Educating Educators about Virtual Reality in Virtual Reality: Effective Learning Principles Operationalized in a VR Solution

Henri Pirkkalainen[1][a], Eria Makridou[2], Osku Torro[1][b], Panagiotis Kosmas[2], Charalambos Vrasidas[2][c] and Kari Peltola[3]

[1]*Faculty of Management and Business, Tampere University, Korkeakoulunkatu 7, 33720 Tampere, Finland*
[2]*Centre for the Advancement of Research and Development in Educational Technology – CARDET, Nicosia, Cyprus*
[3]*Wakeone, Hämeenkatu 16 A 11, 33200 Tampere, Finland*

Keywords: Virtual Reality, Design Principles, Learning.

Abstract: Virtual Reality (VR) is transforming organizational training as users are immersed in realistic situations that may not exist yet in the physical world. The theoretical principles that make VR effective for learning in an immersive way are emerging in literature but remain poorly understood in practice nor have they been articulated in available VR solutions. This study demonstrates an IT artifact that is targeted at educators in companies and in higher education. The study synthesizes the key principles that make VR environments effective for learning, derives design principles for a corresponding artifact and demonstrates a VR solution that enables educators to absorb the principles of the power of VR by experiencing them first hand. Creating this artifact and delivering it to educators is important as they are responsible for diffusing VR to current employees in companies and future workforce in higher education.

1 INTRODUCTION

Virtual Reality is becoming an essential business tool for training and design-oriented tasks that are prone to high costs and failure rates. Virtual reality can be defined as a technology that provides "the effect of immersion in an interactive three-dimensional computer-generated environment in which the virtual objects have a spatial presence" (Bryson, 1995). The power of VR is in living through situations that may have not yet happened (Dede, 2009; Slater & Sanchez-Vives, 2016), such as extreme hazards in industrial settings that put human lives in danger, or in settings where expensive design projects are carried through (e.g., with aircrafts or cars) that need to be tested before they are manufactured or even built as high-cost prototypes. This is why it is not surprising that many industrial companies have shifted their operations in VR (Kugler 2017) and major construction companies co-design buildings with "test in VR first and get rid of errors proactively"-approach (Wang et al., 2018). Much of the value of VR is based on settings and disciplines that deal with 3D content that is optimally viewed in 1-on-1 scale (Berg and Vance 2017), such as the surrounding environment where you, the reader, are at this very moment. Indeed, psychological immersion makes VR a distinct technology since the individual typically perceives it as a comprehensive and realistic experience (Dede, 2009).

VR is just about ready to be embedded in daily practices of professional training in companies and in higher education (Jalo et al., 2020). VR hardware, platforms, APIs and both commercial and professional applications are developing at a tremendous speed as major IT companies have started investing heavily in VR (Berg and Vance 2017). Recent literature shows that the many previous bottlenecks relating to immature technology (e.g., low computing power and refresh rates) have been overcome and the interest in VR is currently higher than ever (Mütterlein and Hess 2017). Current

[a] https://orcid.org/0000-0002-5389-7363
[b] https://orcid.org/0000-0003-0706-5010
[c] https://orcid.org/0000-0001-6499-5180

Hutagalung, S., Aruan, L. and Tampubolon, E.
Utilization of Traditional Karo Marriage Symbol as Teaching Material for Deutsch Für Tourismus.
DOI: 10.5220/0010359100003051
In *Proceedings of the International Conference on Culture Heritage, Education, Sustainable Tourism, and Innovation Technologies (CESIT 2020)*, pages 584-591
ISBN: 978-989-758-501-2

adoption of VR is highly based on simulation and training scenarios (Jalo et al., 2020). However, the principles that separate VR from other types of virtual worlds or 2D and web-based environments remain scattered in prior literature. The principles that make VR effective for learning, that is, the extent that VR can be used as an effective tool to transfer know-how and insights in a novel way need to be made explicit to ensure use and adoption of VR to its full potential. We seek to bridge this gap by uncovering the theoretical principles that make VR effective for learning.

