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Abstract

This contribution in the field of innovative approaches to training and education in technical subjects focuses on the potential of modern teaching and learning environments. The contribution is based on a theoretical introduction to Mixed Reality Systems and virtual teaching and learning systems, and as such provides an overview of current research regarding modern learning environments. In particular, it takes a close look at motivational effects in the context of web-based learning structures, human-object interactions, gamification and immersion. The article discusses both technical, user-relevant and pedagogical aspects as well as suggestions for further research in the context of Ausbildung 4.0.

Keywords: Industry 4.0, Vocational Training 4.0, Mixed Reality System, virtual learning

Lernen in Mixed Reality System im Kontext von Industrie 4.0

Zusammenfassung

Der Beitrag fokussiert im Bezugsfeld innovativer Ansätze der Aus- und Weiterbildung in technischen Domänen die möglichen Potentiale von modernen Lehr- und Lernumgebungen. Aufbauend auf einer theoretischen Einführung zu Mixed Reality Systemen und virtuellen Lehr- und Lernsystemen liefert der Beitrag einen Überblick zum Forschungsstand zu modernen Lernumgebungen und geht hierbei insbesondere auf die motivationalen Effekte im Kontext webbasierter Lernstrukturen, Mensch-Objekt-Interaktionen, Gamification sowie Immersion ein. Im Beitrag werden sowohl technische, nutzerrelevante als auch pädagogische Aspekte diskutiert und Desiderate für eine weitergehende Forschung im Kontext einer Ausbildung 4.0 begründet.

Schlüsselwörter: Industrie 4.0, Ausbildung 4.0, Mixed Reality System, Virtuelles Lernen

1 Introduction

In recent years, Industrie 4.0 has become the central topic of industrial and manufacturing economics with the fourth industrial revolution driven by the internet about to take place right now. In 2011, the German Federal Government called Industrie 4.0 the one integral part of the high-tech strategy project "High-Tech Strategy 2020 for Germany", whose aim is to strengthen the competitiveness of the German manufacturing industry. Based on literature research, Hermann et al. argue that Industrie 4.0 is "a collective term for technologies and concepts of value chain organization" with the four key components of Cyber Physical Systems, Internet of Things, Internet of Services and Smart Factory (Hermann, Pentek & Otto 2015, p. 8). Industrie 4.0 provides an opportunity to expand German industry. By now, German manufacturers and companies have already found a way to follow the steps of Industrie 4.0 and strengthen the market, including a Cloud platform to store machine data, software to analyze information, facility tools to support the network of machines and predictive maintenance to avoid the costs of machine maintenance and downtime (IDC 2015).

Coined by the German government, Industrie 4.0 has by now become a term known across the world to refer to the next generation of industry development, making it essential to and worth it to discuss comparable ideas from a global perspective.

In October 2014, the governments of Germany and China co-chaired the third round of intergovernmental consultations in Berlin with the theme "Innovative Cooperation", starting the new generation of Chinese-German cooperation. As the key achievement of this consultation, the two countries issued the Action Outline for the Chinese-German Cooperation, which included 110 specific cooperation projects and initiatives, making it the most comprehensive cooperation document between Germany and China to date. The document includes four priorities of the cooperation, which are "Closer political cooperation and shared responsibility: equality and mutual trust", "Sustainable economic development and cooperation in the financial field: Mutual benefit and win", "Innovation as a driver for a modern society: Shaping the future together" and "Cooperation in Education and Culture: Exchange and mutual learning". In the Action Outline for the Chinese-German Cooperation, "Cooperation in Industrie 4.0" is one of the sub-sections of "Sustainable economic development and cooperation in the financial field", indicating that the digitalization of industry, which is the main subject of Industrie 4.0, plays a crucial role in the economic development of both countries, and that both governments should offer policy support for companies to participate in the revolution process. Close cooperation in the context of standardization is also proposed, committed to carrying out a more systematic and strategic cooperation. Both governments decided to focus more strongly on forward-looking sectors, such as e-mobility, energy-efficient Smart Energy Control/Smart Home, water supply and sewage treatment. Additionally, based on the fair and open competition of trade and products, the cooperation of both sides in the fields of mobile internet, internet of things, cloud computing, and big data will be intensified.

In May 2015, based on the plan of industry digitalization and inspiration from the German Industrie 4.0, the Chinese State Council unveiled the project "Made in China 2025", which is headed by Premier Li Keqiang, in order to raise the level of competitiveness through automation and technology, combining information technology and industry technology. Under the industrial revolution with its instantaneous changes in production and manufacturing, it is fundamental to pay attention to the training of the competencies of the person occupying the role in this virtual working environment.

In the context of Industrie 4.0, the future requirement of employee competence has changed immensely. Positions now filled by machine operators along the assembly line will gradually be replaced by smart equipment and workers with technical knowledge as well as the competence of planning, coordination, evaluation and decision-making. A transfer will take place of the competence requirement from the specific working ability to a composite of competences. Sustainable employee competence development will also be taken into account because of the multidisciplinary and interdisciplinary nature of smart manufacturing.

Therefore, the major challenge of the development of Industrie 4.0 would be updating the system of vocational training to meet the corresponding growing skills demands. Even some employees with years of working experience at the assembly line may lack sufficient knowledge of the internal structure and functional principles of the manufacturing equipment.

The enhancement of the quality of vocational training is in line with the need to support the development and prosperity of Industrie 4.0. The concept Ausbildung 4.0 is to be raised, which refers to the next generation of digitalization and virtualization of vocational training, encompassing learning on demand, cloud learning, learning with gamification as well as learning in a mixed reality system.

