for universities and 15’000 EUR / year for enterprises. Prices and functionalities as of end of 2020.

Theasys

Theasys is an inexpensive VR platform that makes it possible to create good-looking VR tours with the essential features in a straightforward way. Of course, the variety of functions has its limits, but it is a good choice for lower-budget projects and experimenting. It even has a free version to play around with and create raw sketches.

Kuula

Kuula convinces through its intuitive workflow and ease of use. Additionally, after the VR tour is created, the navigation through the tour is very smooth and user-friendly. This excellent service comes at a very reasonable price. Additionally, Kuula can be paid monthly, which brings great flexibility and reduces the commitment you have to bring to the table when purchasing. Same as Theasys it has a free version as well.

3DVista

With 3DVista it is possible to create very professional VR tours. This professional look can be achieved by an extremely wide variety of functions. This leads to a more complex use than other VR platforms. However, relative to the countless possibilities there are with this platform, the ease of use is still considerably high. 3DVista is one of the few platforms that are purchased with a one-off payment. This can be regarded as an advantage if the creator plans to use the tool over a longer time or as a disadvantage if a couple of months are sufficient.

Uptale

With a rather high subscription-based price of 3000 EUR per year, Uptale belongs to the more expensive high-end VR platforms. Its advantages are its unique gamification features and data analytics options. Features like quizzes, timers, and scoreboards make it possible to create highly gamified learning experiences embedded into a single VR tour. We used Uptale for the use case presented later and have been mostly satisfied with this software.

Box 1. Links to VR platform providers

Beginner platforms

VeeR Experience:	https://veer.tv/landing/experience
Marzipano:	https://www.marzipano.net/
Orbix 360:	https://www.orbix360.com/
Theasys:	https://www.theasys.io/
Matterport:	https://matterport.com/de
CloudPano:	https://www.cloudpano.com/
Kuula:	https://kuula.co/

Intermediate platforms

My360:	https://my360propertyvirtualtours.com/
GoThru:	https://gothru.co/
Panoskin:	https://www.panoskin.com/
InstaVR:	https://www.instavr.co/
Cupix:	https://www.cupix.com/

Advanced platforms

Uptale:	https://www.uptale.io/en/home/
Pano2VR:	https://ggnome.com/pano2vr/
3DVista:	http://www.3dvista.com/
Krpano:	https://krpano.com/home/
NavVis:	https://www.navvis.com/

Location selection

Finding a potential location to create the VR content is the next step. For a good education experience in a manufacturing setting, we believe the following two requirements should be fulfilled: *concept variety* and *process maturity*.

First, it is important to check if the company includes the variety of concepts that should be captured in the VR environment. For instance, in the example of the industrial case study, which will be further discussed later in this whitepaper, several examples of process improvement (so-called "Lean") concepts were needed. With the goal in mind to teach production management, this was an important criterion.

A good education experience requires concept variety and high process maturity.

Second, one should try to capture processes that have something to teach. For example, good candidates are processes with high capabilities and good performance or processes with apparent improvement potentials. To increase the motivation for students external reputation of the process or the company to be captured can help. If the students know or even admire the content or the company shown in the VR experience, their motivation to explore it will be much higher, and therefore, they will probably spend more time immersed in the VR.

After having a pool of potential locations, fine planning needs to be performed. Due to the data security policies in working environments regarding capturing processes and employees, top management commitment is required. To achieve this commitment, the ability to show a demonstration of how a VR environment looks can help. There are several online. Of course, the focus should be on value-add for the company, which can be the training of employees, comparing different working spaces to each other, or showcasing innovativeness for shareholders (or students).

Filming

When the hardware is selected, the location is set, and the content that will be captured is decided on, the process of capturing VR footage can start. Below we share some tips we have learned through our own experience from past VR projects.

Tips for filming

Bring enough **external memory**. VR footage takes up more memory space than conventional filming. A one-minute VR video takes up about 1.25 GB of storage.
Film during the daytime to ensure good **lighting conditions**. Additionally, check your camera if there are different modes such as "HDR" that improve image quality in poor lighting conditions.
Set the monopod to an average **eye height** (165-175 cm) to provide a fully immersive experience.
Place the monopod in **logical places**, where workers actually stand. Try **not to film too close** to any objects since this magnifies the 360-degree fisheye effect.
Always film some **extra footage** initially and at the end of the desired process to make sure you cannot be seen walking away from or towards the camera.
Make sure to respect any **privacy regulations** given by the company or the workers themselves.
Clearly communicate with everyone involved, especially with people being filmed, and inform them on what you are doing and with what intention. This ensures that everyone feels comfortable in front of the camera.
Use an **aerial shot** of the work process, which later on can be used as an overview scene.