VR needs to be experienced first-hand as it is quite impossible to understand what psychological immersion means until one experiences it (Dede, 2009). Recent VR literature situated in the educational context has further argued that pedagogical thinking, as in prioritization of the major strengths of VR, has not been taken into consideration in the available VR solutions (Radianti et al., 2020). This is why it is critical to convert those principles that make VR advantageous into VR, by operationalizing them in an IT artifact.

This paper takes on a Design Science Research (DSR) approach to deliver these VR principles of effective learning into a VR environment where educators in companies and higher education may absorb those principles in an immersive manner. This study firstly identifies those theoretical VR principles for learning that demonstrate why major companies run their intensive training and simulations in VR. Then, we convert those theoretical principles into design principles that are further operationalized in an IT-artifact, taking the form of a VR tutorial for educators. The implications of the study and the VR solution are further discussed.

2 THEORETICAL PRINCIPLES OF EFFECTIVE VIRTUAL REALITY ENVIRONMENT FOR LEARNING

A summary of the most effective principles that make VR particularly powerful for learning is demonstrated in this section.

Theoretical Principle #1: Virtual reality can embed context-specific IT tools and means for both synchronous and asynchronous communication.

An important benefit of using Virtual Reality technologies is that they support both synchronous and asynchronous communication (Jalo et al., 2020). Avatar-based discussion and dialogue between users enable them to communicate both with text and voice, not to forget gaze and body language. This flexibility of VR is critical because synchronous and asynchronous communication tools have been proven beneficial and useful for e-learning environments, while they facilitate collaboration among individuals, and groups of people who interact with each other (Anderson 2004).

Prior research on VR has also established that avatar appearance and characteristics can affect individuals' behavior in virtual reality and afterwards when the user switches back to the physical world (Bailenson et al. 2006). One particular application in which a user's self-representation is modified in a meaningful way is the Proteus effect. When a user interacts with another person, the user's behavior adjusts to the modified self-representation, which is most of the time dissimilar to the physical self (Yee & Bailenson, 2007; Yee and Bailenson, 2009). For example, when users adopt attractive avatars, they feel free to share more personal information and approach others more closely than they might have done in the real world (Yee & Bailenson, 2007).

Theoretical Principle #2: Adaptability: Elements of a VR interface can be adjusted according to the situational and preference-related factors.

Interfaces of VR are flexible and adaptable to the user preferences in many ways, giving control to users and allowing them to work in their own speed, pace, and preferences (Sutcliffe, 2013). This way, engaging problem representations, which describe the contextual factors that surround the problem makes the interaction with a virtual environment as interesting as one cannot imagine. A user can be placed in any real-like or completely imaginary location and interact with others while adjusting the scenes and the location he/she is on according to the needs (LaValle 2020).

The user can also choose its own appearance from a large variety of options, making him/her capable of taking different roles (Chen et al. 2009). However, adaptability should be somehow limited in relation to the context of each virtual reality application, so that the consistency of the interface is not to be eliminated and the purpose of each application is not hidden (Sutcliffe, 2013).

Theoretical Principle #3: Virtual reality is not bound to time and space.

In a virtual environment, educators and learners are not bound by physical limitations that exist in classrooms and in the real environment. Specifically, users in a Virtual Reality environment have the opportunity to experience imaginary situations or situations of the past (such as historic events recreated in VR), turn off gravity in an environment and immerse in ways that are not possible in real life (Jalo et al., 2020), offering flexibility for repetition and self-pacing (Jonassen 1991). Additionally, this manipulation of the context of interaction in space and time (Bailenson et al. 2006) enables participants to go back in conversations with other users, pause an action, activity or situation and continue again only when they feel like doing it (Bailenson et al. 2006).

Theoretical Principle #4: Virtual reality is best absorbed socially.

One of the tremendous recent opportunities of VR relates to the multi-user perspective. Many recent applications make it possible for multiple users to enter the same virtual environment (Jalo et al., 2020). The social interaction among participants in the collaborative learning group has as an effect the development of greater social skills, while learners get together to know each other and solve problems collaboratively (Huang et al., 2010).