Of all the parts of Ausbildung 4.0, vocational training in a mixed reality system may be the most virtualized part, providing the possibilities to train under challenging working or training conditions, improve training quality and reduce the occupational health and safety risks (Bosché, Abdel-Wahab & Carozza 2015). For example, the result of an analysis of the mechanical working system situation indicates that learning or training in a real mechanical working environment is often limited by incalculable and irreversible risks and sometimes even impossible (Blümel, Jenewein & Schenk 2010). Some international corporations are already in the process of developing smart manufacturing, and developing and testing products in a mixed reality environment, not to mention the modern training method of training in a mixed reality system.

Motivation may be one of the most critical ingredients of effective training. With respect to Ausbildung 4.0, learning motivation and learning interest are always major topics of vocational training, with a close relationship with a mixed reality learning environment. Thus, the aim of this essay is to explore the ways in which the above-mentioned functions of a mixed reality system can work in vocational education with regards to up-to-date technology, and specifically learning motivation and learning interest.

In terms of the following parts of this essay, Chapter 2 commences by laying out both the theoretical and empirical research background and the technical progress of mixed reality systems in vocational training. Chapter 3 mainly discusses learning motivation theory and how a mixed reality learning environment enhances situational interest in vocational training. Chapter 4 is concerned with the challenges of learning in the mixed reality system and Chapter

5 gives the conclusion of this paper and depicts further research possibilities in the area of mixed reality learning in the context of Ausbildung 4.0.

2 Background: Learning in a mixed reality system

A number of concepts in a mixed reality learning environment should be discussed before moving on to the applications of vocational education. The definition and range of mixed reality system are discussed in the following sector. The overview of present studies includes three aspects of mixed reality systems that are closely related to Ausbildung 4.0, research models of learning in a mixed reality system, the authenticity of a learning environment and its prominent features, such as immersion, flow and spatial presence. In the context of Ausbildung 4.0, it is necessary to have clear ideas of the up-to-date theoretical and technical situation to create an appropriate and corresponding learning environment.

2.1 Mixed reality system

Mixed reality, a mix of reality and virtual reality, refers to the wide domain of the continuous transition between the two extreme ends, physical reality to virtual reality, which is shown in the following figure (Milgram & Colquhoun 1999, p. 7). At the left end of the continuum is the real environment (RE), which would be training in the traditional classroom, laboratory (e.g. school learning factory, for an overview see e.g. Zinn 2014) or working on-site in the context of vocational training. Yet the inevitable restrictions would be the occupation of time and space of onsite project equipment, not to mention the occupational health and safety risk. At the right side of the continuum is the virtual environment (VE), enabling training to proceed in the environment with all the artificial sensory experiences such as sight, touch, in addition to immersion and spatial presence. Steuer (1992) argues that presence is the core element of a virtual reality system, which will be discussed in the following sections.

According to Milgram and Colquhoun (1999), when some virtual elements are imported into a real world environment, we have augmented reality (AR), which is basically reality augmented by virtual elements. For example, some of the transparent interfaces of Head Mounted Display can support the training and even implementation of complex maintenance tasks. Vice versa, when some real world elements are imported into a virtual environment, we have augmented virtuality (AV). An application example of AV is a virtual production line connected with a real CNC (Computerized Numerical Control) platform in order to train the steering and management of the CNC control platform (Blümel, Jenewein & Schenk 2010). In terms of the comparison of virtual reality and augmented reality, VR is a fully immersive and closed experience (Oculus Rift), while AR is like wearing a transparent mobile phone on your face (Hololens).

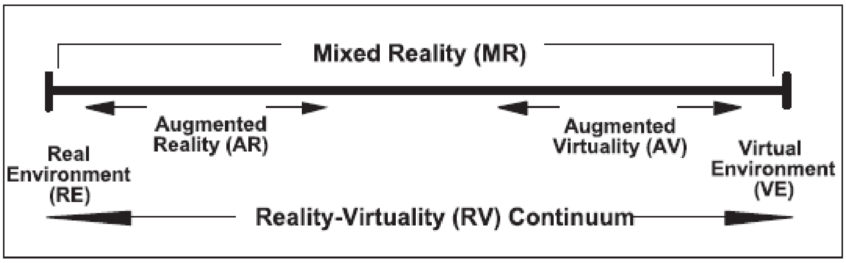

Illustration 1: Reality-Virturality-Continuum (Milgram & Colquhoun, 1999, p. 7)

Mixed Reality is gaining popularity in modern vocational training thanks to its real-time visualization, simulation and interaction in a virtual world. One of the practical examples in the construction training field would be excavator training, in which trained operators have been shown to be more efficient than traditional method-trained operators at the beginning of their real life work (Jun, Kim & Lee 2013). Another example would be the construction assistance tool developed in a VR project by the University of Twente, which focuses on the development of visualization of communication and training methods to acquire new working knowledge (Vasenev et al. 2011). From a didactical perspective, in the mixed reality the learning process is controlled mostly by the students themselves, which, as declared in the Bologna Declaration, is important for students to develop their employability.

Moreover, a carefully set up mixed reality environment consisting of various fitting learning elements with proper strategies and decorations will be important for the students to enjoy the immersive experience as well as acquire the knowledge (Schuster et al. 2014). The overarching aim of an appropriate design in a mixed reality system would be to match the users' characters (e.g., age, pre-existing knowledge). In this case, the mixed reality learning system from Shanghai Jiao Tong University was developed with a Data Analysis Center, which collects and analyzes the process data from teaching and learning in the logfiles of web-servers to enable the further development of the learning system, including students browsing online courses and querying course materials (Callaghan et al. 2010, p. 270).

