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Learning and Teaching in a Virtual World: Evaluation of the Learning Effectiveness and the Motivation

Reconstruction of Ancient Pompeii for a Virtual Learning Experience and Comparing it to a more Traditional Learning Approach with a User Study

GEO 511 - Master's Thesis

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Abstract

This Master thesis presents a stereoscopic 3D virtual world as an engaging and motivational learning add-on for teaching ancient history. The objective is to create an accurate replica of the ancient Pompeii in a virtual world and provide users with facilities to explore the virtual city and learn about its past and historic facts about the Romans and to evaluate their learning effectiveness. Modern 3D visualizations often focus on the design and graphics and neglect the pedagogical and educational aspects. Consequently, in such virtual reality environments the user is not really asked and engaged to learn and it is difficult to evaluate the learning effectiveness of such virtual worlds. This thesis incorporates these pedagogical and educational aspects and generates and proposes a virtual learning environment of Pompeii usable for information and communication technology lessons (ICT), which are an important issue in the curriculum of Swiss grammar schools.

To validate the impact of using virtual worlds as a learning method, a case study was conducted which confirmed the beneficial educational aspects of a virtual world. In this case study a test group learning in the virtual world of Pompeii (virtual group) was compared with a test group learning by reading a text (text group) that contained identical contents and learning objectives. With regards to the learning effectiveness, which was evaluated using exactly the same exam for both test groups, the results indicated that the virtual group outperformed the text group with a statistical significant difference. Furthermore, the participants from the virtual group stated enjoying the learning in the virtual world and being more engaged than the participants from the text group. Traditional learning approaches like reading a history text are lacking interactivity and engagement, even though these are important features to make learning more effective.

A spatial ability and a sense of orientation test distinguished low spatial and high spatial participants. Results showed no significant effect of the spatial ability on the learning method. For ensuring the comparability of the two test groups the participants were requested to give information about their profession, knowledge about Romans, computer skills, study background and much more. The results and improvement proposals are discussed in this thesis.

Keywords: Virtual reality, virtual environment, virtual world, virtual learning environment, information and communication technology (ICT)

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1 Introduction

Once computers were remote and sacred objects to be seen only in certain computer rooms, but they have become much more smaller and handy over the last years and nowadays almost everyone carries around a smartphone. Computers play a major part of our lives today. Computers are expanding to the mass of workplaces and homes, providing everything from entertainment and education to critical office work in all domains, such as data processing. At most extreme, with immersive virtual environments the computers are beginning to supply us with new places to inhabit and share, determining our very sense data, resulting in new bodies and new powers (Slater & Wilbur, 1997).

This thesis studies the impact of an immersive virtual environment (definition in Section 2.2) for educational tasks through an empirical user experiment. In an experiment a group of participants learning from a text document were compared to a group learning through interacting in a virtual world of the ancient city of Pompeii. Due to the need for an appropriate framework of the thesis and more comparability between the two test groups, more information about the participants were collected. Among other things, they were asked about their historical knowledge, experience with virtual worlds and they completed standardized tests to evaluate their spatial ability and sense of direction.

1.1 Motivation

Nowadays computer and video games play an important role in the leisure time of the children and the youth. Not by children and teenagers, these games are also enjoyed by millions around the world and they have become an integral part of our social and cultural environment (Oblinger, 2004). At the turn of the millennium the increasing development of virtual reality technologies has matured enough to expand research from the military and scientific visualization realm into more multidisciplinary areas, such as education, art and entertainment (Gaitatzes et al., 2001). The growth of the entertainment industry has certainly affected many aspects of our lives including education. Maria Roussou (2001) stated already in 2001 that video and computer games technology show a huge growth drift towards entertainment and education. In 2005 this prediction was confirmed by Oblinger & Oblinger (2005), when video and computer games have emerged as the largest entertainment providing industry and impacted the entertainment industry in general. The game technologies have changed the way the young generations live, play, communicate and learn.