Adding to this, Roussou (2004) also argues that interactivity in learning, with other people and with virtual artefacts, is a fundamental mechanism both for the acquisition of knowledge and for the development of important cognitive and physical skills (Roussou, 2004).

Virtual Reality Technologies can provide the space for people to interact with each other without the limitations of the physical world (Lanier 1992; LaValle 2020). The use of Virtual Reality allows us to adjust and alter the way we see and approach interpersonal communication in novel ways that we could not achieve in reality, boosting social cooperation and interaction (Bailenson et al. 2006; Bailenson et al. 2004).

Theoretical Principle #5: Learning by doing instead of reading about it.

According to the constructivist approach, a user learns efficiently when he actively constructs knowledge out of the engagement in meaningful activities that are important for him/her (Roussou, 2004), drawing information based on prior experiences. Constructivism is widely admitted as the driving force for the development of highly interactive environments, where the user actively tests, modifies, builds, and tests ideas (Roussou, 2004). These perspectives have affected the improvement of intelligent and virtual learning situations, which appear to connect well to the "learning by doing" and "hands-on" educational practices.

Dede (2009) argues that the real power of VR is in situated learning. That is when the user can live through and interact in a situation they are learning about. Also, since virtual reality advancements give a wide scope of opportunities for this sort of intelligence and backing for dynamic investment in the development of the substance, they become appropriate, incredible media for use by educational institutions at large, galleries and edutainment focuses (Roussou, 2004).

It is also argued that interactivity is probably the most important property of a virtual reality environment as VR provides the user with the means to "feel" the experience, and feel placed in a scene while engaging with the surrounding environment (Roussou, 2004). In this perspective, a VR environment allows free exploration and manipulation of artefacts in a virtual environment, and can also provide feedback or interaction with other learners via visual, auditory, tactile, and/or kinaesthetic cues by other participating learners (Chen et al., 2009). Therefore, VR interfaces should function based on the user's commands, without attempting to control the user and interfere in the learning process (Sutcliffe, 2013).

Theoretical Principle #6: Allow sense-making by taking multiple perspectives in VR.

VR is known to allow users to view the environment and objects therein from multiple perspectives in order to gain a comprehensive understanding of their surroundings (Chen et al. 2009). The user can view the virtual environment and objects there from a first-person view, or alternatively, from a birds-eye (Dede, 2009). There are no boundaries in this regard.

Specifically, through the interaction of a user in a three-dimensional environment multiple viewpoints of a known or unknown situation can be faced. This way, a user can focus or exclude specific elements in a virtual environment that may interrupt one from the primary importance. The independent controlled viewpoint for each learner may also vary, depending on the interests and scope of use of VR (Chen et al. 2009).

However, the immersion level of a user to the Virtual Reality environment is also related to user's capacity to adopt the nonexistent environment and is dependent to factors such as the type of equipment, the degree of realism of the application, the activities to be implemented in the environment by the user, and the user's motivation to participate in the simulation (Fox et al. 2009).

Theoretical Principle #7: Content creation is limitless.

VR can occupy any digital content but is best absorbed in 3D environments the users can interact with and can present a situation in a shared three-dimensional environment that simulates aspects of the real world (Chen et al. 2009).VR often applies 360- or 180-videos because they are easily embedded and provide an immersive experience even without any advanced or realistic interactions with 3D objects of the environment. However, it is likely that certain disciplines and industries benefit from the opportunities of VR more than others in terms of content absorption (Jalo et al. 2020). For example, in design-intensive tasks where 3D plans (from cars and buildings to additive manufacturing) are co-created.

3 METHOD

3.1 Deriving Design Principles through Design Science Research

Design Science Research (DSR) is an approach that seeks to develop IT artifacts (e.g., prototypes, conceptual designs, products) that adhere to scientific justificatory knowledge and have practical utility (Hevner et al., 2004). Such IT artifacts are described with descriptive statements that provide details on how the particular artifact solves the utility for its user (Gregor and Hevner, 2013). This is typically achieved by design principles (Gregor et al., 2020). DSR is a paradigm with multiple notable approaches for demonstrating the utility of the IT artifacts. For example, these include the design science research methodology with proposed sample steps to conduct the research (e.g., Peffers et al., 2007) and Action Design Research that describes multiple actions and potential sequences of activities of artifact development in which the researcher has an active role (Sein et al., 2011). Although steps of the research may vary, the justificatory knowledge on the utility of the IT artifact needs to be carefully documented (Gregor et al., 2020).