2.2 Overview of present studies

The technology of computer simulation has been developed for education and training - not only for vast and complex systems like the economic system (company management), ecological and geological system (climate changing), social system (city construction and management) and scientific system (outer space and underwater system), but also for sophisticated micro-processes like medical training, manufacturing control, finite element structural analysis and geometry (Lin et al. 2013; Bosch et al. 2015; Kerres 2012; Deng, Xue & Zhou 2009; Kamphuis et al. 2014; Tolio et al. 2013; Huang, Ong & Nee 2015; Lin, Chen & Chang 2013). A great advantage of learning in a mixed reality system is its dynamic visualization, in which not only the spatial structure of objects but also the spatial connections and configuration can be shown, no matter whether this is building the molecules that run in veins and arteries, the structure of an opposed cylinder engine or the formation of the glacier. Industrial simulation, the simulation of realistic industry, may be an effective idea to enhance development efficiency and to reduce unnecessary risks in the context of Ausbildung 4.0.

Industrial simulation can be applied in any parts of production, including reports, designs, sales, market promotion, after-sales services and website. In terms of employee training, industrial simulation promotes the activity and enthusiasm of employees, which in return enhances the efficiency of the training. With the rapid evolution of information technology, the concepts of modern “teaching” and “learning” are clearly changing and, across time and context, will move from “multimedia learning” via “e- learning” to “learning in a mixed reality system”.

Framework and research models of learning in mixed reality

A mixed reality system is a totally different environment from the ones the students are used to. Therefore, the general model of learning in an immersive mixed reality system has a pivotal role to play in research in the context of a mixed reality system, which describes the cooperation and interplay between almost all of the learning factors of the learning process.

Salzman et al. proposed a model for understanding how mixed reality aids complex conceptual learning (Salzman et al. 1999, p. 312). They used three types of learning contexts for the evaluation of a learning environment, based on which they proposed the hypothetical model, describing how VR features, characteristics of learners, the interaction and learning experience work together to influence the learning process and learning outcomes. In a recent article, Lee et al. proposed a conceptual framework of the outcomes in a desktop VR-based learning environment based on Salzman’s model (Salzman et al. 1999, p. 312), in which the entire learning procedure is divided into three parts for the empirical model, income, process and outcome, including the constructed variables of VR features, usability, presence, motivation, reflective thinking, immersion and learning outcome (Lee et al. 2010, p. 1431).

If mixed reality is to be used to support vocational training, then it is needed to examine the relevant important constructs to help to achieve this goal. Although the learning components have been studied by various scholars in the non-virtual environment, it is necessary to discuss the situation of these components in a mixed reality system. Furthermore, the already existed theories and methods could be modified and adapted in a new environment.

Some research has been done on this topic. In terms of VR features, Schuster performed a comparison experiment using the hardware of the Virtual Theater with HMD as well as omnidirectional floor versus desktop virtual environment. However, Schuster’s study of learning in a virtual theater shows that immersion in virtual environments with a natural user interface does not lead to better learning outcomes than a desktop virtual interface, which is still limited only to learning outcomes in maze game, which could be unsuitable for learning in virtual reality (Schuster et al. 2014). In terms of learning motivation, one of the assumptions of the cognitive-motivational theories is that motivation is not one’s stable character but inherently changeable depending on the context of learning (Linnenbrink & Pintrich 2002, p. 318). In the findings of Virvou et al., VR features are significant antecedents to motivation, especially situational motivation (Virvou et al. 2005, p. 60). With regards to learning outcomes, the study of Lee et al. has shown how mixed reality enhances the learning outcomes, in which control and active learning, as well as reflective thinking, are significant antecedents to learning outcomes (Lee et al. 2010, p. 1431).

Authenticity of the learning environment

From the perspective of constructivism, a computer-based constructive learning environment should be as authentic as possible and offer complex output problem (Reinmann, Mandl & Prenzel 1994), including realistic problems and authentic situations. In the context of Ausbildung 4.0, the authenticity of learning in mixed reality is required to match the real working situation to enable the students to easily apply their learning to a real work environment after the training. The learning environment should integrate multiple perspectives and multiple contexts, including social context, making it possible for the learners to articulate their thoughts and reflect on their thinking structure (Köhler et al. 2008, p. 484). The authentic and dynamic 3D visualization in a mixed reality system makes spatial understanding easier for learners, including for learnings with a low ability of spatial recognition according to the research of Münzer on learning from animation in a mixed reality system (Münzer 2012, p. 509). For instance, operations training for industrial equipment in a mixed reality system would help the students to perform the operation prior to the site condition (Carter 2015, p. 47).

The obstacles of simulation in some cases may be too much authenticity when the user has less experience as a beginner in terms of using computers. When learning in a virtual environment, the irrelevant aspect of graphic representation would be avoided because of the certain tolerant limit of perception of learners (Lindsay 2009, p. 230). Unnecessary examples of realization of vocational training would be: the noise of the working space, rust of the old machines or redundant instructions of operations. The result of an experiment conducted by Duchastel (1980, p. 283) shows that learners concentrate more on learning materials and learning memories when only easy and essential details are shown to the learners and the irrelevant aspect of graphic representations are omitted. On the other hand, although vocational education students can distinguish between original and model, reality and simulation, as well as actuality and possibility (Müller, 2005), the debugging intention of the environment and materials in a mixed reality system may also hinder the learning process, with the solution being the suspension of disbelief, under which the learners recognize the bug of system and accept it in order to process learning (Vorderer et al. 2004, p. 3).