Creating the VR app

Tips for editing

Make sure to set the **start perspective** of each 360-degree scene towards the focus of the scene. The user can feel very disoriented otherwise and doesn't know where to look first.
Do **not display too much blended information** at once. VR scenes can get much clustered, which makes the user feel overwhelmed and decrease its motivation to explore.
Use a **consistent design language** (colors, font, sizes of objects, etc.)

Dealing with parallel sequences

Film entire parallel footage sequences linearly. This means that there is only one "door" (= portal) to enter and one to exit in every scene, as opposed to a nested system of several pathways. This idea is visualized in Figure 5. This ensures that the user will not get lost in the VR environment, which easily happens with nested sequences. Not picking the right exit door to the next scene can lead to frustration and make users leave the experience. Even though parallel sequences limit the possible pathways, a clearer, straightforward sequence proved to be more informative and enjoyable.

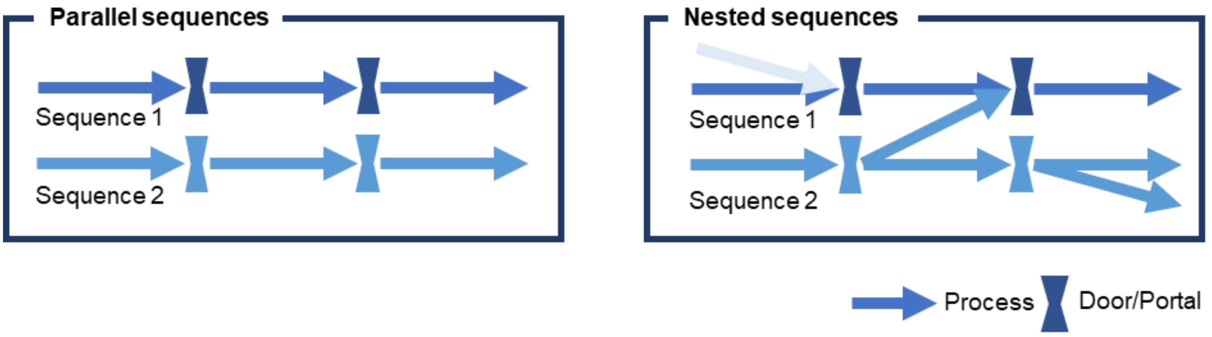


Figure 5 – Parallel vs. nested logic

Introduce gamification

Gamification assists learning. In the VR-app, this can be implemented by, for example, the use of a level-up or win-to-continue logic. Thereby, a quiz is added at exit doors to test the user's acquired knowledge. If answered correctly, the user advances to the next scene. Whereas, if answered incorrectly, the user remains in the same scene and needs to retake the quiz. To facilitate learning, additional information can be blended in to explain why the answer was incorrect. This concept is visualized in Figure 6.

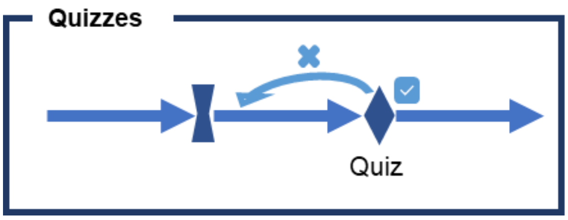


Figure 6 *– Quiz level-up logic: wrong answer repeats scene, right answer continues*

Cost and time estimates

To give an idea of the time and money required to create a fully operational proof-of-concept VR app in a company, we report the numbers from our project with Hilti in 2020, in which we created a VR app with general content from the factory overall and the details of one production line. It is important to understand that resource use will vary widely depending on what is being filmed, level of experience selected soft- and hardware, and locations. Thus, the below figures should only be regarded as a rough guideline.

Table 5 *– Rough cost estimate for hardware and software costs*

Hardware / software	Cost estimate
Insta360 X One Camera	380 CHF
Bushman Monopod V2	127 EUR
Sanddisk 128 GB MicroSD	34 CHF
Total developers' hardware	**Ca 600 USD**
Uptale	3000 EUR / year (academic lisence)
Total developers' software	**3000 USD / year for software**
Standard cardboard or plastic headsets	10-30 USD per user
Smartphone / computer for users	use own device
Total users' hardware	**10-30 USD per user**

Table 6 *– Rough time estimate for personnel (ETH Zurich only)*

Activity	Time per person	Persons involved
Planning the shooting	24 h	3
Filming on-site	16 h	3
Editing VR footage	72 h	1
Reviews and pilot tests	8 h	4
Total	**112 h**	**224 h**

Notes: Additionally, the company that provides facilities for filming invest time and resources, and any travel to and from the company/site incurs time and money use.

