Abstract
The 21st Century is driven by the enrolment of the industry 4.0 to a society 4.0. The concept of being digitally connected in human-machine-networks is more and more spread over the entire society. Smart Cities, eGovernment and quantified-self movements are only some of the key phrases. Physical reality and virtuality increasingly melt together and international teams collaborate across the globe within immersive virtual environments. The training of virtual and joint problem solving within networks of avatars, virtual human and machines therefor is a huge field of research which has to be done. In the context of the development from purely document based learning systems to complex virtual learning environments (VLEs), a shift towards more interactive and collaborative components within higher educational e-learning can be noticed, but is still far from being called the state of the art. Benefits of those virtual worlds can be summarized in the possibility of hazard-free, explorative learning, visualization of invisible processes, the slow-motion of fast processes as well as the immersion in those worlds on the basis of natural user interfaces. Those environments bear a huge potential to support the student lifecycle by situated learning, problem based learning and immersion as a key resource for high transfer achievements of developed knowledge and skills. Tomorrows teachers need technological competencies in order to create VLE and interact with students in within VLE. This digital literacy includes not only the design of VLE but also experience in digital coaching and joint problem solving in virtual worlds. The paper shows the state of the art discourse by examples of VLE and outlines three different studies, designed and conducted to increase the success of implementing VLE in engineering education.

Keywords: Digital coaching, Engineering education, Virtual Learning Environment

1. Learning in Virtual Worlds

1.1 What Determines Virtual Worlds?

Digital transformations, wearables, virtual worlds – today’s possibilities of being digitally connected are more diverse than ever and become indispensable over the entire society. The 21th century is characterized by the transition to “society 4.0”, a term that is defined by hybrid multi-agent teams which are completely interconnected among themselves and their environment. Physical reality and virtuality increasingly melt together and hybrid multi-agent as well as international teams collaborate across the globe within virtual and real industrial environments. To educate...
and train for those “4.0. scenarios” the digitalization of education and hence the call towards more interactive and collaborative components within higher educational e-learning can be noticed, but is still far from being called the state of the art. But currently virtual worlds and simulations more and more arise as promising educational instruments. By imitating real-world processes, personnel skills can be developed, increased or maintained (Ubell, 2010). Especially if the learning process requires expensive equipment or usually would take place in a hazardous environment, the use of simulations is not only beneficial but absolutely necessary (Ewert et al., 2013; Malkawi, Al-Ariadah, 2013).

A virtual world is an abstraction or model of reality. The level of detail that is simulated determines the proximity to reality. Within virtual worlds social networks can be established by interacting avatars as well as the simulation of processes or events. In comparison to (most of the) multi-player-games, virtual worlds do not necessary contain a special or fixed purpose of use. Almost all of the virtual worlds allow users to interact (process controlling, problem solving etc.) while being there, and a huge number of those virtual worlds are modifiable (e.g. through the creation of new elements) by the user interactions (Höntzsch et al., 2013).

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1.2 DIVING INTO VIRTUAL WORLDS THROUGH NATURAL USER INTERFACES (NUI)

A natural user interface is a common computing term describing user interfaces that are effectively invisible, and remain invisible to the user as she or he continuously learns increasingly complex interactions. The word natural addresses the way the NUI enables learning and refers to the goal of NUI in the user experience, rather than the interface itself. While most traditional computer interfaces use artificial control devices whose operation have to be learned, a NUI requires learning, but the process of learning is eased through a design that gives the user the positive feeling of instant and continuous success. Thus, with the aid of NUI the way of interaction with the technology becomes naturally to the user. A common example of a natural user-interface
is the use of flight simulators including authentic user interfaces within pilot training instead of using just the simulation on a regular desktop computer. In this case, according to the classical memory theory, if the context in which we use our knowledge i.e. in which we have to transfer it to new situations resembles the context in which we learned the information in the first place, our memory works better (Schuster, Hoffmann et al., 2014).