In accordance with the constructivism paradigm, students are confronted with accessible and authentic mixed reality training situations (Oerter 2001, p. 69). Learners generate knowledge and experience in the closed information system autonomously based on the interaction between former knowledge and experience in real laboratories or other working spaces, not from the teacher exclusively (Baumgartner & Payr 1994, p. 107). The teacher involves the learners in order to improve their knowledge structure with the alternative experience and knowledge and the learners recognize the association of complicated situation and generate the problem solutions, using the alternative experience, feelings, behaviors, lifestyles and communication.

Immersion, flow and spatial presence

In comparison to the traditional learning environment and e-learning environment, vocational education in a mixed reality system can offer benefits in terms of immersion, commonly explained through flow and spatial presence.

With the development of the 3D immersive technology of a mixed reality system, immersive mixed reality interfaces possess great advantages over 2D interfaces when it comes to training with interaction, movement or communication. Immersion used to refer only to the physical experience of being submerged in water, yet now immersion refers to the sensation of being in a completely different environment that takes over your attentions and perceptions (Murray 1999, p. 98). So far, an explicit definition of immersion has not been raised by scholars because of its complexity and multiple perspectives, including a broad spectrum of phenomena in various forms and various results. Immersion in virtual reality has at least the following characteristics: teleporting of time and space, interaction with the machine and autonomic activities (Schuster et al. 2014).

The immersive situation occurs in many cases no matter whether it is a fictional world or a non-narrative environment. From a historical and cultural perspective, the idea of transporting people virtually to another enclosed illusionary environment with different sensations has existed since ancient times (Grau 1999, p. 365). When the audience finds itself amidst life-sized, highly realistic and scenographic frescos of the second Pompeian style, the border between physical reality and virtual reality seems to dissolve (ibid.). One of the most remarkable immersive spaces of the Renaissance is the Sala delle Prospettive by Baldassare Peruzzi, surrounding the audience with virtual columned hall and illusionistic views of the countryside (Ewering 1993, p. 57). After the Industrial Revolution, the imaging and recording technologies provide the audience with previously unknown dimensions of illusionary effects. Most of the developments of the immersion apparatus were first used as military inventions and later become popular in the public sphere, such as panorama in the early nineteenth century for political propaganda (Grau 1999, p. 369).

In discussions, immersion is closely related to flow and presence, which are both immersive components of mixed reality, but there are clear differences.

The concept of flow experience was brought up for the first time in 1975 as a psychological construct by Csikszentmihalyi. He described flow as the optimal mental state of intrinsic motivation, being fully immersive in a highly engaging activity, time passing by and even losing the sense of self, during which the other temporary concerns like time, food and ego are totally ignored (Csikszentmihalyi 1997, 29). When firstly adapted into computer use by Rheinberg et al., six components of flow are summarized from the eight component category by Csikszentmihalyi, including clear action goals and feedback, optimal feeling of control, smooth and logic sequences, unintentional concentration, an altered time experience as well as a loss of reflexivity and self-awareness (Rheinberg 2000, p. 153; Rheinberg, Vollmeyer & Engeser 2003). The importance of flow is emphasized by Sherry as well as Voiskounsky et al. in terms of computer games, who both point out that flow is one of the main sources of enjoyment and attraction of computer games (Sherry 2004; Voiskounsky et al. 2004).

Spatial presence is the extent to which one feels present in the created circumstances rather than one’s own physical location and how much one’s self-consciousness immerses into the virtual world when the mediated contents seem real (Steuer 1992; Draper 1999; Slater 2003). When the learner’s perception is mediated by communication technology, he has to accept two reference frames in the present experience: the actual physical presence and the environment presented by the medium (Steuer 1992). In an international research project called “Presence: Measurement, Effects and Conditions (MEC)”, the group of researchers proposed a two-level model of spatial presence, which suggests the formation processes of spatial presence. The first step is the construction of a mental model of spatial information in mind. The second step is the formation of spatial presence, including experiencing the primary egocentric reference frame and perceiving self-location and possible moves in the environment (Wirth et al. 2007; Vorderer et al. 2004).

Both theoretical and empirical studies have been performed to investigate the similarities and differences of flow and presence. The results of the experiments show that flow and presence have similarities (Fontaine 2002) and a positive correlation (Weibel et al. 2008; Hoffman & Novak 1996; Novak, Hoffman & Yung 2000), but the differences are also discussed (Weibel et al. 2008; Fontaine 2002). Weibel and Wissmath (2011) have conducted three gaming studies and found that flow and presence both depend on motivation and on the immersive tendency of users and they both have positive effects on performance and enjoyment, whereas there is rarely a common variance in the factor analysis, namely, they are distinct constructs. The empirical studies of Weibel and Wissmath (2011) conclude that presence can be defined as the sensation of being there in the mixed reality environment, whereas flow indicates the sensation of being involved in gaming action in the mixed reality system.

The technical environment provides students with the opportunity not only to watch 3D simulation and animations, but also of better immersion, which will be described briefly in the next sector.

