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**Virtual/Augmented Reality in Education Analysis of the  
Potential Applications in the Teaching/Learning Process**

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**Virtual/Augmented Reality in Education  
Analysis of the Potential Applications in the Teaching/Learning  
Process**

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Austria**

**Abstract**

Mark Zuckerberg, founder and CEO of Facebook and owner of the virtual reality company Oculus, posted the following on Facebook on October 6, 2016: “Here's the crazy virtual reality demo I did live on stage at Oculus Connect today. The idea is that virtual reality puts people first. It's all about who you're with. Once you're in there, you can do anything you want together - - travel to Mars, play games, fight with swords, watch movies or teleport home to see your family. You have an environment where you can experience anything.” Virtual Reality has become hyped in recent years, thanks especially to new hardware and software packages. However, this hype already existed in the 1990s, and it was being speculated that Virtual Reality would soon enter the classroom. Aaron Walsh founded the Immersive Education Initiative (<http://immersiveeducation.org/>) at universities where the possibilities of VR were being investigated (e.g., Virtual Harlem at the University of Arizona). But the technology didn't manage to establish itself in the teaching/learning context. The Internet bandwidths were too low, the technical requirements for schools and university much too high. This has changed in recent years. The development of new, cheaper technologies as well as fast Internet connections have created the prerequisites for the use of virtual and augmented reality in the teaching/learning process. The aim of this article, following a general description and overview, is to consider Virtual and Augmented Reality in the teaching and learning context of schools and universities. Starting from the principles of learning and action theory according to Baumgartner and Kalz 2004, possible potential applications of VR/AR in the teaching/learning context are described and linked to the theoretical teaching/learning paradigm. The article concludes with a short summary.

**Keywords:** Virtual Augmented Reality Education Learning

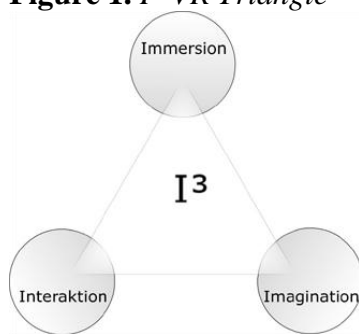
## Basic Principles of Virtual und Augmented Reality

Nothing is as powerful as an idea  
whose time has come.  
Victor Hugo

### *What is Virtual Reality? Characteristics and Definition*

The term “virtual reality” (VR) was first coined by Stanley G. Weinbaum in the science fiction short story "Pygmalion’s Spectacles” (1935). In 1989, Jaron Lanier, whose company VPL produced, amongst other things, data gloves, described VR as “a computer generated, interactive, three-dimensional environment in which a person is immersed” (Aukstakalnis & Blatner 1992). This technically orientated definition highlights three of the most important characteristics of VR, which are closely interlinked: *imagination*, real-time *interactivity* and *immersion* (cf. Burdea & Coiffet 1994, p.4).

**Figure 1.** *I<sup>3</sup>-VR Triangle*



### Imagination

The ability to visualise oneself in a virtual environment depends not only on personal factors, but also to a large extent on the quality of the 3D real-time simulation, the real-time interaction and thus the immersion.

### Interaction

In order to enable effective interaction between user and computer, in addition to the acoustic interface, it is essential to ensure that also user position and orientation, e.g. following body movement (tracking) or head movement (head tracking) are recorded using 3D interactional devices and transferred to the virtual environment in real time. This makes it possible to interact with virtual objects, to generate the image of the user, and, depending on the direction in which the user is looking, to automatically adapt the 3D environment and display the new perspective (cf. Dörner et al. 2013, p.13).

## Immersion

Immersion is the term given to the impression that “the user has left the real world and is now ‘present’ in the virtual environment” (Sadowski & Stanney 2002, p.791). The degree of immersion can be dependent on both the portrayal of the virtual environment and the interaction of user and virtual objects. The aim is to create an illusion of total submersion in the virtual environment, namely total immersion. In order to achieve this, it is necessary to convey a sense of reality in the virtual environment by engaging the senses of the user as realistically as possible, i.e. not only sight, but also the user’s hearing and sense of touch (the senses of smell and taste are still, from a technological point of view, relatively insignificant).

The question of mental immersion experience in VR is amongst the most important in VR research. Immersion in the virtual world can be so complete that the user has the subjective feeling of existing completely in the virtual world (“being there”). Slater (2009) describes this as “presence,” consisting of three partial aspects:

- a) Place Illusion: the feeling of being in the virtual world. The quality of place illusion is constantly being improved by the use of new developments in hard- and software (e.g. Head Mounted Displays-HMDs or data gloves)
- b) Plausibility Illusion is created when simulated events in the virtual environment seem plausible and believable, i.e. when they seem to the user to be really taking place.
- c) Involvement describes the level of interest and attention. Both Plausibility Illusion and Involvement are generated by VR content (cf. Dörner et al. 2013, p.18f).

### *What is Augmented Reality?*

Whereas in a VR environment the real world is replaced by an artificial environment, Augmented Reality (AR) allows the user access to the real world, supplemented by artificial virtual content, both worlds merging into one.