How well a certain virtual environment is perceived is very much dependent of the corresponding hardware that is being used. Apart from that, a basic question of the research that is conducted and described within this paper is whether the control of computers via natural user interfaces deliver any advantages regarding learning processes in comparison to classical user interfaces such as a mouse or a keyboard. Controlling an interface with natural gestures has long left the area of science fiction movies such as Minority Report (Steven Spielberg, Dreamworks 2002).

By now, it seems completely normal to swipe the screen when looking at pictures at your tablet, scroll through longer articles and to zoom in and out by putting together or moving apart your index finger and your thumb. Apart from that, computers can detect human body postures, movements and gestures, translate them into commands and to execute them. This can be realized with device-based or camera-based tracking sensors, e.g. in the hardware component Kinect of the gaming console Xbox (Microsoft, 2014). The focus lies on interfaces which translate physically real movements into corresponding movements of e.g. an Avatar in a virtual world. To do so, physically real movements are being tracked and the movement information is transformed to virtuality. Saldik and Ott (2011) describe natural user interfaces (NUIs) as the third big step within human computer interaction, after commando lines and graphical user interfaces (GUIs). According to Bollhoefer (2009), “a natural user interface (NUI) describes an interface, which is controlled directly by one or many senses of the user. Therefore it forms a superordinate concept for many ways of interaction through the human-machine-interface” (Bollhoefer, 2009, p. 6. Translated by the authors). According to Blake (2010), one of the biggest advantages of NUIs is that it builds on already existing capabilities, i.e. motoric movement.

An interesting side-effect of controlling a virtual world with natural movements is that it can help us to remember things better. How well we can retrieve knowledge from our long term memory depends on the quality of how well we encoded the information (Zimbardo, 2003). In the case of computer-aided learning and according to Sweller’ Cognitive Load Theory, encoding information can be considered as a task, which is partitioned in at least two parallel sub-tasks: dealing with the content and controlling the learning environment with the respected user interfaces (Sweller, 2010). Therefore a lot of research and development activities follow the assumption that if the user can interface with the system in a natural way, more focus can be used for training than for the control itself (Johansson, 2012). It can be assumed that those virtual environments bear a huge potential to support the student lifecycle by situated learning, problem based learning and immersion as a key resource for high transfer achievements of developed knowledge and skills.

The next chapter focusses the meshwork of presence, immersion and flow as a determining set of factors to enable the potential of virtual learning environments.
1.3 PRESENCE, IMMERSION, FLOW

According to the entertainment sector, the extent to which a game or in general a virtual environment can “draw you in” functions as a quality seal (Ewert et al., 2013). This phenomenon is often referred to as immersion. A figurative definition is given by Murray: “Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air that takes over all of our attention our whole perceptual apparatus.” (Murray, 1997). Enabling natural movement as the most basic form of interaction is considered an important hardware quality to create immersion (Slater, 1995). Manufacturers of hardware that are supposed to enhance immersion claim that “Moving naturally in virtual reality creates an unprecedented sense of immersion that cannot be experienced sitting down” (Virtuix Technologies, http://www.virtuix.com/). Almost 20 years ago, this could already be confirmed by Slater (1995). Another basic assumption in the context of virtual learning environments and natural user interfaces is that greater immersion means better learning and potentially higher training transfer (Witmer, Singer, 1998; Johansson, 2012). This suggests that immersion would be the precondition for better learning, caused by the qualities of the user interfaces. However, if virtual environments are used in educational contexts, those assumptions need to be confirmed by empirical evidence. If assessed in an experimental setting, the construct of immersion needs to be specified. Spatial presence and flow are considered key constructs to explain immersive experiences. In general, flow describes the involvement in an activity (Csikszentmihalyi, LeFevre; 1989; Rheinberg et al., 2002), whilst spatial presence refers to the spatial sense in a mediated environment.