2.3 Technical environment

The market report “Virtual Reality (VR) in Global Gaming Market 2015-2019” (Technavio 2015) suggests that massive commercial opportunities will be created by the manufacturers of virtual reality hardware, including most of the key vendors. It is also estimated that the mobile-integrated VR headset will be overarching in the market due to its ease of use, portability and independency. The combination of smartphone and VR headset will be another development in the field of VR such as the products Samsung Gear VR and HTC-Vive. From a commercial perspective, in a new statistical report called “Augmented/Virtual Reality Report 2015” (Digi-Capital, 2015), it is forecast that AR/VR could hit $150 billion of revenue by 2020, of which the majority would be the revenue generated by AR/VR hardware, indicating that the market for new technology will grow quickly and change the world.

In the context of e-learning modules, learning applications in a virtual learning environment might include the following parts to realize the learning activities: knowledge space, communication community, active action and facility toolkit (Pan et al. 2006). The web servers used for learning system data transmission and data storage are of great importance in the computer infrastructure. Given that the servers or platforms of a mixed reality system might be set up behind the firewall of colleges or companies, VPN (Virtual Private Network) would be necessary for remote users (Callaghan et al. 2010, p. 277). Another part would be the realization of communication in text, audio or video methods.

Additionally, besides the basic elements of e-learning, a mixed reality learning environment also has its own technical features. The technical part of the media elements of the mixed reality system plays a pivotal role due to the effects on the media users, no matter how helpful or obstructive for the users' feeling of fidelity. In the manufacturing application field, two crucial technical factors for the realization of the virtual learning environment might be: the precision of visualization of knowledge and the precision of interactions among human and objects (Pan et al. 2006). The resolution level of the virtual element, the speed level of the data transmission and the accuracy level of system reaction are valued as the key points of technical parts from the perspective of the users' experience.

To create an immersive environment for students, a set of hardware can be useful, such as a Head Mounted Display (HMD), data gloves, multi-dimensional treadmill as well as various position tracking devices, which are considered to be ideal devices to create an immersive environment, as well as other haptic and acoustic feedback devices which give the learner a more authentic feel than normal software-based applications.

The first requirement of a virtual reality environment in vocational training is the authenticity of the learning environment. 3D virtual model of machines or systems is necessary for training. In order to create an authentic environment, the setting of both hardware and software should include physical coefficients such as gravity and environment damping, rigid body dynamics, kinetics interactions between user and objects, as well as interactions among objects. For example, a virtual model of generators and other equipment are built in the projects of Fraunhofer IFF (Fraunhofer Institute for Factory Operation and Automation IFF). With these virtual models whose parts can be transparent or deleted temporarily, students can clearly get to know how the inside functions and elements connect to each other, how they can better maintain the equipment, as well as the assembly and disassembly of the equipment (Blümel, Jenewein & Schenk 2010).

Given the limitations of the technical situation of a mixed reality system, the negative interaction results are still research issues, such as motion sickness caused by the conflict of virtual local motion and physical local static, or caused by the motion delay resulting from a low refresh rate. Based on the rapid development of mixed reality technical hardware and software, training and manufacturing in mixed reality will likely be realized step by step, with the aim of realization of Ausbildung 4.0.

3 Learning motivation in a mixed reality system

Scholars have raised a number of questions regarding the topic of learning in a mixed reality system. Even though a mixed reality system could support constructivist vocational training in many ways, there is still insufficient research that addresses the issue of "How each of the features of mixed reality system enhance learning outcomes or learning understandings" rather than "Does mixed reality system enhance learning outcomes" (Lee et al. 2010, p. 1433; Salzman et al. 1999, p. 309). From a pedagogical perspective, there are various elements that influence the learning outcomes. In both empirical research and theoretical research of student learning achievements, learning motivation is considered to be one of the fundamental factors, which has continued existence and lasting influence on the learners (Prenzel et al. 1996, p. 109). Thus, it will be discussed following how to enhance the learning motivation of students in a mixed reality system.

3.1 Learning motivation theory

Motivation has always been a core topic in the field of educational psychology, concerning almost all the aspects of activation and intention of human behavior. Although it is sometimes treated as a single construct, it has various factors and sub-constructs due to the experience and emotions of individuals. In terms of learning, a student might finish his homework because it gives him satisfaction to finish it, or to avoid punishment when not finishing it. A student might engage in a physics experiment due to his own interest or to be awarded high scores from the teacher. People can be motivated due to their own internal values, interests, endorsement, volition and choices, or due to external seduced, coerced or pressured impacts on them, which form one of the basic categories of motivation, autonomous motivation and controlled motivation, namely, intrinsic motivation and extrinsic motivation (Ryan & Deci 2000, p. 68).

Based on three kinds of human needs, i.e. competence, relatedness and autonomy, the Self-Determination Theory (Ryan & Deci 2000, p. 68) argues that motivation can be divided into three categories, amotivation, intrinsic motivation and extrinsic motivation. In great detail, the authors propose the spectrum of motivation based on the regulatory styles of behaviors from non-self-determined to self-determined behavior as shown in the following figure.

