Bringing the factory to the students: Enriching teaching cases with Virtual Reality

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Abstract

Recent developments in virtual reality technologies offer new opportunities for teaching operations management. In partnership with a global manufacturer, we developed a teaching case that integrates virtual environments of the manufacturers' real factories. We used the case in two operations management courses taught at ETH Zurich and evaluated the effects on students' learning experiences. To assess the effects, we used focus groups, feedback forms, and surveys. We find that students generally perceived that virtual reality improved their learning experience, but also that the current state of the technology has several limitations.

Keywords: Teaching operations management, Factory management, Virtual reality, Situated learning, Constructivist learning theory

Introduction

"If the mountain will not go to Muhammad, Muhammad must go to the mountain." While the roots of this wisdom go back several centuries, recent advances in virtual reality (VR) technologies provide unprecedented opportunities for "bringing the mountain to Muhammad". In this paper, we describe how we have "brought the factory into the class room" by integrating VR in an operations management teaching case. We draw on the concept of immersion and the constructivist learning theory to discuss how the teaching innovation is expected to affect students' learning experience. Finally, we use randomized focus groups, an evaluation survey, and feedback forms to assess the effect on students' learning experience.

There are repeated calls for more active learning experiences in operations management courses (Brandon-Jones et al., 2012; Scholten and Dubois, 2017). Teachers frequently use written cases to show how the syllabus translates into the real world (Keith, 1998). The *teaching case method*, pioneered at Harvard Business School in the 1920s, has proven to be a very effective way of teaching business curricula and is popular among students (Charan, 1976; Norman et al., 2017). It has been shown to increase student engagement (Foran, 2001; Davis and Wilcock, 2003), to encourage initiative and critical thinking (Han et al., 2013), as well as support learning at a higher cognitive level (Davis and Wilcock, 2003). But the teaching case method is not without limitations (e.g., Argyris, 1980; Mumford, 2005; Shugan, 2006). Although the inclusion of cases adds relevancy and vividness to classroom and textbook-based teaching, cases often lack detail and oversimplify reality. Moreover, most cases in operations management are simply written descriptions of an event or problem at a company (c.f. collection of operations cases at www.thecasecentre.org). Though case authors have enriched case material with video clips and photos, the case method has remained by and large unchanged over the last decades.

Another usual method to teach the applicability of topics is to organize field trips. Field trips can help students to understand, learn, and remember concepts for a substantially longer time than other classic teaching forms (e.g., Orion and Hofstein, 1994; Greene et al., 2014). Field trips are also common in production and operations management courses, but have serious limitations. It can be difficult to get access to factories and entering all the areas relevant to the class may not be permitted. Factory visits require considerable resources to coordinate and organize – especially for class sizes exceeding 25 students. It can also be difficult to fit factory visits into busy study and teaching schedules during the semesters. Because field trips to factories are burdened with these administrative and logistical challenges, they are, if at all, often organized only once per course semester. So, what if we could instead bring the factory to the students?

In partnership with the ABB Group, we have developed a teaching case enriched with VR where students solve production and operations management challenges by collecting data from a virtual but real factory environment. The VR-enriched teaching case offers students the opportunity to make virtual visits to a number of ABB's factories, located in Switzerland, Germany and Finland. By allowing students to immerse into the shop floor reality it provides students' an experience similar to that of a field trip. In this respect, the use of VR provides an advantage over solely relying on written case material and images. Therefore, we expect that students benefit from the introduction of this teaching innovation. To evaluate this, we ask the following research question: *How does the integration of VR in teaching cases affect student's learning experience?*

We have organized the paper as follows. In the next section, we draw on situated learning theory and constructivist learning theory to discuss how a VR-enriched teaching case is likely to affect students' learning experience. Then, we present the details of the teaching case and our scientific research method. After that, we present, analyze, and discuss our qualitative and quantitative feedback data from students who experienced the teaching innovation. Finally, we conclude our research investigation and offer advice for teachers who want to integrate a VR-enhanced teaching case in their classes.

Theoretical foundation for VR-enriched teaching cases

Research by Mahrer (2014) showed that students with access to VR resources outperformed those who only had access to written material. VR is an artificial environment that is presented to the user in such a way that the user experiences it as a close-to-real environment. A simple form of VR is 3-dimensional images or videos that can be explored with a computer interface or wearable VR glasses. In this form of VR, the user uses the senses of seeing and hearing to experience the digital environment. The

VR environment can be an artificial creation, a digital copy of the real world, or a combination of the two.