The DSR project reported in this paper is built on the utility for educators. Thus, according to the guidelines of DSR (Gregor and Hevner 2013; Hevner et al. 2004), and as reflected in Section 2, the problem statement of and objectives for the solution are articulated as follows. The problem that the solution aims to tackle is two-fold. First, the principles that make VR an effective tool for organizational learning are poorly known. Second, the principles are VR-specific, meaning that they need to be experienced in VR to fully absorb them. The objective for the solution is an evident follow-up to the two-fold problem: The VR solution should enable an educator (in organizations and in higher education) to absorb the principles of effective learning of VR, in VR, in order for them to utilize these principles in practice.

In this paper, we draw from the guidelines of Gregor et al., (2020) on formulating informative design principles for IT artefacts. Design principle statements should provide information on the aim of the principle and potential enactors and users related to the principle. Example statement (principle #1): The VR solution should allow educators (ENACTORS) enrich their understanding of the properties and features of VR (AIM) so they may apply these properties and features in their organization (APPLICATION FOR THE USERS). Furthermore, each principle needs to build on rationale that clarifies the need for the principle within the context it should be embedded in.

3.2 Technical Specification of the IT Artifact

The IT artifact was built using Unity version 2019.1.5f1 as the development platform. Code was written in C# due to the usage of Unity. Basic interactions and movement of the avatar were implemented using the Virtual Reality Toolkit (VRTK) framework. Furthermore, audio guidance of the user was implemented using Azure Cognitive Services API. Although the artifact was implemented as a real-time (online) solution, audio clips were added to the build itself in order to enable offline use.

The IT artifact was intended for wide-scale use and was therefore designed for Oculus Quest-devices to ensure wide outreach for potential users. The solution was also primarily tested using that specific headset. Due to having a standalone VR device as the target platform, performance was a key concern when designing the user experience and implementing the VR application. Thus, development was done in an iterative manner. The application will be made available for download at vrinsight.org.

4 DESIGN PRINCIPLES FOR VR SOLUTION

Next, the identified theoretical principles that make learning in VR effective will be reflected as specific design principles that showcase the utility of the IT artifact. These principles were used as a basis for the VR solution development.

Design Principle #1: The VR solution should allow educators to enrich their understanding of the properties and features of VR so they may apply these properties and features in their organization.

One of the major hindrances of VR adoption is the lack of awareness on the possibilities of VR (Jalo et al., 2020). Platforms such as SteamVR, PS4 and Oculus include a range of commercial and professional applications with a range of features that are distinct from one another. Similarly, custom-built solutions for companies may make use of simulation and interaction that are not typical for applications that are freely available through major platforms. Recently, VR content is streamed on the cloud which has enabled various multi-user or social VR applications (Jalo et al., 2020). Many of those opportunities are spreading rapidly but are not yet mainstream. This is why the first principle is to articulate the essential functionalities and properties of VR to the user so that they can have a broad overview on the functionalities and features they may utilize in practice.

Design Principle #2: The VR solution should allow educators to adjust their virtual avatar so they understand how realistic or non-realistic avatars may impact user behavior in VR.

The second design principle is about the virtual representation of the user. Interaction with other users, and with the virtual environment, requires an avatar (Yee & Bailenson, 2007; Yee & Bailenson, 2009). However, the virtual representation of the user shouldn't be limited to the real-life characteristics of the individual. The design principle is to allow the user to see first hand how the change in avatar features, size or photo-realism may affect the use situation in VR, for example, to demonstrate the proteus effect (Yee et al., 2009).

Design Principle #3: The VR solution should allow educators embed themselves in settings that are meaningful for themselves so they know how users are not limited to specific locations.