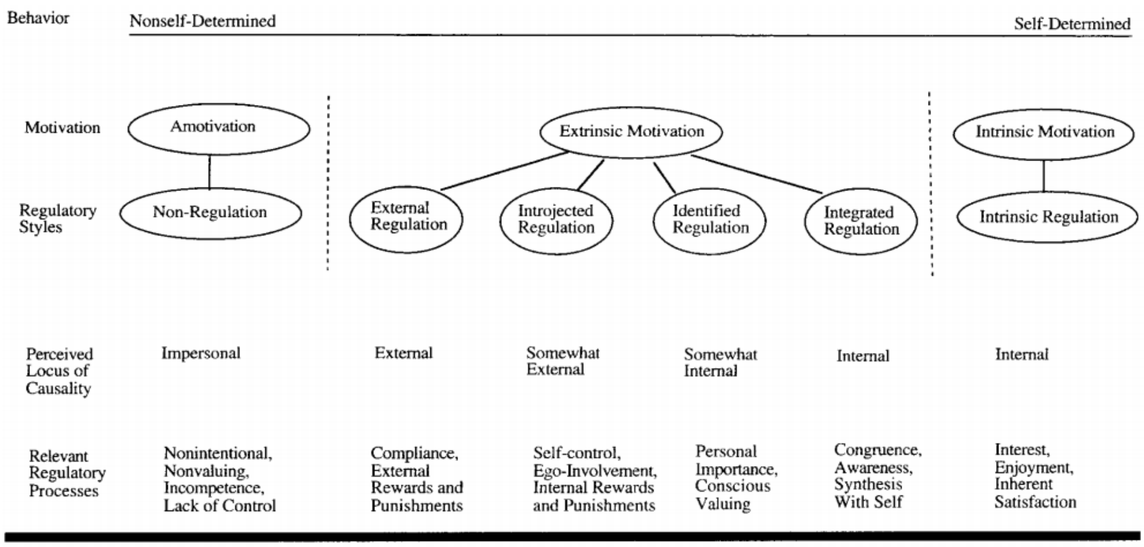

Illustration 2: The Self-Determination Continuum Showing Types of Motivation with Their Regulatory Styles, Loci of Causality and Corresponding Process (Ryan & Deci 2000, 72)

Based on self-determination theory (Ryan & Deci 2000) and pedagogical interest theory (Krapp 1999), Prenzel proposed six variables of learning motivation (Prenzel et al. 1996, p. 109), including amotivated motivation, external motivation, introjected motivation, identified motivation, intrinsic motivation and interested motivation.

Scientific investigations show that when people have intrinsic motivation, they tend to have more creative behaviors, to be better problem-solvers, display better performance, and enjoy more positive emotions, psychological and physical health than the people with extrinsic motivation (Ryan & Deci 2000). Therefore, the facilitating integration of extrinsic motivation is also one of the topics of psychologists.

Krapp, Hidi and Renninger identified three conceptualizations of interest to clear up the definitions and identifications of motivation and interest used in the research area, which are individual interest as a relative stable disposition, situational interest (interestingness) as a reaction of environmental input (Krapp, Hidi & Renninger 1992). They also defined a superordinate definition of interest as a psychological state actualizing individual interest and situational interest. The differentiation between two interest parallels to the classical trait-state differentiation in psychology (Hidi & Renninger 2006, p. 113).

With respect to situational interest (interestingness), this leads to a high level of attention and fosters the readiness of involvement in learning, therefore raising the probability of successful learning (Krapp 1999, p. 23). It is exemplified in the empirical study that shows that situational interest turns out to have positive effects on both immediate and delayed recall in the learning process (Wade & Adams 1990, p. 331). Therefore, the following section of the article will discuss the influence of learning in a mixed reality system on situational interest as well as the improving method of situational interest in the environment. The terminology of situational interest will be used to refer to the learning interest triggered by a mixed reality environment.

3.2 Situational interest of learning in mixed reality system

This section discusses how the learning environment of a mixed reality system can enhance the situational interest of students, namely, the capabilities of a mixed reality system that positively affect the development of situational interest of students.

The utilization of a mixed reality system is based on different characteristics of technology or system architecture, thus the applications of a mixed reality learning environment are not homogeneous, but some common competences of these applications of a mixed reality system exist.

Previous studies have also shown that spatial presence, social presence, authenticity, engagement as well as emotiveness are key influencing factors of the situational interest of students, not only in the context of a traditional classroom (Schraw, Bruning & Svoboda 1995; Schraw, Flowerday & Lehman 2001) but also in the context of a multimedia e-learning environment (Sun & Rueda 2012; Cho, Yim & Paik 2015). Therefore, the effects of the major features of a mixed reality system on these factors of situational interest will be discussed in the context of Ausbildung 4.0.

Web-based learning structure promotes communication

Internet-based manufacturing is the major focus of Ausbildung 4.0. One of the main infrastructures of a mixed reality learning system is the web-based learning environment where the collaboration of students can be realized irrespective of time or location no matter whether synchronously or asynchronously (Wang & Chiu 2011). This can be seen in the case of the Java-based open source project Darkstar by the company Sun[1], in which virtual collaborative offices and conference rooms are built for both working and training. Although the project was shut down after the acquisition of the company, it was beneficial for vocational training in a mixed reality system.

In the application field of Ausbildung 4.0, for example, major construction engineering students can learn to build a house together and major interior design students can discuss the decoration of any house or apartment. Together with institutions and companies from six European countries, the Sustainability Research Center (ARTEC) at the University of Bremen developed a mixed reality learning system called MARVEL for the vocational training of students in mechatronics to support the remote ubiquitous access to the physical workshops and laboratory facilities, combining a local and remote, real and virtual environment (Müller & Ferreira 2003, p. 66). Based on the web- based collaborative mixed reality system, collaborative learning and working is one of the focuses of MARVEL research. Compared to isolated learning and working, group collaboration is closer to real-work situations, with the functions of improving the non-technical soft skills of students such as social communication skill, foreign language ability, intercultural competence and customer orientation (Müller & Ferreira 2003, p. 70). In the project of MiRTLE (mixed reality teaching and learning environment) by the University of Essex, the students dispersed across the mixed reality classroom are able to see the avatars (3D model in mixed reality representing the animations of actual users) of others and talk to others, building connection between physical reality and mixed reality (Callaghan et al. 2010, p. 271; Gardner & O'Driscoll 2011).