Two theoretical lenses are particularly useful when studying how such technologies affect teaching and learning: the concept of immersion and constructivist learning theory (Dunleavy and Dede, 2014). Compared to the stylistic teaching case, a VR-enhanced teaching case offers a higher level of *immersion.* According to Dede (2009, p.66) immersion can be defined as "the subjective impression of participating in a comprehensive, realistic experience". VR enables students to step into the world of a factory and, at their own speed and following their own curiosity, explore what it looks like and how it operates. This immersion helps move the learning from simple consumption of information, to an actual experience which they must actively navigate. Deci and Ryan (2000) show that the intrinsic motivation of adults is encouraged when they experience autonomy and are able to make choices relating to their own learning.

A related concept, *constructivist learning theory* (Dewey, 1938; Yager, 1991), offers additional explanation of how a VR-enhanced teaching case may affect students' learning experience in a positive way (c.f., Dede, 1995). Constructivist learning theory posits that students construct knowledge by actively engaging with the content of learning, rather than from information alone. This requires them to draw on prior knowledge in order to make sense of the new information, thereby constructing new meaning. The learning experience of a VR-enhanced teaching case will therefore vary among members of the same class, following the same lectures and doing the same teaching case due to their different levels of prior knowledge.

Taken together, these theoretical concepts suggest that VR can have a positive effect on students' learning experience.

Research setting and approach

We introduced VR as content material in a graded case assignment in the spring semester course "Global Operations Strategy" at ETH Zurich, which is attended by about 60 graduate students every spring semester. This setting allowed us to assess the impact on students' *learning experience* of integrating VR in a teaching case. We used the case throughout the course from February to June 2018. The graduate course consists of two different student groups: Students enrolled in a regular master's program and students enrolled in a continuing education master's program. We use focus groups and an evaluation survey to evaluate the effect of the VR-enhanced teaching case on learning experience. Both of these approaches are established as meaningful evaluation methods in the educational sciences (Watts and Ebbutt, 1987; Wilson, 1997). Focus groups are particularly well suited to collect feedback on new ideas (Stewart and Shamdasani, 2014) and complement surveys by contextualizing the data. To further triangulate results and empirically calibrate our survey design, we also used a different version of the VR-enhanced case in a Master of Business Administration course and collected additional data using written feedback forms.

The VR-enhanced teaching case

To introduce a virtual factory environment for the students, we teamed up with the ABB Group that offers VR environments of some of their factories located in Switzerland, Germany and Finland. The ABB VR environment is made by 3D Studio Blomberg and offered for free download on the major app stores ("360 VR Tours" on Apple App Store and Google Play). The app consists of 360 degrees still pictures and videos from five factories, blended with virtual instructions and information, such as a plan of the factory layout. In the app, students can visit a number of predefined areas in the factory in any order they like. The VR environment works on any smart phone which can then be used with any commercially available VR viewer, such as Google Cardboard. The typical price range for simple VR viewers for smart phones is from 3 USD to 50 USD (e.g., Google Cardboard, Samsung Gear VR). High-end VR viewers costs around 500 USD (e.g., Oculus Rift). We provided the students cardboard viewers for their phones.

Fig. 1 – The VR app (left), student using VR (center), and snapshot from the app (right).

The teaching case covers three modules; production network configuration, factory planning and design, and production network coordination. In the first part, students can use the VR environments to collect information about the production process and products in specific factory locations. In the second part, students can use the VR environments to observe and analyze the production layout, internal logistics and general productivity of the sites. In the third part, students can use the VR environments to compare factories in order to suggest a multi-site production improvement program. To complement the information accessible through the app, the course team and ABB provided a presentation with additional case-related information (for example, facts and figures, supply chain structure, organizational structure, market development, and so on). (The current app, teaching case and presentation are available upon request to the authors). Note that the ABB VR app was developed independently of the teaching case designed for the ETH courses. Readers can use the ABB VR app to design their own case and questions better suited to the learning objectives of their specific courses.

Focus group interviews

Our primary data collection method was moderated focus group interviews (c.f., Watts and Ebbutt, 1987; Stewart and Shamdasani, 2014). We took a number of steps to reduce the risk of biased responses for the focus groups. Firstly, the assessment of learning experience was entirely administered and conducted by ETH's department for educational development and technology (LET). LET was not involved in any other activities of the course, including grading. Secondly, there was no compensation to the students. Thirdly, participating students were guaranteed full anonymity. Fourthly, we used randomization to invite a representative number of students to the focus groups.