Use case example

For a quick impression of the below-presented use case, check out the following video presentation https://youtu.be/3mUghoxnWLU, from 1.15 min to 1.25 min.

VR app for teaching at ETH Zurich

This section illustrates the application of the presented procedure using a VR teaching material developed in cooperation between ETH Zurich Chair of Production and Operations Management (POM) led by Prof. Netland and Hilti AG.

For students to learn production and operations management, it is most important to "go and see"; that is, to visit the shop floor where manufacturing processes happen. However, with an increased number of students (150+), shop floor visits get more and more difficult to organize. Further, these visits are vulnerable to external influences. For instance, due to the ongoing pandemic, shop floor visits are next to impossible. To overcome these hurdles, we started to use VR to (virtually) bring the students to the shop floor.

Since 2018, we have taught *Production and Operations Management classes,* including a case study in which students virtually visit the shop floor of leading companies such as Toyota or ABB. The students have to explore the shop floor in VR in order to solve the exercises of the case study. The exercises are graded and count as a part of the final grade.

In the first years, the Chair of POM relied on external VR material, such as ABB's 360-degree app or Toyota's 360-degree YouTube Videos (see Netland et al., 2019 and Netland et al., 2020). In the fall semester of 2020, the Chair of POM developed its own VR application. Developing an own application provided the possibility to create a tailored VR environment that better suits the purpose of teaching students.

In the case study, the students were given a set of questions regarding the topic surrounding Lean manufacturing. To be able to answer most of the questions, some sort of interaction with the VR environment was required. For example, the students had to:

- Find Lean methods that were implemented in shown process steps.
- Find specific types of waste in the assembly.
- Find useful ways to implement Lean methods that have not been implemented yet.
- Asses the company's degree of maturity regarding the Lean philosophy.
- Conduct time measurements of process steps and include them in calculations regarding important performance indicators such as takt time.

Answers had to be given in the form of screenshots of specific scenes in the VR or in the form of short explanatory texts. By creating an own VR application, these ways of questioning the students are possible, which wasn't the case before. Hurdles with external VR apps were:

- Speeded up and cut videos which makes it hard to understand the details.
- Too many static scenes, which decrease the immersion of the experience.
- No gamification, which decreased the motivation to interact with the VR environment.

Figure 7 *– The ETH app "FactoryVR" won Bronze in the category VR/AR in the "Oscars of Education" 2020*

«I personally love it, it's an easy way to bring the production to the class» (MBA Student, ETH Zurich)

Using the VR app for training at Hilti

The Hilti Group is an international corporation with about 30'000 employees worldwide, active in a fast-developing construction business environment. A focus is set on developing employees' skills and knowledge. The latest employee training concept includes for example on-the job learning and online courses with content close to practice and with the goal of having employees being able to directly apply what they learned on their job.

As part of the Hilti business strategy, Lean methodology is anchored as the way to operational excellence. To foster employee's knowledge on Lean tools and behaviors a structured upskilling approach is rolled out by an expert team. Today, employees are used to technology-mediated learning, for example, with live online classes, self-learning courses or virtual mentoring.

However, where in-person and on-site meetings are not possible, learners miss out the personal experience, for example, of the traditionally used Lean simulations or Gemba walks. Several benefits were expected from including VR into the training curriculum. First, offering a new learning experience should foster employee motivation to participate in Lean training. Second, taking employees virtually to the place where Lean is applied should support the understanding, transfer of abstract knowledge to the workplace, and long-term retention. Furthermore, a requirement was that the content could be accessed at low cost from different devices, ideally with a computer, smartphone, cardboard, or high-end goggles.

Being encountered with the challenge to determine whether and when learning with VR about Lean methodology is effective for the employees, Hilti developed in corporation with the chair of POM at ETH Zürich a VR training for Lean methods in production. More specifically, the learning content covered the application of Lean in a Hilti power tool assembly line. The footage was captured with a 360-degree camera based on a storyboard without any impact on running production processes. After going through the interactive VR course with a high-end goggle, employees reported high engagement as well as acceptable usage of hardware and software. Also, the visualization, content close to practice, and low distraction during learning were appreciated. In contrast, the learning time should be limited due to possible simulator sickness or impression overflow. Even though the interactive and gamified VR experience might not be optimal for all types of learners and persons, for learning the basics of Lean, best practice sharing, and virtual non-real-time Gemba walks it is a value-adding complement to traditional learning media at Hilti. More 360-degree training about Lean in the area of logistics and tool service centers are to be developed in cooperation with ETH Zurich.

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