Azuma (1997, p.2) defines AR as systems which have the following three characteristics:

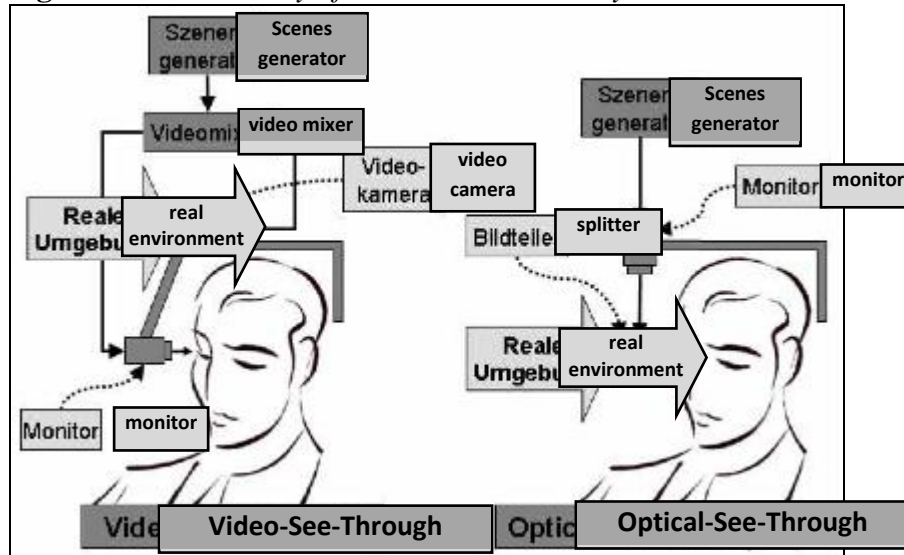
- a) Combines real and virtual
- b) Interactive in real time
- c) Registered in 3-D

One of the most successful AR projects worldwide is the smartphone game “Pokemon Go” from Nintendo. The smartphone camera captures real places, into which virtual Pokemons (small fantasy creatures) are inserted. The combined image appears on the smartphone display and the user’s task is to “capture” the Pokemons.

Pokemon Go is a **Video See-Through-System**. Video-See-Through systems can also be implemented using head-mounted systems.

In contrast, **Optical-See-Through** systems enable the user to perceive the real environment directly. Virtual content is overlaid in perspective using glasses (cf. Dörner et al. 2013, p.248). Figure 2 illustrates how both systems function:

**Figure 2. Functionality of Head-mounted AR Systems**



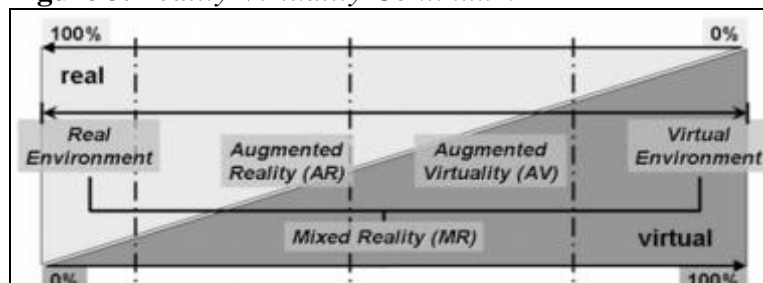
Source: Tegtmeier 2006, p.18

A third form of AR is **Project-Based AR**. Virtual content is projected onto real-world objects (e.g. surface characteristics, additional information displayed on the surface, hidden structures behind the object) (cf. Dörner et al. 2013, p.249f).

*Definition*

In order to be able to describe combinations of virtual and real information (“Mixed Reality”), Milgram and Kishino (1994) created a taxonomy based on a reality – virtuality continuum.

**Figure 3. Reality-Virtuality-Continuum**



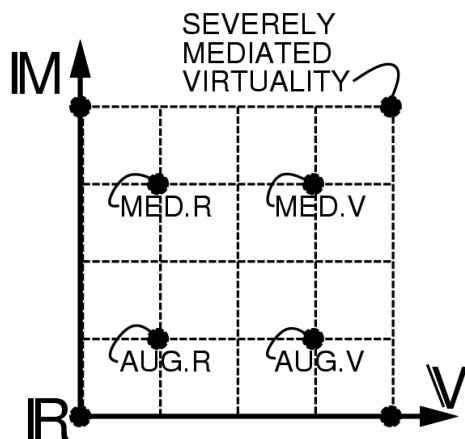
Source: Tegtmeier 2006, p. 13

Figure 3 shows us the continuum between both poles - 100% real and 100% virtual environment. In between we have Mixed Reality, which may be described as Augmented Reality (AR) or Augmented Virtuality (AV), depending on how much computer-generated information is added to the real environment, or how many real objects are added to the virtual environment.

Steve Mann (2002) is critical of this continuum, stating that it fails to take into account that the real environment may be technologically altered by using glasses or contact lenses (Mediated Reality).

He extends Milgram and Kishinos' continuum, creating a two-dimensional taxonomy of Reality (R), Virtuality (V), and Mediality (M).

**Figure 4.** *Taxonomy of Reality, Virtuality and Mediality*



Source: Mann 2002

**Figure 5.** *Illusory Transparency or the Real Image*



Source: Mann 2002.

This taxonomy measures on the Y-axis the modification of reality and virtuality and combinations of both, thus allowing Augmented Reality to be represented alongside Mediated Reality, and Augmented Virtuality alongside Mediated Reality.

#### *Components of VR-/AR-systems*

A VR-/AR- system has to meet the technical requirements of an interface between man and machine. To achieve this, in addition to the computer system, the following output and input devices are essential:

- a) **Computer system:** The computer system, with corresponding VR-/AR- software is an integral component of the VR-/AR- system, which detects, and reacts to, the user by simulating the virtual world, or virtual objects. It thereby creates impulses, through means of the appropriate output devices, allowing the user to perceive the virtual or augmented environment.
- b) **Output devices:** The most important device for immersive perception is the visualisation unit. Options include Head Mounted Displays, which can be used for both 100% virtual, or Mixed Reality images, or stereoscopic projection systems, which operate using passive or active stereo glasses. The scope of these systems ranges from displays on computer screens, to single- and multi-surface projections and cave settings. In addition to visual systems, audio system options include loudspeakers, and with larger VR/AR systems haptic systems (force feedback), motion platforms and wind generators.
- c) **Input devices:** A position-monitoring device (tracking system) is essential for the VR-/AR software to be able to react to the user's movements and thus adapt the environment to the position of the user. Using this system, it is possible to monitor not only the position and orientation of the body, but also the position of the head (head-tracking), fingers (finger-tracking) and the line of vision of the user (eye-tracking). There is a current trend towards optical tracking systems, but mechanical, electro-magnet, and ultra-sound systems are also used. With AR, for example, in an outdoor environment, GPS data may also be used. Other input devices include acceleration sensors, cameras, microphones and pressure sensors. To interact with objects in the virtual environment 3D interaction devices such as data-gloves, flysticks, etc. may be used (cf. Reif et al. 2007, p.6; Dörner et al. 2013, p.21f).