LET carried out a random invitation until nine students had volunteered to participate in focus groups (16.5% of class size). We split the invited students into two groups. Both focus groups consisted of students with mixed study backgrounds, ages, and genders. The focus groups were led by a professional educational developer and lasted 45 minutes. They were recorded, transcribed and anonymized. The anonymized transcriptions contained around 10,000 words each. We coded the transcriptions by themes discussed and organised these into positive, neutral, and negative statements related to the perceived effect of VR on learning experience.

Evaluation survey

We complemented the focus group interviews with an anonymized evaluation survey sent to all students taking the course (N=54). The evaluation survey contained ten questions designed to capture learning experience and control factors. We use a formative construct of learning experience covering six items related to the use of VR in the case: Enjoying the case work; General increase in curiosity for the topic; Ability to explain to others what was learned (retainment proxy); VR's helpfulness in solving the case; Stimulation of team discussions; and, immersion in the case. We also included three control variables: Prior experience with VR; Industrial Experience; and Time spent in the VR environment. We used a five point Likert scale (1 – "strongly disagree", 2 – "disagree", 3 – "neutral", 4 – "agree", 5 – "strongly agree"). (The full questionnaire is omitted for brevity and is available from the authors on request).

We sent the survey to all students two-thirds of the way into the course semester. After three reminders, we had collected 34 responses from students, which denote a response rate of 65%. The final sample comprises 19 continuing education students and 15 Master of Science students (of which 8 study industrial management and 7 mechanical engineering). We checked for non-response bias by t-testing whether there were mean-differences in our learning experience variables among groups of early and late respondents. We found no significant differences among the two groups, suggesting that nonresponse bias is not a concern. Descriptive statistics is given in Table 1.

Table 1- Descriptive statistics and correlations for survey results (n = 34)

Variable	**Mean**	**M**	**Std. dev.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1 Enjoyment	2.70	3	1.09	1.00								
2 Curiosity gain	3.03	3	1.03	0.50**	1.00							
3 Retainment	3.38	4	1.02	0.71***	0.63**	1.00						
4 Helpfulness	3.26	4	1.05	0.65***	0.47*	0.64***	1.00					
5 Stimulation of discussion	3.29	3.5	1.14	0.10	0.28	0.14	0.26	1.00				
6 Immersion	3.44	4	1.08	0.68***	0.53**	0.56***	0.75***	0.31*	1.00			
7 Prior VR experience	2.77	3	1.51	0.07	0.18	0.04	-0.13	-0.27	-0.47	1.00		
8 Industrial experience	2.94	3	1.32	0.11	0.11	0.31	-0.16	0.17	0.00	0.02	1.00	
9 VR use time	2.32	2	1.17	-0.11	0.12	-0.11	-0.10	0.15	-0.07	-0.01	0.01	1.00

Additional evidence

We took advantage of the fact that we also teach a version of the VR-enhanced case in a focused 3-hour session in an MBA course. For that course we used written feedback forms to collect immediate experiences and opinions. We triangulated the results from the focus groups and survey with the feedback from the MBA class. Because this course is ungraded and students pay for enrolment, the risk of biased feedback was low. Therefore, this feedback was collected directly by the professor. Eleven of fifteen students taking this course voluntarily submitted their feedback.

Findings and discussion

Our coding of the two transcribed focus groups identified themes related to the students' learning experience, and to the opportunities and limitations of integrating VR technology in teaching cases. We counted the number of mentions of the themes and sorted the mentions into positive, neutral, or negative statements. Five key themes emerged from our coding. Two of the themes were mostly regarded as having a positive effect on students' learning experience: *Immersion* and *motivation*. One theme was regarded important but have a mixed effect on learning experience: *integration of VR in the case.* Two further themes regarding the current state of VR technology were reducing the learning experience: *current state of technology* and *physiological side-effects*. Table 2 summarizes the key findings.

Table 2 – Key findings emerging from the focus group interviews.

Theme	**Mentions**	**Positive**	**Neutral**	**Negative**	**Summarized effect on learning experience**
Immersion	41	32	7	2	Use of VR technology offers new positively perceived possibilities for immersion in the teaching case. It allows students to explore at their own pace and availability
Motivation	26	15	6	4	Use of VR as a new teaching form positively affects students' motivation for the course and subject in the early phase.
Case integration	19	7	8	4	Use of VR technology has to fit the teaching case.
Current state of technology	55	2	13	27	The current state of VR technology (affordable for large classes) and apps available have several problems and limitations.
Physiological side-effects	14	0	4	10	Current VR technology has negative physiological side-effects (for example, dizziness)
Total	*155*	*56*	*38*	*47*	*VR has mixed effects on students' learning experience.*

Immersion

The students in the focus groups commended the new opportunities VR offers for immersing in a close-to-real factory environment. "*One picture is like 1000 words, so by looking at this app, the information you're getting is much more than someone could explain in 45 minutes,*" asserted one student. This aspect of VR was a recurrent theme in the focus groups. Immersion was also the highest ranked item in the survey (μ= 3.44; σ=1.08). In short, the students' feedback aligns well with the literature on immersion (Dede, 1995; Dede, 2009).