But even without the walking component, with natural user interfaces such as VR-Goggles immersion, presence and flow can be realized and bear a huge potential for many different sectors. A great media echo could be observed after the social media company Facebook bought Oculus VR in early 2013, a small tech-start-up from Silicon Valley that for the first time in decades had been able to create a pre-market product that amazed the community. Facebooks takeover boosted the interested in the new technology even more, as an analysis in Google Trends shows:
Facebook’s CEO Mark Zuckerberg posted a statement in his own Facebook account shortly after the business deal that should demonstrate the plans his company had with the new technology branch: “After games, we’re going to make Oculus a platform for many other experiences. Imagine enjoying a court side seat at a game, studying in a classroom of students and teachers all over the world or consulting with a doctor face-to-face – just by putting on goggles in your home” (Zuckerberg, 2014). The next chapter therefore focusses already existing virtual worlds for research and training purposes.

**2. EDUCATION IN TIMES OF 4.0**

**2.1 VIRTUAL WORLDS IN RESEARCH AND EDUCATION**

During the last decade a few virtual environments such as Second Life and Minecraft have been spread to a wider public use. Not surprising at all that a variety of attempts are already made to utilize those environments for educational or research purposes.

A typical finding of crawling those virtual worlds is that Second Life is more used in the domain of research and higher education and Minecraft is more used within school education contexts as well as for engineering and IT hardware scenarios. This results e.g. in Virtual Science Centers like the Oddprofessor’s Science Center in Second Life. This Science Center is a virtual physics lab used by the students at the National Technical Institute for the Deaf over at the Rochester Institute of Technology. The center is open to the public and can be accessed and used over its Second Life Address (secondlife://MUJIGAE/128/223/140). Another Second Life Example is the Science Circle which makes use of the virtual reality environment of Second Life to visualize Science. “In this environment we educate, have field trips and lead discussions. The Science...
Circle is an alliance of scientists, educators and entrepreneurs.” (http://sciencecircle.org). The Science Circle meets twice a month with their student groups in Second Life for field trips and presentations.

Moreover public virtual reality solutions, there is already also a variety of specialized simulations for education and training purposes e.g. for the Federal German Armed Forces. The system named KoCUA (cooperative computer-aided training) is used since 2005 and comprises a virtual world for the training of bridge building and ferry services. Therefore 3D models of amphibian vehicles, boats and floating bridges are available and have to be assembled to ferries and bridges. Features of this virtual world comprise variable configurations of training scenarios (e.g. flow, sight and wind conditions), monitoring view for trainers, data glove and real-time tracking of gestures. This project was awarded with the Corporate Media Award in 2005.

But also for the training of fire and medical emergency situations a variety of virtual worlds exist, such as the transport and accident information and support system of the German chemical industry (TUIS-VR). Within five scenarios firemen can train their behavior on complex transport accidents with dangerous goods on motorways, rails and country roads. As most of the firemen have not been called very often to those accidents in their daily business, they can train their behavior and decision processes of coping those complex operations. The scenarios are
Those VR training environments show that there is a brought variety of domains where creative problem solving is the key competence to be trained. But also the training of team competencies and behavior such as the coping with major incidents is already been undertaken in virtual worlds (Heinrichs et al., 2008; Encarnação, 2008; Höntzsch, 2013). Most of the scenarios address settings which you can’t train in real world scenarios to that extend – e.g. due to cost or danger reasons. For the implementation in higher education especially in engineering subjects the question of the benefits for virtual training of every-day engineering tasks is raised to make the education of engineers in virtual labs and worlds a normal curse and not an exception. Therefore more insight in the learning and training process within virtual worlds are needed. The next chapter focusses about some useful insight from current studies.

2.2 EDUCATING ENGINEERS FOR THE INDUSTRY 4.0

In the context of Industry 4.0 and the increasing globalization, a large market arises in the field of virtual trainings, settings for collaboration and schooling. The training of virtual and joint problem solving within networks of avatars, virtual human and machines therefor is a huge field of research which has to be done. Not every approach that is technically feasible improves users’ learning outcomes; hence the danger of designing expensive VLEs without having a positive effect on the users’ learning is obvious. Thus, for ensuring sustainable learning outcomes in VLE, it is necessary to find out in a first place, which conditions and precursors lead to and show successful (collaborative) learning processes.