#### *Applications of VR-/AR-systems*

VR-/AR systems are used in a wide variety of fields. VR systems are used in the field of medicine in therapy and rehabilitation of patients: treatment of post-traumatic stress disorders, phobias and addiction, pain control for victims



of burns and amputation, treatment of autistic children, investigation of patient behaviour and feelings. For medical staff, VR- and AR-innovations are being used in initial and in-service training, diagnosis as well as in surgery.

In the **field of industry** VR-AR solutions are used for training procedures, in cases where the required training environment is expensive, inaccessible or dangerous (e.g. pilot training in flight simulators, on oil rigs, in power stations, for military use or in space flight). VR-systems are widely used in the field of planning, particularly in production planning (e.g. virtual assembly in the motor industry), infrastructure and construction planning, building prototypes, ergonomic evaluation, and the assessment of area studies in geology. In the field of marketing, VR systems are often used for 3-dimensional presentations to customers.

VR- and AR- applications are increasingly to be found in everyday, leisure, and entertainment use, for example gym apparatus with VR support. There is also increasing use in the games and edutainment field. AR systems are being tested on car windscreens or ski goggles, holiday destinations, hotels, tourist sights can be viewed from home, virtual exhibitions and museum visits are being made possible and much more besides.

Virtual Reality opens up many opportunities for scientific visualisation in many areas, making it possible to go on space voyages, or journeys through the human body or through atoms. VR- or AR reality offers interesting opportunities in the field of education, the suitability of which for teaching/learning, must, however, be carefully tested (see chapter “Potential Applications of Virtual-/Augmented Reality in a Teaching/Learning Context”).

### *Problems and Criticism*

Experience of trainee pilots in flight simulators has shown that using virtual surroundings can cause “simulator illness” with symptoms ranging from dizziness and sickness to vomiting, tiredness of the eyes or headaches. It is assumed that these symptoms are caused when the sense organs are irritated or subjected to deception (e.g. the user is moving in the virtual world, but the user’s sense of balance sends a message to the brain that no movement is taking place and so there is a delay between interaction and system response) (cf. Mehlitz 2004, p.11). The occurrence of simulator sickness seems to be dependent on individual disposition and technical factors and the type of VR application.

Table 1 describes the individual factors, Table 2 the technical factors that may be linked to an increased occurrence of the illness.

Table 1. *Selected Individual Factors*

Factor	Comment
Age	Greatest susceptibility between 2 and 12 years. Susceptibility decreases successively until the age of 50, then it disappears.
Experience with simulators	Experience with VR lowers susceptibility
Gender	Women more susceptible to simulator sickness
Ability for mental rotating	Enhanced ability to mental rotation decreases incidence

Source: Mehltitz 2004, p.12

Table 2. *Selected Technical Factors*

Factor	Comment
Binocular vision	Stereoscopy increases susceptibility
Field of View (FOV)	Greater FOV increases susceptibility
Use of tracking systems	Geometric distortion and other sources of error may lead to greater susceptibility
Display refresh rate, interaction interval	Every delay in the display, either due to slow refresh rate or long interaction intervals may lead to greater susceptibility
Speed	Higher speed during navigation rather causes simulator illness.

Source: Mehltitz 2004, p.13

These factors must be considered from a methodological/didactic point of view when using VR applications as part of the teaching/learning process.

A significant problem might be the addictive potential of this new technology. No data has as yet been published, but the intensity of immersion makes the supposition highly probable. The use of VR technology in the classroom requires safety procedures, which can guarantee the protection of pupil data. This is a task for the providers of national and international educational servers, to develop workable strategies in co-operation with schools and universities.

Summarising, it can be said that Virtual and/or Augmented reality in all its forms is, thanks to low-cost hard- and software, gaining a foothold in many areas of our lives. Education is no exception to this. Chapter “Potential Applications of Virtual-/Augmented Reality in a Teaching/Learning Context” describes the potential applications of VR and AR in schools and universities and how they may be used effectively, “not as part of a revolutionary change, but as part of the teacher’s pedagogic repertoire” (cf. Klampfer 2005, p.10).

### **Learn- and Action- Theoretical Basics**

If VR and AR are to be used in schools and/or universities, then any discussion of potential applications must be based on pedagogical-didactic considerations. The following paragraphs are intended to give a brief overview of the scientific models of learning and action theory, which form the basis for

this paper (for further information see Klampfer 2005, p.10f; Baumgartner and Payr, 1999; Baumgartner and Kalz, 2004).

### *Teaching I – Knowledge Transfer*

This model is based on the behaviourist approach typical of Watson or Skinner and is characterised by an active, capable, and knowledgeable teacher, whose aim is to bring about a certain behaviour in an “unknowledgeable,” incapable, and passive learner. The teacher uses prepared stimuli (vocabulary exercises, grammar drills, times tables, frontal teaching, practice exercises etc.), reinforced with appropriate feedback, to communicate to the learner relatively abstract orientation knowledge (“know-that”). Baumgartner and Kalz see “Teaching I” as a knowledge transfer model with predominantly presentational teaching methods. The teacher is in a strong position of authority/power, and decides what is to be learned and how. “Teaching I has proved to be a good and efficient starting point, “Particularly at the beginning of a learning process, and in contexts where reactions need to be practised or automatized” (Baumgartner & Kalz 2004, p.7).

Criticism of this approach includes that neither the self-concept motivation and emotions of the individual are given any consideration, nor does the approach explain any new behaviour, creativity or innovation, led in the 1970s to the so-called “cognitive revolution.” Suddenly, the focus was on the internal processes of the human brain.