New users of VR might find it difficult to understand what VR is and what is possible therein (Jalo et al., 2020). In addition to understanding their virtual representation as an avatar, the VR solution should make the user observe that the virtual space may be practically any real-life or fictional location that they can experience in 1-to-1 scale (Steffen et al., 2019).

Design Principle #4: The VR solution should allow educators realize that virtual spaces can occupy other users who are similarly represented as avatars.

The information load to using VR can be overwhelming in early stages of use (Jalo et al., 2020; Yee & Bailenson, 2007). Not only do the users need to get comfortable with their own digital extension, they are observing fictional and real locations in versatile virtual spaces (LaValle, 2020). As emphasized by recent VR research (Jalo et al., 2020), VR should not be limited to single-user experiences as it can serve as a communication channel that expands possibilities from the physical environment as demonstrated in Figure 1. By this, the VR solution should allow the user to observe the social fabric of VR by meeting other users represented as avatars in the virtual space.

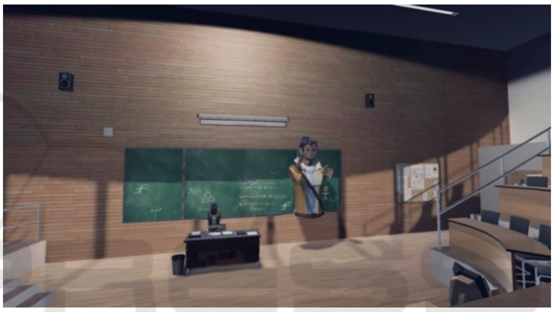

Figure 1: Showcasing multi-user setting and the protheus effect in the VR solution.

Design Principle #5: The VR solution should allow educators to simulate a real-world, or hypothetical, activity without physical restrictions (e.g,. gravity) so they know how to think outside the box &…

Design Principle #6: The VR solution should allow educators learn in the context by doing that helps them apply VR in practice.

Next, we reflect on two closely related design principles. The possibility of learning by doing is a major advantage of VR in comparison to other technologies (Dede, 2009; Jalo et al., 2020). This is something that is hard to explain to a user unless they can try it out in practice. This is why the VR solution should stretch beyond a VR experience that allows the user to observe aspects of VR. Instead, the VR solution should allow rich forms of interaction with the 3D objects embedded in the virtual space. They should be programmed in a way that the user can seamlessly simulate a real-world activity that they can relate to, but probably have not engaged in before, and further, allowing them to touch, move around and alter the objects embedded in the simulation, as demonstrated in the VR solution (Figure 2).

Figure 2: Learning by doing in the VR solution.

Design Principle #7: The VR solution should allow educators to switch between exo- and ego-centric perspectives to help them understand that users can enter places they wouldn't be able in real life.

The opportunity of VR in taking multiple perspectives is often related to a certain object that the user views in first-person - and in bird's eye (e.g., Dede, 2009). The VR solution should design this aspect in relation to a specific object or space so that the user knows the bird's eye view is just another perspective to the object they were observing in first-person.

Design Principle #8: The VR solution should allow educators distinguish between distinct content types that may be integrated into the virtual environment for the users.

As VR can potentially integrate any kind of digital data from plain 2D documents to 180 and 360 videos and rich 3D objects (that capture realistic details with millions of polygons), the VR solution should expose the user should to as many different types of content so that they understand the distinction between content that is static as in they are merely observable (e.g, 2D content that is not programmed for interaction) and content that they may interact with (e.g., 3D content programmed with realistic features similar to the physical world). A key aspect is that the user identifies that the content does not have to limit to the understanding of rules and conventions (e.g., laws of physics) embedded in the physical world.