Task performance in virtual learning environments

In an experimental study conducted in 2013 the influence of immersive hardware on task performance had been tested in a single learner scenario. A detailed description of the study and its results can be found in previous publications (Schuster et al., 2014; Schuster et al., 2015). The experimental group had to fulfill a preparatory task in a mixed reality simulator (the Virtual Theatre) which consists of a head mounted display and an omnidirectional treadmill. The control group had to fulfill the same task at the laptop. After a short introduction and testing phase, where the
participants of the study were given the opportunity to get used to the respective hardware, they were given the actual task, which referred to their spatial abilities and their spatial memory. The virtual environment participants were put in a maze. Within this maze, 11 objects were located. The participants were given 8 minutes in order to explore the maze and to remember the location of the objects. After this phase of encoding the new information, participants had to retrieve the newly gained knowledge by using an app on a tablet computer. First, they had to recognize the objects they had seen before in the maze. After that, participants from both groups had to locate the objects on a map of the maze (drag-and-drop). Both tasks – the encoding and the retrieval task – are demonstrated in Figure 6.

![Figure 6. Mixed Reality Simulator with corresponding view of the VLE used in the encoding task (experimental group); Tablet computer and app used in the retrieval task (both groups).](image)

Participants’ task performance was measured by the number of recognized objects, as well as reaction time (“total duration”) and the accuracy of locating the objects on the map (“deviation”). Moreover, the subjective experience of spatial presence and flow as indicators for immersion were measured with elements of the MEC Spatial Presence Questionnaire of Vorderer et al. (2004) and with the flow shortscale of Rheinberg et al. (2002). A total of 38 students between 20 and 33 years ($M = 24.71; SD = 3.06; n = 13$ female) took part in the study. Hypotheses regarding influences of hardware conditions on subjective experiences and task performance measures were tested with ANOVAs.

The results showed that mixed reality indeed leads to more spatial presence and to more flow than using classical user interfaces (Schuster et al., 2014). However, the task performance of the experimental group was significantly weaker. Students, who tried to remember the objects’ location in the virtual theatre didn’t recognize as many objects as the students who encoded that information using the laptop. These findings led to further analyses of the data, in order to answer the assumption that immersion and task performance can interfere with each other. Indeed, a significant interaction between flow and hardware characteristics was found in the case of the task performance indicators “deviation” and “total duration”. High values of experienced flow subside with better task performance, if a laptop has been used for learning, but with worse task performance if a mixed reality simulator has been used. These findings lead to the assumption that in a mixed reality simulator, the subtasks of learning “switch roles”: controlling the mixed reality environment including the phenomenon of “diving in” becomes the main task,
while dealing with the actual content-related task moves gets less attention (Sweller, 2010).

**Getting started with and training in virtual learning environments**

Those results brought up the question if VLE are only suitable for learners with a high experience in gaming and the use of natural user interfaces e.g. like Microsoft Kinect systems from the entertainment sector. If so, a habituation phase should be a mandatory element – especially for participants with less VR experience, such as trainers – who currently do not yet belong to the digital native generation. And finally it has to be researched if active teaching is a suitable mode for those environments at all or if self-directed experimental learning is the only recommended way for using VLEs.

Based on this questions a study was conducted investigating the trainer’s view and behavior. Ten professional trainers aged between 24 and 60 years ($M = 40, 7; SD = 13, 2; n = 2$ female) participated. During the experiment, the participants’ spatial behavior within the VLE Minecraft was assessed with a screen capture tool. After the experiment, a structured interview that gave additional insight into trainers experience in the VLE was conducted. As the setting for the VLE, the open-world game Minecraft was chosen, a program that was used successfully for learning and teaching purposes beforehand and allows participants among other things the free exploration of a virtual environment (Schifter, Cipollone, 2013). An engineering task was given to the participants, who entered the virtual environment by wearing a head mounted display (Oculus Rift, DK 2), displayed in Figure 4 (left side). The Oculus Rift allows controlling the field of view by natural head movement. Horizontal movements are controlled through clicking on the arrow keys of a simplified keyboard, not via movements on an omnidirectional treadmill. By clicking on the keys of the mouse, the trainers were able to select different kinds of tools they need to solve the stated problem.