If there was a choice, the students would be in favour of physical factory visits. But in case where visits cannot be arranged, the students saw VR as a good substitute. In some aspects, VR was also reported superior to field trips. For example, VR offers an unmatched *availability* of immersion. One student explained: "*I mean you can still see it when you go there… but you'll have to actually go there and this way you can just put on your VR headset and take a look, you know, it's a lot more convenient.*" The possibility for immersing in the factory environment independent of time and place is a great advantage that this technology brings to teaching operations management.

Relatedly, VR is also unlocking an opportunity for students to go and explore for themselves. "*It was good that you could discover the factory on your own speed,*" was a typical statement. Guided field visits to factories usually follow a tour- and communication plan, which can restrict students' active participation in learning. One student explained, "*[…] since you have to look around, you start thinking… hey, so what am I actually looking at, or what should I be looking at?*" Another student added, "*I think it's because it's more like an active discovery than like a passive*". Hence, VR can help make operations management courses more active (c.f., Brandon-Jones et al., 2012; Scholten and Dubois, 2017).

In the survey, students indicated that they will be able to explain their learning from the VR to others (μ= 3.38; σ=1.02). Also the feedback from the MBA course indicated that students appreciate the possibility of immersion offered by VR. One MBA student mentioned the advantage of "[…] *doing a site tour without leaving the class,*" and another student reported that "*the VR experience was tremendous. Great way to get a good insight in production facilities and to start analyse the situation.*"

Motivation

The students expressed that the VR-integrated case had a "wow-effect" when introduced. The following comment from a student captures the general feeling in both focus groups: "*It's something new. I mean, personally I didn't have previous experience of that. So, it's always interesting when you have something new"*. However, most students also expressed that this initial excitement quickly tapered off after using the VR app a few times. One student explained, "*you were gonna take a look in the factory… at first in my opinion it sounded cooler than it actually was... because it's just an app you can download in the app store."* One explanation may be that the students in our class developed unrealistically high expectations about what they would get from the VR technology. Teachers can mitigate this by planning their introduction accordingly.

During the focus groups, several students speculated that VR should be more helpful for students with none or low experience from factory settings. This hypothesis could find some theoretical support in the constructivist learning theory (Dewey, 1938; Dunleavy and Dede, 2014). However, controlling for the effect of industrial experience, we did not find support for this assertion. Our insignificant results does not suggest that this relationship is nonexistent, just that there seem to be other factors that mitigate or dominate the effect of experience. For example, while unexperienced students will benefit from exploring a factory for the first time, more experienced students can benefit from relating what they see to previous experiences.

Overall, the focus group students reported that VR increased their motivation somewhat for the case work in the early phase of use and less so later on. This finding is supported by the survey results, in which the students report they are generally indifferent when it comes to VR's effect on "enjoyment" (μ=2.7; σ=1.09) and "curiosity" (μ=3.03; σ=1.03). The early-phase positive effect on motivation was supported by the feedback from the MBA class. Because we used a shorter version of the case in a focused one-day class we noticed that the initial excitement among the MBA students sustained through the class. A typical statement from the MBA feedback forms reads, "O*verall, I appreciated the use of VR and would like to have it again.*"

Case integration

The benefits from VR is of course dependent on its fit and integration in the case. Not all the questions in the teaching case developed with ABB required the use of VR and other questions did not explicitly tell students where to find information in the VR environment. This design evoked different reactions from the students. Some liked it, as captured by the following comment: "*I enjoyed the idea that I could relate what I was working on* *with the reality and really look at what is happening*". Other students did not like it. For example, one student said, "*it was just a bit helpful for doing the assignment because if it's a lot of things to see, then you start looking for everything and that is overwhelming.*" Most students were more neutral, as in the following comment: "*[…] you're given a limited set of information and you have to do some detective work.*" This mixed evidence was supported by the survey, in which students reported that the VR was slightly helpful for solving the case (μ=3.26; σ=1.05) and that it to a minor degree stimulated group discussions (μ=3.29; σ=1.14).