5 DISCUSSION AND CONCLUSION

5.1 Research Implications

The main aim of this study was to transfer the key theoretical strengths of VR in an immersive VR tutorial for educators in companies and higher education. Prior studies had extracted many of those key strengths, which had remained somewhat unconsolidated in prior research, and were not typically addressed in available VR solutions (Radianti et al., 2020). This study focused on overcoming this gap in research. The study made two key theoretical contributions to the literature. The first contribution is in compiling the specific theoretical principles that make VR effective for organizational learning. The principles for effective learning in VR have been scattered in the literature and practitioners have typically lacked an overview on the contemporary advantages of VR (LaValle, 2020; Radianti et al., 2020). Many of the key advantages of VR are aspects enabled by comprehensive psychological immersion. For example, the fact that VR technology can occupy more or less any content up to elaborate digital twins of cities and experiences that go beyond the rules of physics (Jalo et al., 2020; LaValle, 2020).

The second theoretical contribution is the provision of specific design principles. This contribution is specifically on DSR and IS literature. An IT artifact was missing that could deliver the principles to the educators who are responsible to train and educate future employees and workforce on VR application. Only through the immersive experience the user can observe the major differences to utilization of other technologies in learning, such as 2D virtual worlds or browser-based computing. This research delivers such an IT artifact. The design principles are not limited to a form of a tutorial but can be deployed in any further VR environment targeting organizational training and simulation.

In addition to the two key theoretical contributions, the study has two streams of practical implications.

First, the unique feature of VR is in its immersion which makes it imperative to learn about it in VR. The IT artifact that was created to serve this purpose-designed to work as a utility for educators in organizational training and in higher education at large. The artifact and the theoretical principles underlying it are best served as a tutorial to VR technology so that the educator may identify its potential for institutional utilisation in a structured, step-by-step-manner that they can rerun as many times as they want. As many organizations are currently revamping their design and training processes with VR, we believe many more will be able to do so effectively once digesting the theoretical principles of effective learning in VR delivered via the IT artifact.

Second, the IT artifact can also help companies that develop VR solutions. The design principles that were demonstrated by the IT artifact should be treated as the fundamentals of VR intended for training purposes. The detailed requirements deriving from the users and organizations should be built on this basis. We urge developers to take advantage of these design principles so that they can design VR solutions that are a better fit for purpose and are likely to result in value-adding usage of the upcoming VR solutions.

5.2 Limitations and Future Research Topics

The presented DSR project does have certain limitations. Many of the limitations related to the VR development environment that set restrictions for the development and distribution of the solution. The IT artifact was prepared for side-loading for Oculus Quest and is only available via a direct download. We chose Oculus Quest for the maximum distribution via a standalone HMD device that would not require a powerful laptop to run.

For the above reason, the IT artifact could not be used as an actual simulation environment with rich synchronous multi-user capabilities. As a counteract, the IT artifact was adjusted in a way that it points out multiple available VR solutions that handle specific aspects illustrated in the tutorial. For example, the user is given suggestions for multi-user VR solutions that may be used for remote collaboration.

We identify many potentials for future research. One of the potential topics is to study the effectiveness of these principles in different settings. For example, organizational use is likely to have subtle differences across industries. We also urge researchers to dive deeper in to the social fabric of VR, which has only recently surfaced. Upcoming studies may also study performance-related aspects of VR to ensure many of the principles can be utilized without technical limitations in standalone VR devices that are affordable and likely to be reached by wider sets of users.

5.3 Conclusion

As more organizations are moving their operations to VR, the importance of guaranteeing positive outcomes of use becomes increasingly important. Those positive outcomes are more likely reached when VR is designed to its full potential in terms of user experience and unique features. However, the key principles that make VR stand out from other technologies have not been obvious even for practitioners working with VR. Our research attempted to uncover the theoretical principles that make VR a powerful utility. We hope that wider uptake of VR is one step closer as those theoretical principles were operationalized in an IT artifact that allows experiencing them first hand in an immersive VR environment.

ACKNOWLEDGEMENTS

This research was co-funded by Erasmus+ project VRinSight (2018-1-DE01-KA203-004277).