The dedication for lifelong learning is based on voluntariness and self-motivation (Cliath et al., 2000). It is crucial to look for ways to improve teaching and try to keep the methods relevant and interesting to the children and students. The students of today demand engaging learning experience. The current literature suggests video games as one of the best mediums to provide these virtual learning experiences to students (e.g. Bogdanovych et al., 2012; Krotoski, 2005) and these modern educational games are thought to be effective tools for teaching hard and complex procedures (Kebritchi & Hirumi, 2008). This statement is supported by Wiecha et al. (2010) who said that virtual worlds are rapidly becoming part of the educational technology landscape. Regarding learning and teaching methods, one of the great benefits of virtual realities are the interactive and engaging aspects that allow users and students to study a topic in a "real" environment. In this thesis, the use of virtual worlds for learning and teaching is defined as "Concept of Learning in a Virtual World", which is introduced in Section 2.3.5 and is similar to the work of Bogdanovych et al. (2012).

Another motivating aspect is the fact that the discussion about new learning methods such as virtual reality environment and information and communication technology (ICT) is happening right now. Various guidelines and advanced trainings about new media are proposed to teachers to integrate computers in their classes (Zulli et al., 2010). The often-discussed and disputed current *Lehrplan 21* is a common curriculum for the German-speaking and multilingual cantons of Switzerland and it shall be launched in the schools in autumn 2014. Computer education and ICT lessons are important issues in the new curriculum (D-EDK, 2013).

1.2 Study Scope

The main focus of this thesis is the examination of the effect of a virtual world on the learning effectiveness and the comparison to a more traditional approach. Furthermore the method of learning in a virtual reality is analysed and examined in more detail. According to Tüzün et al. (2009) one of the fundamental characteristics of current computer games is the existence of a 3D immersive environment. This characteristic is important for designing the presented learning environment of ancient Pompeii. As reported by Hegarty et al. (2009) people have a strong preference for realism and in their study realism was rated highly desirable and effective. However, Smallman & John (2005) argued that this preference stems from fundamental misconceptions about how perception works and about the fidelity of what perception delivers, including the folk fallacy that scene perception is simple, accurate and rich - when, in fact, perception is remarkably complex, error-prone and sparse. When virtual reality is used for educational purposes, however, these virtual games represent a powerful and effective learning environment (Kebritchi & Hirumi, 2008). Robertson & Howells (2008) even stated that playing computer games gives learners a mental workout that can develop numerous cognitive skills. The authors Virvou et al. (2005) specified that in this respect computer games could be exploited by educational software designers to render educational software more attractive and motivating.

Despite the considerable potential of this technology as an educational tool, there is also a downside. In the opinion of Bogdanovych et al. (2012) in common classrooms, teachers set the agenda and structure of the learning task towards attainment of learning outcomes. However, in virtual worlds students are often left to themselves without a teacher and without a structured learning procedure. Presently in virtual realities, users are often guided through visual cues, message boards and similar pointers, but this aid still requires users to explore environments by themselves. This free exploration with almost unlimited choice and seemingly endless information makes learning with standardized learning objectives difficult (Bronack et al., 2008). In the last few years not a lot of new findings have been discovered concerning the educational scope. On the other hand the tremendous technical development of interactive techniques and of new software and hardware in recent years led to a decrease in cost (Styliani et al., 2009). The author Jung (2005) stressed that today's technologies are essential tools for educational purposes and as believed by Roussou (2001) virtual realities are interactive technologies that fascinate the broad public and have an impact on all aspects of teaching and learning.