### *Teaching II – Acquiring Knowledge*

In this approach, the focus is particularly on individual activity, on all phases of the learning process, intermediate steps, difficulties and partial results (know how). “Learner activity is an integral component of the learning process and must be planned, checked, reflected on and corrected by the learner himself” (ibid. p.7). The learner is encouraged to “work and reflect independently upon their own learning success” (meta-level – learning how to learn) (ibid. p.8).

In this approach, the teacher is a tutor, who prepares suitable tasks, observes the learner during the problem-solving process and offers help. The aim is the actual learning process, the construction and acquisition of procedural knowledge structures, rather than the learning of facts.

Observation serves to assist the learning process, in contrast to Learning I, where the aim is to improve input. Teaching II is based on the Cognitivism model of, for example, Mischel or Bandura. Critics of this approach maintain that emotions, as a factor influencing cognitive processes, are ignored, and that the world around us is more complex and cannot be reduced to the mere solving of “objective” problems.




*Teaching III – Generating and Constructing Knowledge*

Teaching III is based on the Constructivist model. The problems around us are “complex, unclear, unique and without an obvious solution” (ibid. p.10). The central question is how the learner can be guided towards “an independent identification with, and solution to problems” (ibid. p.10). This is known as “knowing-in-action.” The teacher’s role is to provide neither problems nor solutions, but rather to support the learner in constructing knowledge and their own subjective interpretation of the world. Communication takes place as a structurally linked and mutually influential system between teacher and learner (perturbation).

*Conclusion*

Table 3 contrasts the most important aspects of the teaching/learning paradigms discussed above:

**Table 3. Contrasting Learning Paradigms**

<b>Transfer</b>	<b>Tutor</b>	<b>Coach</b>
		
Factual knowledge („know-that“)	Procedural knowledge („know-how“)	Social behaviour („knowing-in-action“)
Transfer	Dialogue	Interaction
Knowledge, learning by heart	Practice, problem-solving	Reflective action, inventiveness
Giving correct answers	Selection and using correct methods	Dealing with complex situations
Remembering, recognising	Abilities, skills	Responsibility, real-life situations
Teaching, explaining	Advising, helping, exemplifying	Co-operating, Solving problems together
<b>Teaching I Behaviourism</b>	<b>Teaching II Cognitivism</b>	<b>Teaching III Constructivism</b>

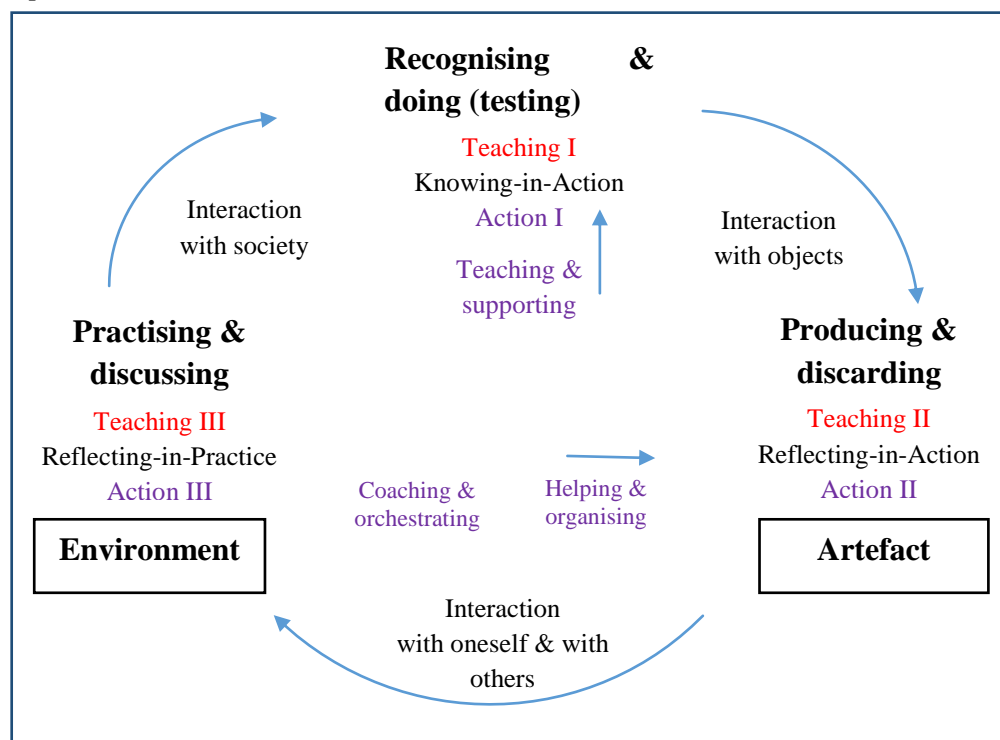
Source: Baumgartner & Kalz 2004, p.14

In practice, the differing needs of the learner, as well as the differing learning contexts and the differing talents and didactic preferences of the teacher, require a combination of methods, which may conform to either Teaching I, II or III. Each of these paradigms has its place in the teaching/learning process, but it must be remembered that they never occur in the “pure” form described. Rather they are best understood as prototype epistemological guidelines. It is not possible to ascribe VR- or AR- teaching scenarios to any

single one of the approaches described above, as a differentiated analysis is required for each individual teaching/learning situation.

Baumgartner and Kalz (2004, p.16) describe learning as a process of development that takes the form of a spiral from Teaching I via Teaching II to Teaching III. In this way, the inexperienced learner gains more experience of the learning process, so that the teacher can progressively reduce the amount of instructions until teacher and learner are co-operating at Teaching III in the problem-solving process. The learning spiral progresses as a result of these action outcomes to a higher level. Figure 6 illustrates the spiral development of the learning process:

**Figure 6.** *The Learning Process as a Spiral Form of Development and Operational Structure*



Source: Baumgartner & Kalz 2004, p. 18

### *Pedagogical and Didactic Classification*

Baumgartner and Kalz (2004, p.18f), extending the theories of Donald Schön (1987), make a connection between the phases of the cognitive process and action structures. There follows a brief description of these connections, which are already incorporated into Figure 6.