REFERENCES

Anderson, T. (2004). Toward a theory of online learning. In T. Anderson & F. Elloumi (Eds.) Theory and Practice of Online Learning, 33-59. Retrieved June 23, 2020 from: http://cde.athabascau.ca/online_book/ch2.html

Bailenson, J.N. & Beall, A.C. (2006). Transformed social interaction: Exploring the digital plasticity of avatars. In R. Schroeder & A.-S. Axelsson (Eds.), Avatars at work and play: Collaboration and interaction in shared virtual environments (pp. 1–16). New York: Springer

Bailenson, J.N., Beall, A.C., Loomis, J., Blascovich, J., & Turk, M. (2004). Transformed social interaction: Decoupling representation from behavior and form in collaborative virtual environments. Teleoperators and Virtual Environments, 13, 428–441.

Berg, L. P. and Vance, J. M. (2017). Industry use of virtual reality in product design and manufacturing: a survey. Virtual Reality, 21 (1), 1–17.

Bryson, S. (1995). Approaches to the successful design and implementation of vr applications. In R. Earnshaw, J. Vince, and H. Jones, eds., Virtual Reality Applications. San Diego, CA: Academic Press, pp. 3–15.

Chen, C., Jeng, M., Fung, C., Doong, J., Chuang, T. (2009). Psychological benefits of virtual reality for patients in rehabilitation therapy. Journal of Sport Rehabilitation. 18, 258–268

Dede, C. (2009). Immersive interfaces for engagement and learning: Cognitive implications. Science, 5910, 66–69.

Fox, J., Arena, D. & Bailenson, J., (2009). Virtual Reality. Journal of Media Psychology, 21(3), 95-113.

Gregor, S., & Hevner, A. (2013). Positioning And Presenting Design Science Research For Maximum Impact. MIS Quarterly, 37(2), 337–355.

Gregor S, Kruse LC, Seidel S (2020) The anatomy of a Design Principle. Journal of the Association for Information Systems, 21 (6), 2.

Hevner, A., S. March, J. Park, & S. Ram. (2004). Design Science In Information Systems Research, MIS quarterly 28(1), 75–105.

Huang, H., Rauch, U. & Liaw, S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. Computers & Education, 55(3), 1171-1182.

Jalo, H., Pirkkalainen, H., Torro, O., Lounakoski, M. & Puhto, J. (2020). Enabling Factors of Social Virtual Reality Diffusion in Organizations. Proceedings of the European Conference on Information Systems (ECIS). Research Papers. 7.

Jonassen, D. H. (1991). Evaluating constructivist learning. Educational Technology. 31, 28-33.

Kugler, L. (2017). Why virtual reality will transform a workplace near you. Communications of the ACM, 60, 15–17.

Lanier, J. (1992). Virtual reality: The promise of the future. Interactive Learning International, 8, 275–79.

LaValle, Steven (2020). Virtual Reality. Cambridge University Press.

Mütterlein, J. and Hess, T. (2017). Immersion, Presence, Interactivity: Towards a Joint Understanding of Factors Influencing Virtual Reality Acceptance and Use. In: Proceedings of the 23rd Americas Conference on Information Systems (AMCIS), 1–10.

Peffers, K., Tuunanen, T., Rothenberger, M. a., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24(3), 45–77.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers and Education, 147(December 2019), 103778.

Roussou, M. (2004). Learning by doing and learning through play. Computers in Entertainment, 2(1), p.10.

Sein, M., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. MIS Quarterly, 35(1), 37–56.

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. Frontiers Robotics AI, 3, 1–47

Steffen, J. H., Gaskin, J. E., Meservy, T. O., Jenkins, J. L., & Wolman, I. (2019). Framework of Affordances for Virtual Reality and Augmented Reality. Journal of Management Information Systems, 36(3),, 683–729.

Sutcliffe, A. (2013). Multimedia And Virtual Reality. Hove: Psychology.

Wang, P., Wu, P., Wang, J., Chi, H. L. and Wang, X. (2018). A critical review of the use of virtual reality in construction engineering education and training. International Journal of Environmental Research and Public Health, 15 (6), 1204.

Yee, N., & Bailenson, J.N. (2007). The Proteus effect: Self transformations in virtual reality. Human Communication Research, 33, 271–290

Yee, N., Bailenson, J.N., & Ducheneaut, N. (2009). The Proteus effect: Implications of transformed digital self-representation on online and offline behavior. Communication Research, 36, 285–312.