Because of the price reduction of the hardware over the past decades, nowadays virtual reality environments can be an addition to traditional learning approaches. However, to use these tools of computers and virtual worlds effectively and efficiently, not just modern hardware is needed. As explained by Jung (2005) teachers need visions of the technologies' potential, opportunities to apply them, training and just-in-time support and time to experiment. The process of integrating virtual worlds in the curriculum is not simple or straightforward. As reported in the media concept of the central department for education in Zulli et al. (2010), because teachers lacking computer skills, the computer is not often used in the classes. Nevertheless, even though the cost of hardware, software and the effort of preparing such a learning environment have enormously decreased, creating such environments and applying pedagogically correct information still remains challenging and it is not often done (Kebritchi & Hirumi, 2008). The question arises, whether this status needs to be changed and processed to make more use of computers in the lessons. Otherwise the computer rooms will stay empty and the costly purchased hardware will be unused for some more years.

The experiment in this Master thesis allows close comparisons to other similar research where virtual worlds have been discussed as a successful learning medium, like the work of Virvou et al. (2005); Bogdanovych et al. (2012); Wrzesien & Alcañiz Raya (2010), just to name a few. However, the presented thesis compares the virtual learning method directly to a more traditional learning method and examines virtual worlds as an additional method to traditional approaches, whereas in most papers virtual worlds are just presented and vaunted, but not directly compared to other learning methods. For instance the research study of Tüzün et al. (2009) examined primary school students' achievement and motivation in geography learning through an educational computer game. The students were tested with the same achievement test before using the game-based learning environment and after they experienced the virtual environment. The authors conclude that the students made significant learning gains by using the game-based learning environment. Based on the suggestion found in literature, in this project a virtual world of ancient Pompeii with stereoscopic 3D is created, and participants are asked to interact with this visualization. After the virtual walk-through in which they are able to explore information attached to virtual object, they are asked to take an exam. This learning method is compared to a second group, which has exactly the same learning objectives and takes the very same exam, but they have to read a text about Romans and Pompeii instead of using the interactive virtual environment.

In the next chapter (Chapter 2) the concept of learning in a virtual world and other definitions are specified, a literature review is conducted and the current use of virtual reality environments is presented as well as an introduction to pedagogical aspects is given. Chapter 3 addresses the research questions, which form the core of the thesis. Then, the implementations with the software and the creation of the virtual learning environment are described in Chapter 4. In Chapter 5, the experimental design, procedure and other methodological aspects are explained and defined. Chapter 6 reports and illustrates the results which are discussed in Chapter 7 in relation to the research questions and compared to the literature. Finally, the conclusion in Chapter 8 summarizes the findings and gives a brief outlook.

2 Background

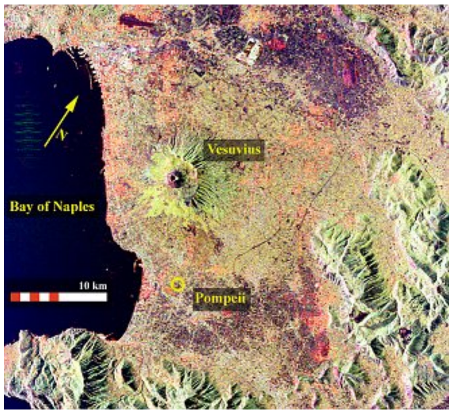
2.1 A Brief History of Romans and Pompeii

This section illustrates a very short historical introduction to ancient Pompeii and the volcanic eruption of Vesuvius in the Roman epoch. For this experiment a virtual world of the ancient city of Pompeii was created, developed on the basis of Maïm et al. (2007), which is, according the authors, based on archaeological data. Some parts of the excavation of old Pompeii with the Vesuvius in the background are pictured in Figure 2.1a. The geologists and geophysicists Giacomelli et al. (2003) wrote that Vesuvius is one of the most studied volcanoes in the world and one reason for it, is the first well-documented historic explosive eruption in 79 AD. Apart from Pompeii, this eruption also destroyed Herculaneum, Oplonti and Stabiae. The eruption of Vesuvius followed a long quiescence period and the inhabitants of the region were surprised by the volcanic event.