### *Action I – Knowing-in-Action and Knowing-on-Action*

At the beginning of a learning process, when a teacher “influences” the learner (see Teaching I), the insight is still largely separate from the action

process (“knowing-on-action”). As soon as actions become automatic, then knowledge, insight, and action are no longer separable. We live in the action (“Knowing in action”). Verbal communication is of particular importance for the transfer of knowledge and contributes greatly to its efficacy.

#### *Action II – Reflection-in-Action and Reflection-on-Action*

Once a particular action has been automatized (e.g. driving a car), the only way to improve the inner qualities of the action is to reflect on it and its effects. Language itself is no longer sufficient. “Reflection-on-action” describes reflection following the action, while “reflection-in-action” denotes during the action. In this case reflection and correction constitute the action itself.

#### *Action III – Reflecting-in-Practice and Reflecting-on-Practice*

Action III emphasises the practical context in which the action must be embedded, that is to say, it must not occur in isolation. The demonstration of an action complements the verbal options in the learning process and thus becomes a highly significant didactic tool. The main focus of the learner is on the societal context of the action (cf. Klampfer 2005, p.15f).

### **Potential Applications of Virtual-/Augmented Reality in a Teaching/Learning Context**

Taking the theoretical background as its basis, this chapter analyses the relevance of Virtual and Augmented Reality for schools and universities and looks at learning scenarios, the way in which VR and AR may be used as part of the teaching/learning process and how they can be integrated into the Teaching and Learning models. Bearing in mind that hardly any schools as yet possess the necessary hard- and software, and that in future years many, as yet unforeseen applications may be discovered, we should analyse the pedagogical potential of VR/AR not only from a theoretical point of view, but also look at the many practical applications. Here the question of content is a central one.

#### *Why Use VR/AR in Schools?*

“A modern school must address the didactic potential of new developments” (Klampfer 2005, p.18). VR and AR offer new methods of perception in various areas of learning, a proximity to content previously almost unattainable. They open up new approaches to gaining new knowledge and competences and make them more tangible. Of course, it must be remembered that technology alone does not mean good teaching. New didactic approaches must also be based on a theoretical background.

Based on an analysis of case studies, Köhler et al. (2013, p.109) set out the following principles with regard to the didactic use and efficacy of VR:

- “The use of VR as a didactic tool is established in well-defined areas, but is not currently widespread.
- The use of VR focuses principally on the initial stages of the simulation, where the main focus is on the interaction between user and machine.
- Current didactic VR scenarios make it possible to practise interpersonal action, the focus is on communication and co-operation.
- VR makes it possible to create complex learning- and work-related environments. These offer possible courses of action with regard to social interaction in communicative and collaborative processes, as well as with regard to the relevant teaching and learning content.
- Playing different roles with its accompanying depersonalisation is of particular importance in VR learning scenarios.
- (...) VR-based scenarios are of use in learning and research, but equally for the transfer of theory to practice.
- In comparison with traditional forms of online learning, such as learning platforms, E-learning courses, fora and wikis, learning in and with VR is still not widespread in academic circles.”

#### *Teleportation - Man in a Real Place (Real Time 3DExperience)*

The human brain possesses amazing capabilities for transfer, enabling us to re-live or feel experiences by reading texts or looking at photos or videos. VR, on the other hand, gives us the opportunity to experience things as though we were actually present, be it as a spectator or an active participant.

VR can extend the boundaries of the traditional classroom. Learners can by means of virtual teleportation be transported from their classrooms to real places which are normally too far away, too dangerous or too inaccessible. The aim here is discovering, experiencing, and exploring new educational content. Numerous static 360° photos of well-known places to explore can be found in the Internet. Similarly, 360° videos are available, in which the user can either observe or actively participate (the user is able to move around). Mike Schroepfer (technical manager at Facebook<sup>1</sup>) expects that by 2025 technology will be advanced enough for users to be able to interact with objects and even see and even “touch” other people in the virtual world<sup>2</sup>.

#### Pedagogical and Didactic Classification

The examination of various VR applications has shown that teleportation, in the sense described above, enables us to visit real-world locations as an observer, but also, to a certain extent, to be an interactive participant (e.g. it is

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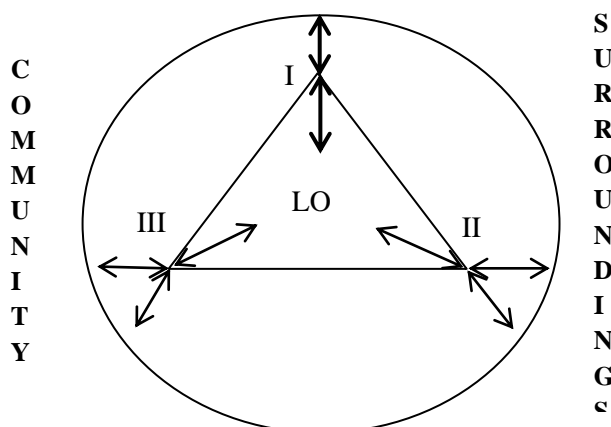
<sup>1</sup> In 2014 Facebook Inc. took over Oculus VR, a company that produces head-mounted displays (Oculus Rift)

<sup>2</sup> cf. <http://www.popsoci.com/youll-soon-be-able-to-hang-out-and-take-selfies-in-virtual-reality> (26.8.2016)

possible to walk around the Eiffel Tower in Paris and explore the surroundings). It is also technically possible for a group of pupils to do a tour together, with the teacher giving information and selecting objects via headsets (e.g. in the Google Expedition Kit).

Analogous to Baumgartner and Kalz (2004), Figure 7 shows how the learning scenarios fit into the teaching models.