Again, the MBA students were more positive in their feedback. One MBA student wrote, "*The ABB case content and VR app were well-prepared. I truly appreciate the effort and the new teaching method. It was very fun to experience a different learning method and it linked well with the topic of operational excellence.*" But they also correctly pointed out that using the VR technology was no team experience and that there are *"no possibility to ask questions during virtual tours."*

Current state of technology

The current state of affordable VR technology still gives rise to several limitations that reduces the students' learning experience. Students in both classes expressed concerns over technological limitations on both the hardware side and the software side. On the hardware side, some students have experience with high-end VR viewers such as Oculus Rift and were disappointed by the limited possibilities and low resolution offered in the cardboard variant. There are also general problems; as the following feedback from a MBA student indicates, vision-impaired students using glasses could not make good use of the VR viewers: "*As I wear glasses all the time and I am near-sighted, I faced some problems*."

Software limitations related directly to the ABB app that was used and can be solved by developing or using other apps. For example, students asked for better navigation options, more embedded information and explanations, the possibility to change perspective from visitor to worker, more 360 degree video content, screenshot options, zooming options, better app stability, and compatibility with older smart phones.

Physiological side-effects

Most students reported that they experienced dizziness during the use of VR. In almost all cases, the dizziness passed very quickly when students removed the VR viewers. A few students reported headache as another physical side effect and some mentioned unpleasant heat radiation from the smartphone as a problem. Using the VR in public spaces can also have psychological side-effects, which was well captured by the following comment from a female focus group participant: "*We feel ridiculous*".

To avoid these troubles, several students reported that they stopped using the cardboard viewers and instead looked directly at the smartphone screen or computer. This workaround reduces the level of immersion but comes with other advantages such as the possibility to tour the virtual facility with others and take notes simultaneously, in addition to eliminating dizziness, headache, and radiation.

Conclusions

To the best of our knowledge, this is the first study that reports experiences with integrating VR in a teaching case in operations management. Together with ABB, we have developed a VR-enriched teaching case and used it in two classes at ETH Zurich in 2018. Using data collected through focus group discussions, an evaluation survey, and feedback forms, we have analysed the effect of using VR on students' learning experience. Theoretically, the concept of immersion and constructivist learning theory were useful for understanding the underlying mechanisms of this relation.

We conclude that VR offers great opportunities for enriching operations management courses and improving student's learning experience, but it is not without challenges. The major benefit that VR offers is the possibility to immerse in the field from almost anywhere, at any time. With VR, we can bring a factory to the classroom, or students can conduct a virtual visit to a factory from home. As a new and exciting technology, VR can also boost student's motivation for the course, although this effect was found to be temporary. It is important that the use of VR is well integrated in the case or course and that the content of the virtual work has a good fit the learning objectives and assignment tasks. However, VR still has technological limitations that reduce student's learning experiences and many users feel dizzy when using this technology.

Implications for teachers

We summarize our main recommendations as follows:

1. VR is highly effective in situations where field visits are not an option, however a field visit is always the preferred option by students. VR can complement an actual fieldtrip by serving as a refresher and enabling the students to revisit particular areas to help refresh their memories.
2. Teaching staff need to ensure the VR content is relevant to the assignments students are required to complete. There should be a clear link between what is being asked of them in the assignment and the VR content.
3. Teaching staff need to manage expectations by describing the VR resource accurately, potentially with a short demonstration in class. They should also caution students about prolonged use of VR in terms of physiological effects.
4. Teaching staff (and app developers) should ensure that the VR content can be viewed on a range of devices, including VR viewer, smartphone without the viewer and with web browsers. This ensures that students can choose to view the content in a way that suits them best and does not force them to only use the VR feature on phones.

The VR-enriched teaching case discussed in this paper is available from the authors and the ABB VR app is available for free in the app stores of Google and Apple.

Implications for companies

For companies willing to share insight into their factories, VR can be a great opportunity to connect with and attract talent. To be useful as teaching material, a VR case should be as immersive as possible and relevant to the content that is being taught in classrooms. Companies can take advantage of the technology by providing (virtual) access to areas where students may not be permitted during fieldtrips, such as close views of dangerous machinery in action or sensitive areas, like clean rooms. The apps should put as much control as possible in the hands of the viewer. The option to skip sections, and to actively navigate in particular. Both focus groups agreed that a Google Maps type navigation would be a welcome addition, where students could move around incrementally. Companies should try to reduce the limitations of the technology and the physiological side-effects discussed in this paper. We believe we will see many such apps being developed in the next years. It can be a first-mover advantage for companies that are quick to market and offer their apps for teachers to use in classes and cases.

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