Given the cost of remote lab equipment, in a further research project, Müller and Schaf (2009) developed a mixed reality system of a collaborative remote laboratory CORELA as an easy and inexpensive method to support engineering education, with which students can access a real programmable logic controller (PLC) both locally and remotely.

Moreover, diversified ideas can be realized on the 3D models with both the authenticity of real objects and the possibility of reconstruction, which is one of the great advantages of a mixed reality system. With students transferring from passive participants to active contributors, cooperation in a mixed reality system has positive effects on idea expression, material sharing, task collaboration as well as the development of situational interest.

In the context of Ausbildung 4.0, the conversations and cooperation among stakeholders of vocational training, such as a vocational school, apprenticing company and university, are necessary to be highly effective. A mixed reality system can have the ability to make this easier with the web-based integrated system.

[1] Sun Microsystems, Inc. was an American IT company and acquired by Oracle Corporation in 2010, http://www.oracle.com/us/sun/index.html.

Human-object interaction enhances initiative

In the era of Industrie 4.0, the cooperation and interaction of humans and robots can be used to realize an intelligent, smart factory. In the same way as the programmed robots in the smart manufacturing process, programmed objects and interactions with objects in a mixed reality training system not only have the advantages of the realization of objects that are not easily accessible but also have the ability to imitate various applied situations.

In most of the operational learning subjects, laboratory exercise plays a fundamental in building student knowledge, which is one of the practical substitutions of on-the-job training, because it is possible for students to have haptic experience of learning content of subjects rather than only theoretical knowledge building (Morrison et al. 2011). On the other hand, the limitations of expensive and fragile equipment, sophisticated experimental settings, as well as experimental hazards sometimes can be obstructions to learning and training. However, in the context of Ausbildung 4.0, the development and application of mixed reality for a learning and experimenting environment emerge and become necessary, where most of the limitations of local real experiments can be omitted with the help of simulation and interaction of a mixed reality system.

Human-object interaction in a mixed reality system enables students to take control of avatars which are present alongside the real or virtual objects in the learning environment. The interaction is companied with instant feedback from the system, offering the students a clear and vivid sense of the learning content, such as in experiments on mechanical models and structures in the mixed reality system. Psychological training and testing can be done under the conditions of a mixed reality system. After the input of precise programming, the avatar (simulated human in a mixed reality system) can be the instructor, evaluator and observer as an experiment conductor.

During the process of learning, based on the learning process and instant feedback from students, it is possible for the mixed reality system to adjust and modify the content and difficulty of current or later tasks, enhancing the effectiveness of learning and keeping the students interested in learning. This is evident in the mixed reality game engine Unreal Tournament developed by Cavazza, Charles and Mead (2002, p.17) as the development environment of an interactive storytelling application. The intelligent virtual-actors technology enables story generation based on user intervention, supporting the convergence of traditional and interactive media. Consequently, each individual has his or her own learning procedures with compatible competence and learning interest, ensuring a better transfer process than a traditional learning situation with one teacher and numerous students. An appropriate learning procedure is also a key factor to maintain learning interest.

Interactions can not only be performed between human and virtual objects but also be simulated between human and virtual animals. The training of proper treating animals can be realized without threatening the health of either animals or human beings.

For now the avatars in a mixed reality system can have the ability to perform almost all the body, gesture and mimic movements of human beings. Except for the technical challenges of system reaction and delay resolution, these movements are very lively and vivid. In addition, most movements required for teaching and learning procedures can already be performed on a laptop or PC with basic configurations.

Gamification maintains engagement

Gamification is basically the application and interpretation of gaming elements, gaming systems or gaming principles into non-gaming contexts such as learning, training and manufacturing. The import of gamification in the context of Ausbildung 4.0 has both advantages and disadvantages. However, the possibilities of gamification to enhance the satisfactory and maintains engagement must not be ignored.

Serious game is a kind of game developed for application functions other than pure entertainment, which is also a developmental focus of a mixed reality learning system (Callaghan et al. 2010, p. 262). In the 1980s, serious game was first developed for applications of teaching techniques, training and simulation. With the realizations of analysis, visualization and simulation, serious game has included interactive applications not only related to education but also personnel training in industry, policies discussion between governments, emotional training in the military, as well as health care and medical care. Nowadays there is a great trend of application of serious games in education, especially in the field of higher education. Online social communities (e.g. Second Life[2], Opensim[3] and Open Wonderland[4]) have been pervasive in the past ten years where people can interact with other users after logging in. Users can build their own 3D mixed reality environment with the toolkits of the platforms. This has expanded its application area from gaming to learning. Universities across the world have built their own educational institutions in Second Life, including the University of Bielefeld, Saint Leo University and Oxford University Computing Services. The aim of serious game is not to make games serious, but to expand to other research fields, while maintaining the characteristics of games at the same time.

Compared to normal learning applications on computers, serious game has its own feature, gamification, which refers to the process of inputting gaming ideas and gaming strategies into a non-gaming context, in order to improve the user experience and engagement (Deterding et al. 2011). With respect to the educational training domain, it refers to the input of gaming ideas and strategies into the process of training for the long term and high learning motivation.