**Figure 7.** *Teaching Models and the Use of VR for Teleportation*



In the centre of the triangle is the learning object LO (the content). The virtual environment with all the phases of the learning process is portrayed as a circle. The arrows within the triangle represent the actions of the teacher. At first sight, the focus when using teleportation would seem to be on the presentation media. Whereas this may correspond to “Teaching I,” an exploration with pre-given questions would correspond to “Teaching II”, and with constructivist processes to “Teaching III”. The thick arrows are intended to indicate the supposed focus with “Teaching I.”

### *Examples*

#### Geography

There are already many places to visit, the degree of interactivity depending on the provider. Learners can visit Machu Picchu and listen to detailed explanations (Jaunt VR App). It is possible to go on virtual tours of the Great Wall of China (Google Expeditions), the beaches of Hawaii, the Egyptian pyramids (Alchemy VR), the centre of Barcelona, Verona or London (Marriott Teleporter). The Ascape Virtual Travel app, the VR Cinema Network “Littlestar” and the “YouVisit” app all offer collections of 360° video- and virtual tours. Learners can take part in immersive tours and experience Canada’s Great Bear rainforest (“Wild Within”), go on exotic expeditions, swim with sharks, ski with Bode Miller, search for food (“Discovery”) or go diving in the Great Barrier Reef. Projects on these and similar themes are



currently being done at Cambridge Elementary School<sup>3</sup> (Vermont) or at Hilsman Middle School<sup>4</sup> (Georgia).

### Art Education

VR offers limited opportunities to take part interactively in concerts or plays. Sophisticated recording techniques alter not only the picture but also the sound, depending on the user's perspective. Additionally, the user is able to adopt various positions on stage. There are virtual concerts by, for example, ex-Beatle Paul McCartney, the US musician Beck or the Los Angeles Philharmonic Orchestra (OrchestraVR by LA Phil). In "Inside The Box of Kurios" the user finds himself at the centre of a 360° version of a Cirque-du-Soleil-Show and can experience the artistes performance close up.

Museums and galleries also offer interesting possibilities. In Woofbert VR's art gallery the user can not only walk into the gallery, but also walk into the pictures and discover them interactively. For each picture, a virtual museum guide provides details about both picture and artist. The "Gamar" company tries to make museums interesting for children by using AR technology to give additional information about some of the exhibits.

### Biology

VR offers many opportunities to observe flora and fauna in their natural environment by means of teleportation: E.g. the Great Barrier Reef in Australia (Alchemy VR), gorillas in the Congo, a white shark, rain forests and much more. It is possible to explore places, which in real life would be much too dangerous (volcanos, swamps, the deep sea etc.) and interesting future developments may make it possible, using zoom functions, to penetrate the world of micro-organisms.

Other interesting examples of cross-curricular VR options in schools include, for example, "Project Syria" (Nonny de la Peña) and "Clouds over Sidra" (United Nations), which enable the user to visit refugee camps in Syria and Jordan.

### *VR/AR and Communication/Cooperation (Social & Collaborative Apps)*

Since the 1980s virtual environments/worlds have developed into social meeting places, where millions of people all over the world can communicate simultaneously with each other, interact and exchange experiences from their own lives in digital form.

VR will likely alter this form of communication drastically in the next few years. CEO and founder of Facebook, Mark Zuckerberg, predicts that the most widely used social platforms will implement VR within the next 5 years. The

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<sup>3</sup> <http://www.vecotourism.org/news/teaching-school-students-with-veco-virtual-reality/> (27.8.2016)

<sup>4</sup> <http://onlineathens.com/mobile/2015-12-09/virtual-reality-demo-had-students-breathing-fire-clarke-schools-wednesday#> (27.8.2016)

investor Dylan Flynn points out that social and virtual communication will rise to a higher plane, where it is possible to communicate real emotions. “One day we’ll look back on Instagram, Snapchat, and other photo/video sharing applications and see them as completely insufficient to creating real emotion and connection.”<sup>5</sup>

VR will make it possible to meet other people (e.g. development teams) in a virtual environment, to exchange ideas, cooperate on projects and interact with objects in the real world. These “excursions” could be documented and recorded by means of a virtual, 360° video “selfie.” Such “social virtual” environments can be of importance in blended learning. Blended learning schemes are a combination of traditional compulsory attendance periods and e-learning phases, where the advantages of each system are systematically employed.

In this approach, it is necessary to use these virtual environments as learning environments, which can be used both formally and informally. The unlimited opportunities for communication and interaction in these environments offer excellent opportunities for language students to meet with students from other countries, explore places together, exchange information, do language exercises or tasks specially prepared by the teacher. Children forced to be absent from school for a long period of time due to a stay in hospital, for example, could have the opportunity to take part in lessons.

#### Pedagogical and didactic classification

It is not possible to combine VR/AR with communication/co-operation in a teaching/learning classification system of this type as the use in each case is context-specific.

#### *Examples*

##### Nearpod

With its app “Nearpod VR”<sup>6</sup> the Nearpod Company combines VR- and AR technology with traditional classroom learning. The app is basically presentation software, which integrates 360° photos and videos and involves the student in the presentation by means of questionnaires, question-and-answer modules, quizzes, a drawing module and a feedback module. There are over 100 pre-prepared “virtual field trips” which can be adapted by the teacher to a particular learning scenario.

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<sup>5</sup> <https://medium.com/zapchain-magazine/the-5-most-ridiculously-exciting-use-cases-for-virtual-reality-fef1786b78d6#.tk681jee3> (18.12.2016)

<sup>6</sup> <http://nearpod.com>

### EON Reality

The “EON creator AVR” (EON Reality Co.) enables students and teachers without any prior knowledge to create AR and VR learning content, and to work on it in co-operation with others and finally to make it available for all mobile devices. The user has at their disposal a comprehensive AV-/AR library and an analytical database.

### Audio Response Systems

At the Technical University in Graz, tests have been carried out on a prototype AR-system<sup>7</sup> in combination with Audio Response systems to increase interaction between teachers and learners in traditional face-to-face lectures, whereby questions are put to the students and the feedback is blended in via the AR-system.