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**Figure 7.** Left side: participant entering the VLE, while wearing the Oculus Rift (DK 2). Right side: Screenshot of the VLE learning scenario.
In order to get deeper insight into the trainers’ perspective of this new way of education as well as the discrepancy between learning and teaching in the VLE, every trainer pursued two roles: first the trainee and then the trainer part. Hence the participants did not enter the virtual environment alone but in groups of two. The real face-to-face meeting between them is thereby replaced by a virtual meeting in which both participants (the trainer and the other person) are represented by avatars. In the first part of the experiment (the introduction – and trainee – part), the participant was instructed by the research director to restore the electricity in a virtual building (see Figure 7 right side). This phase also enabled the trainer to get comfortable with the VLE and the handling of the new hardware. In the second part of the experiment, a similar problem was stated, but this time the participant had to instruct another person about how to solve the stated problem, without anticipating the problem solving process. Starting with the briefing of the handling of the simplified keyboard and the mouse, the participants had to make sure that the student feels comfortable within the VLE and solve the problem. During the experiment, both screens (trainers and trainees) were recorded and gathered by a video capture tool for assessing the trainer’s and the trainee’s behavior in the virtual world (Figure 8).

The initial results of the study showed the trainers’ positive attitude towards education within the VLE: even if the screening of the gathered video data indicates that age and online gaming experience had an influence on the participants’ spatial coordination within the VLE, these initial difficulties diminished after the first minute of the introduction phase by almost all participants. All participants were able to solve the stated problem quickly as trainee and were capable to instruct another person verbally within the VLE. Thereby it was shown that participants who documented their course of action out loud performed more efficiently. After the experiment, the subjects were asked to anonymously evaluate their previous learning experience in the VLE. The participants’ overall conclusion was very positive. It was shown that even the barriers for the affected teachers are low regarding utilization of virtual worlds for teaching, whereas the benefit of VLE was considered as huge. The additional expert interview gave more insight into the gathered data and the trainer’s view. The way of training and handling the interface was rated as very adaptive and the participants pronounced the feeling of immersion into the virtual world. Especially the resource efficiency and flexibility, the targeting of many senses at once
and the consequential deep learning were emphasized as advantages of VLE. But also potential difficulties with VLEs like initial problems with the usage and the acceptance of technology were mentioned. But the potential benefits of VLEs exceeded the possible adverse effects many times over.

While a detailed data analysis of the study is currently in progress, the preliminary results show that a short habituation phase in the VLE significantly supports successful teaching and learning processes, even if participants have only small experience in VR, gaming or the use of natural user interfaces. Moreover this it can be stated that the active support and collaboration with a trainer is a benefit for learning processes, even in experimental problem solving settings.

Cooperative problem-solving in virtual learning environments

Since July 2015, an actual research design is investigating in detail the aspects of collaborative learning behavior in mixed reality environments. Again the virtual world Minecraft was chosen as VLE, this time for investigating collaboration processes in virtual surroundings. The experimental design of this study consists of two groups that were tested after each other. The experimental group had to fulfill the task by wearing the Oculus Rift. The control group had to fulfill the same task at the laptop. Based on the results of a pre-study conducted in autumn 2014 and the study conducted by Schuster et al. 2014 it is thought that within the experimental group, due to the use of the immersive user interface Oculus Rift, the feelings of immersion within the VLE increase compared to the control group and thereby leads to higher task achievements.

The participants got the same engineering task as the trainers before; the repair work of the electrical circuit. After the introduction phase in which the participants had to solve a problem on their own, the actual task followed. In this phase the two participants, who were located in different rooms, met each other for the first time virtual. The communication between them took place over headphones. Besides the influence of immersion and flow on collaboration also the construct social presence was examined. Kreijns and colleagues defined social presence as “the degree of illusion that others appear to be a real physical persons in either an immediate (i.e., real time/synchronous) or a delayed (i.e., time-deferred/asynchronous) communication episode” (Kreijns, Kirschner et al., 2011). Social Presence is thus an important determinant for participation and social interaction as well as a prerequisite for collaborative learning and knowledge management.