Serious game helps to make the learning system more appealing and attractive. Both the designed gaming elements and gaming strategies have positive influences on intrinsic motivation as well as the development from situational interest to individual interest. Gaming elements, such as points of ranking, progress bar, medal of achievement and other settings in the "gamified" learning system, give the students the impression that they are playing normal games, which helps to keep their situational interest. In terms of gaming strategies, the epic meaning is the first core drive of gaming design. Epic meaning refers to a situation in which players have the feeling of achieving something great and inspiring from both personal and

[2] http://secondlife.com/
[3] http://opensimulator.org/
[4] http://openwonderland.org/

common perspectives when they complete the task (McGonigal 2011, p. 150). This can be produced by the description of tasks or the procedures of conquering. Even where it is not true, a suspension of disbelief helps users to have flow in the game, remain highly motivated and concentrate. The idea of competition is also an ideal strategy for a learning system to keep students motivated.

Certainly, gaming elements and gaming strategies have been leveraged in the teaching process from kindergarten to higher education. However, mixed reality systems provide a larger view of gaming as well as training opportunities. For now, most mixed reality applications driven by benefits are developed as mixed reality games, whereas learning in a mixed reality system with the trait of gamification will be a great trend of digitalized applications.

The integration of gaming systems is still new in terms of Ausbildung 4.0, but the growing number of projects shows that more and more companies are interested in creative and playful solutions to reduce errors and increase the efficiency of training.

Immersion provides multiple perspectives

According to Dede, studies have shown that immersion in a mixed reality can enhance education in at least three ways, by enabling multiple perspectives, situated learning and transfer, which are typically done by the shifting between an exocentric and egocentric frame of reference with different strengths for learning (Dede 2009, p. 66).

Rather than the issue that the user cannot have the feeling of the observer for the simulation of virtual reality, one other noteworthy issue would be that the participant can have interactive activities in the environment. So-called full immersion is not passive acceptance of a gaming plot or directions, but active participation in interaction with the agents or objects in the immersive environment, which enrich the experience of immersion.

Nowadays, mixed reality applications in education are promoted worldwide, no matter whether they are applied alone or connected to other platforms, especially in the field of engineering expertise. The term immersion is frequently used as a subjective impression that one is participating in a comprehensive, realistic experience, which includes suspension of disbelief, cognitive involvement, spatial presence and other symbolic factors that lead to this digital experience (Dede 2009, p. 68). To create sensory immersion, total sensory interfaces are utilized such as head-mounted displays, stereoscopic sound, vibrations and motions. Additionally, actionable immersion empowers the virtual experience of users and the concentration on this activity is intense. The results of experiments show that Virtual Theatre leads to more flow, which is in line with immersion when users can have natural walking on the omnidirectional floor (Hoffmann et al. 2014).

4 Challenges of development and application

Although mixed reality is not new to the domain of games, the application in the domain of Ausbildung 4.0 just begins. Some challenges in pedagogical aspects will be discussed in the following arguments.

According to the self-efficacy theory of Bandura, self-efficacy, the belief that one can succeed in tasks, is one of the most important factors that influence the motivation of students (Bandura 1977, p. 199). When students have more self-efficacy, they will put more efforts into accomplishing the task, by working harder and persisting longer. According to Bandura, teachers should ensure that students can observe effective models succeeding the task to reinforce the desire of students to accomplish the tasks (Bandura 1977, p. 199). Hence, in the mixed reality system, tutorials for students no matter about the operation of the mixed reality environment or about the task content are still important to enhance their self-efficacy and improve their learning. Especially for students who are not very familiar with mixed reality software or computer games, it is crucial not to destroy self-efficacy and self-confidence in the first steps by learning how to deal with the Head Mounted Display (HMD) or omnidirectional floor.

With respect to the illustrations of learning content, the empirical research of Magner et al. on the decorative illustrations in computer-based learning environments postulates that the decorative illustrations have positive motivational effects on knowledge transfer by fostering situational interest, at least compensating for the distraction effect of decorative illustrations of learning content in the learning environment (Magner, Schwonke, Aleven, Popescu & Renkl 2014, p. 141).

The emotional situation of students has effects on the learning interest, indicating that both verbal and non-verbal communication modes are of importance (Picard et al. 2004). Although the equipment for the acoustic, optical or haptic sensors and feedbacks have been developed and even the facial emotional expressions can be simulated in the mixed reality system (Rahim et al. 2015), further studies are still required on how to design the suitable learning process and interactive learning environment with the combination of multiple auxiliary equipment.

5 General discussion

The development of manufacturing in the context of Industrie 4.0 requires different competences from those of normal employees. To some extent, Ausbildung 4.0 counts the preparation of capable working in the era of Industrie 4.0, especially the part of training in mixed reality system. As discussed, learning in mixed reality still faces challenges from both pedagogical and technical perspectives. Many of the aforementioned vocational training ideas in a mixed reality system still need to be studied, experimented on and further developed to become adequate in the corresponding subject training. However, from a didactical point of view, research so far has clearly shown that a mixed reality system offers possibilities for development and improvement in the context of Ausbildung 4.0, overcoming the restriction of current learning methods and broadening the horizon of vocational training, which creates greater achievement in the near future. Like Deci (2012) said in an open global conference TED-talk: “Don’t ask how you can motivate other people, ask how you can create the conditions within which people can motivate themselves.” Mixed reality systems offer an innovative and creative environment with updated teaching skills and learning materials, reflecting the latest findings in education in the context of Industrie 4.0. Training in a mixed reality system in quite a few studies mentioned above has been shown to possess positive effects on learning process and learning outcome, especially by promoting and keeping the learning motivation of students. Thus, further research will focus on the empirical study of the learning motivation of students in mixed reality learning system in the context of Ausbildung 4.0, especially the situation interest of students aroused by the environment.

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