### “Social Virtual” – The functionality of Facebook<sup>8</sup>

As mentioned above, a development team at Facebook is working on incorporating VR into the Facebook website. The new function is called “Social Virtual” which means, as the name implies, that all technical possibilities in Facebook must contain social elements. It will thus be possible to interact in 3D in a very realistic way with other real people in virtual worlds.

Other interesting possible VR applications, the suitability of which for the teaching/learning process must be carefully analysed, include home-cinema simulation apps, where the user can watch a film or football match with friends from the perspective of the best seats. Another example is the development of books that appear in large pages in front of the user, scenes from which can be reconstructed in 3D.

### *VR/AR and Simulations*

Since the development of the first computers, simulations have been a major area of application for this technology (e.g. the Fermi-Pasta-Ulam experiment, flight simulators, vehicle simulators). A simulation is “the reconstruction of a dynamic process in a system with the aid of a model capable of experimenting, in order to gain knowledge which is transferable to real-life situations” (VDI guideline 3633)<sup>9</sup>. Using VR/AR technology, it is possible to create didactic learning scenarios, which would have been impossible without the technology and so would not be available in traditional pedagogical settings. It is important that the knowledge and competences gained in the virtual environment can be transferred to new (real) situations. That this is possible is demonstrated by the training of pilots in flight

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<sup>7</sup> Ebner, M., Mühlburger, H., Ebner, M. (2016). Google Glass in Face-to-face Lectures – Prototype and First Experiences. In iJim – Vol. 10, Issue 1. <http://dx.doi.org/10.3991/ijim.v10 i1. 4834>

<sup>8</sup> Cf. [popsci.com/youll-soon-be-able-to-hang-out-and-take-selfies-in-virtual-reality](http://popsci.com/youll-soon-be-able-to-hang-out-and-take-selfies-in-virtual-reality) (11.12.2016)

<sup>9</sup> VDI = Verein Deutscher Ingenieure (Association of German Engineers)

simulators, train drivers in locomotive simulators, training simulations for gas fitters or professional development in the field of emergency medicine.

Using VR/AR learning content, which is complex or difficult, to convey may be made more easily understandable by using didactic reduction, by making interdependent factors visible or by using time-compression or stretching. Simulations may be carried out which would in real-life be too dangerous to health, too expensive or too infrequent, or situations created from the past or the future. Simulations can be carried out independent of time or place and repeated as often as required. Newer VR systems are capable of offering differing training modes to suit the learning needs of the student and increase the level of control the learner has over the learning process (cf. Jenewein & Hundt 2009, p.7f).

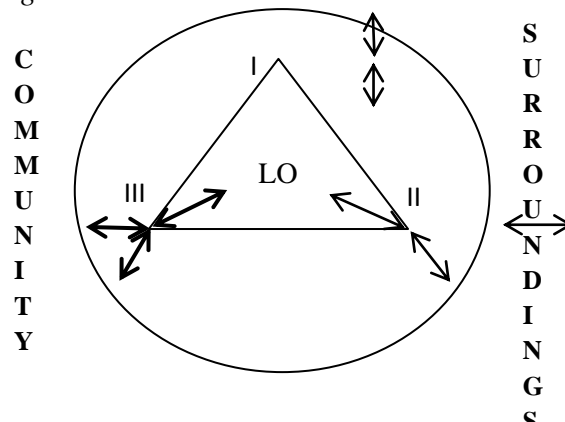
### Pedagogical and Didactic Classification

VR-AR simulations may be used to train differing learner competence levels, which may be selected and (re-)adapted by the teacher:

- a) Exploration of fictional worlds.
- b) Support of initial comprehension processes with complex learning content and processing of information at differing mental levels due to opportunities for interaction.
- c) Training in virtual environments with subsequent transfer of knowledge in real, physical contexts (cf. Schuster et al. 2015, p.4)

VR-AR simulations are designed to enable the construction of knowledge based on authentic situations. The learner is at the centre of the process, while the teacher is a learning guide or coach. Beginners can be given explicit instructions, while advanced learners have the opportunity to formulate hypotheses (in the sense of discovery learning). Technically this can be done alone or in teamwork. VR-/AR simulations can be classified in accordance with “Learning I, II and III”.

**Figure 8.** *Teaching Models and VR-AR-simulations*



## *Examples*

### Physics

- Titans of Space® ([www.titansofspacevr.com](http://www.titansofspacevr.com)) takes the user on a short trip through the solar system. The spatial perception offered by the virtual space environment gives the user new perspectives. The programme has a wide variety of settings and is constantly being developed.
- Apollo 11 VR (<http://immersivereeducation.com/the-apollo-11-experience/>) enables the user to experience the 1969 moon landing from the point of view of the astronaut. It is also possible to take control of the lunar module.

### Biology/Chemistry

- There are many apps available for studying the human anatomy. Virtuali-Tee by Curiscope ([www.curiscope.com](http://www.curiscope.com)) makes use of AR technology to teach about the human skeleton and organs. Using the “World of Comenius” pilot project ([www.worldofcomenius.com](http://www.worldofcomenius.com)) from the Mendelovo Grammar school in Opava (Czech Republic) it is possible to take apart and re-assemble skeletons.
- “The Ark” is a project where the user attempts, using VR technology, to save species threatened with extinction such as the white rhinoceros for posterity.
- MoleculE VR (<https://unimersiv.com/review/molecule-vr/>) is a virtual journey into a cell, in which basic concepts of cell communication are explained.
- EduChemVR (<http://educhem-vr.com/>) gives the user the opportunity to explore atoms and molecules.

### History

- Dassault Systèmes ([www.3ds.com](http://www.3ds.com)) has digitally reconstructed historic buildings and towns, which can be explored using VR headsets. The user can experience Paris through the centuries, explore the pyramids of Gizeh or be present during the D-Day landings in Normandy.
- The Unimersiv ([www.unimersiv.com](http://www.unimersiv.com)) app Colosseum VR enables the user to explore the Colosseum in Rome during its heyday. With the Arnswalde VR app, the user can explore life on the frontline at Arnswalde in Poland during WWII.