The collaboration behavior of the students is examined by using a mixed-method-approach, in order to deal with the complexity of this research setting. Through the aid of screen captures and concurrent voice recording, a detailed analysis of communication, action and interaction is possible. The success of teamwork is thereby measured by means of consecutive learning and task goals. A special tracking system records the spatial coordination for the collection of the participants’ movement patterns, their level of physical activity as well as the mapping and comparison of motion path. In the run-up to the tutorial and the learning scenario, the participants were asked in a pre-test about physical limitation with reference to the used technique, experience with digital games und game controllers, personality traits, behavior roles in learning and work situations as well as acceptance for technology. Following the learning scenario, the participants were ask in a post-test about the acceptance of the previously used technique, questions about flow and immersion, social presence as well as evaluation of communication between team
members. A structured interview supplemented the questionnaires in the fields of acceptance of technique, feelings of flow and immersion as well as team coherence qualitatively.

Initial results show: despite the novelty of those environments, only very few to no problems through the task fulfillment arouse. The drawback arisen until now are that the studies with the experimental group took slightly more time because of the adjustment of the equipment, whereas the control group only had to handle the familiar control system on the laptop, but had significant lower feelings of immersion. Both conditions (experimental and control group) showed different but categorizable cooperative problem solving behavior. The teams developed individual strategies for problem-solving and communicated in different manners with regard to content and frequency. Participants who had more experience with online gaming were able to easily navigate their avatars through the VLE, but made more errors due to velocity.

Final results of the study to collaborative learning and working within VLE are expected for December 2015. Until autumn 2016 a further series of studies with VLEs centering around the question of collaborative problem solving in hybrid “human-machine teams” is planned and will deepen and broaden the described study results in relation to industrial production scenarios.

3. CONCLUSION AND OUTLOOK

The results and initial findings of the described series of VLE-studies show that those environments bear a promising potential for successful implementation of virtual worlds within higher education. The opportunity to teach and train qualifications within fully immersive virtual scenarios on the on hand allows to strengthen literacies which will – as those environments in general – in short time be part of our daily professional and private life.

The examples from the entertainment sector already show that virtual social networks such as Second Life more and more drift into the education sector. It is going to be a challenge for teachers and learners to teach and learn not in the classroom but in the VLE. Trainers will have
to be able to prepare virtual learning environments as they prepare a Power-Point-Presentation today. Furthermore tomorrows teachers need technological competencies in order to interact with students in the VLE. This “digital literacy” includes not only the design of VLE but also experience in digital coaching and joint problem solving in virtual worlds. It is going to be a mode of teaching to tutor and moderate groups of students in VLEs.

The described initial results of the VR-studies are promising, especially to identify if problem solving strategies from real-world scenarios are just transferred into the behavior within virtual worlds or if – due to some limitations of avatars (e.g. no facial expressions) – other strategies are developed. If so, a next question is how this affects the transfer achievements and trade-offs from virtual to real world scenarios. The work on those above mentioned constraints is already in process. Researcher of the University of Southern California and the Facebook Company Oculus showed how the facial expression of a VR-Headset user can be tracked and drawn to a virtual character. With the help of a 3D camera, the systems tracks movements of the mouth. Movements of the upper facial region are tracked by stretch marks, which are integrated within the headset. Drawn together those datasets enable a 3D-picture of facial movements of the user, which can be used for the animation of virtual characters (Simonite, 2015).

Due to such new technological developments the integration of oral and practical examinations in higher education supplemented scenarios are possible. But fundamental design paradigm for assessments, which e.g. take into account the need for a “warm-up” and habituation phase within those worlds need to be developed and the legal situation of assessments in virtual worlds has to be figured out.

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