### Training Simulations

- VR makes it possible to reproduce highly realistic scenes, in which pupils can practise specific skills, for example in role-plays. There are

VR apps for behavioural training in various situations: safety procedures, communication practice, practising surgical procedures in medical training (e.g. [www.conquermobile.com](http://www.conquermobile.com)) and many more besides.

These are merely a few examples that demonstrate the possibility of reconstructing ancient cities and cultures, or significant historical events and immersing the user in them, in order to not just learn about history, but to actively participate in it.

Future years will no doubt bring new interesting VR apps with unforeseen possibilities for schools and universities.

### *VR in Art*

VR makes completely new forms of creativity possible. With creative 3D apps such as Google's Tilt Brush pupils can use the entire virtual environment for drawing. The Disney artist Glen Keane (responsible for, amongst others, Arielle, Aladdin und Tarzan) describes his experiences thus:

“By putting tools in your hand that can create in virtually reality, I can put goggles on and I just step into the paper and now I'm drawing in it. North, south, east, west: all directions are open now. Just immersing myself in space is more like a dance.

What is this amazing new world I just stepped into? When I draw in virtual reality I draw all the characters real life size. They are that size in my imagination. The character can turn. Ariel is actually turning in space. Even if you take the goggles off, I'm still remembering she's right there. It's real.

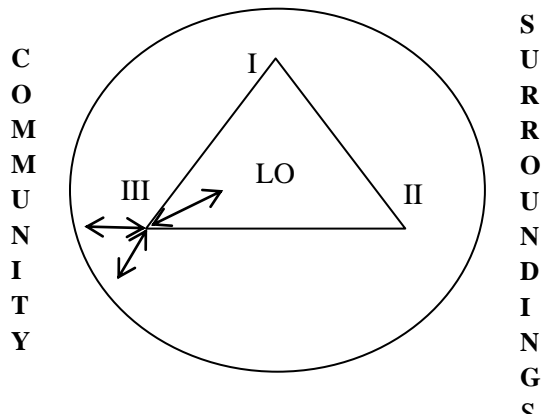
That doorway to the imagination is open a little wider. The edges of the paper are no longer there. This is not a flat drawing. This is sculptural drawing. Making art in three-dimensional space is an entirely new way of thinking for any artist. What does this mean for storytelling?

I love the idea as an animator that you can be anything that you can imagine. As a kid, you're completely free. The soul of any kind of a creative art form is freedom.” (<https://skipwalter.net/2016/04/25/from-pages-to-places-the-transformation-of-presence/>, 2016)

### Pedagogical and Didactic Classification

This creative form of learning in Art presupposes an active, self-directed, reflective learner who organises his own learning process and sets predetermined markers to document progress. This type of learning can be classified as “Learning III”.

**Figure 9.** *Teaching Models and VR in Art*



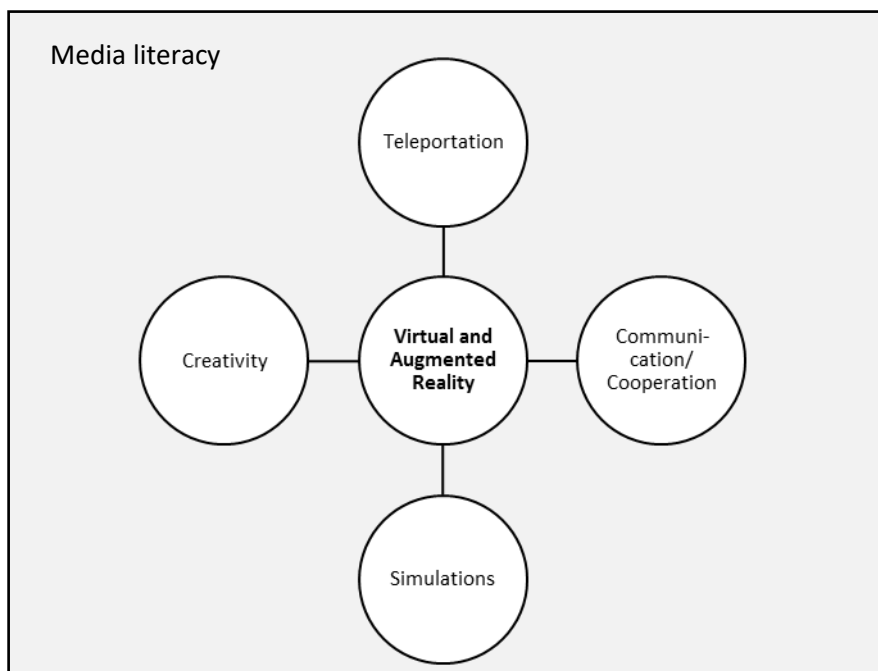
*Example*

- [www.tiltbrush.com](http://www.tiltbrush.com)

**Conclusion**

Building on a general introduction to the fundamental principles of virtual and augmented reality and learning- and action-related backgrounds, this paper has illustrated the diverse potential applications of this technology as a didactic tool in the classroom. Figure 10 gives an overview of the main aspects of this potential.

**Figure 10.** *Potential of VR-AR in the Teaching/Learning Process*



The pedagogic and didactic basis of these potential applications was analysed.

**Figure 11.** *Teaching Models and Areas of Application of VR-/AR*

Teaching I	Teaching II	Teaching III
Teleportation		
Communication/Cooperation		
		Simulation
		Art

The teaching/learning scenarios described have shown that Virtual and Augmented Reality have great potential for use in schools and universities and can be a valuable addition to the teacher’s “didactic toolkit”. VR and AR make it possible to present content in ways previously impossible, whereby the scenarios described have demonstrated that it may be used in the context of Teaching I, II and III. It must be said, however, that this technology can only be used successfully if the basic conditions have been met, namely that the technical and financial means are available, that the age of the pupils has been considered, and that the technology can be used profitably. To achieve this goal, teachers must be prepared to address themselves fully to the task and apply their entire didactic skill.

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