The chronology of volcanic events on 24 and 25 August 79 AD at Mount Vesuvius and its surroundings has been thoroughly put together and documented in the studies of Sigurdsson et al. (1982) and Sigurdsson & Carey (2002), who combined information from written accounts and geologic deposits to reconstruct the sequence of events. The eruption of Vesuvius had two distinct phases; first a Plinian phase, where material was ejected in a tall column approximately 20 km high and created a rain of ash and pumice over a broad area primarily to the south of Vesuvius, carried by prevailing winds, where Pompeii lies, as can be seen on the satellite image 2.1b. This phase lasted more or less eighteen hours, when approximately 2.5 meters of pumice stones fell on Pompeii. Roofs began to collapse, but in comparison with the second phase it posed little direct threat to human life. By the morning of 25 August, it is clear that all covered buildings in Pompeii were uninhabitable. The Plinian phase created a nearly deserted city of buildings without roofs or floors, where the bottom story level was submerged in a layer of pumice (Sigurdsson et al., 1982).

This first phase was followed by a Peléan phase which brought a much more damaging eruption, where material flowed down the sides of the volcano as fast-moving and high-temperature avalanches of gas and dust, called pyroclastic flow. Sigurdsson & Carey

(a) *Aerial view of the ancient Pompeii and the Mt. Vesuvius in the background in 2005 (AP-Photo, 2005)*



(b) *Mount Vesuvius and Pompeii, edited by Martini (1996)*

Figure 2.1: Archaeological site of Pompeii and the location of Pompeii on a satellite image

(2002) defines pyroclastic flow as a hot, chaotic avalanche of solids, pumice, ash, and gasses. Pyroclastic flows can move at high speeds along the ground and pass over substantial obstacles. Their distribution is strongly controlled by topography. This phase caused the major damages with extensive life losses in most towns surrounding the Mount Vesuvius. During the second phase, people were killed either by physical trauma due to the kinetic energy of the pyroclastic flow or by suffocation because of the ash-rich atmosphere (Giacomelli et al., 2003). According to Giacomelli et al. (2003) it is likely that there was a mass exodus from the city. Of Pompeii's estimated 20,000 residents, there were approximately 2,000 victims accounted within the excavated region of Pompeii. It thus appears that the vast majority of the population had fled the city during the preceding 18-hour period of air-fall pumice accumulation. Only further excavations will tell whether they fled to safety or if they were overtaken by the pyroclastic flows outside the city walls.

As stated by the authors Sigurdsson et al. (1982), the term Plinian derives from the name of Pliny the Younger, whose written observations of the 79 AD eruption form an important part of the historic record of Pompeii and the eruption of Vesuvius. More detailed information about the Romans, Pompeii and Vesuvius can be found in the text about the Romans in appendix and in the literature presented in Subsection 5.2.4.

2.2 Definitions

2.2.1 Virtual Reality

There are multiple definitions of *virtual reality (VR)* circulating in the literature and these definitions need to be considered before the techniques used can be discussed. A detailed and timeless definition was already given in the 1990s by Rowley (1994), who told, that our perception of the outside world is controlled by our five senses, through which we have built a world model over the years by our own experience. We interact with the real world by interpreting sensory inputs using our own model, which is in detail, different from everyone else's. In practice, most features of these models are similar, so we interact with the real world in similar ways. As long as the sensory inputs can be interpreted into a coherent result, this will be our picture of the current outside world, however fantastic it may appear, and will be our current reality. If the sensory inputs are being deliberately produced by a computer to represent some other environment, we call the current reality virtual reality. Conforming to Goldberg (1998) the actual term *virtual reality* was first used by Jaron Lanier in 1979. In the year of 1992, Steuer claimed that virtual reality makes reference to a particular technological system. This system usually includes a computer capable of real-time animation, controlled by a set of wired gloves and a position tracker, and using a head-mounted stereoscopic display for visual output. Approximately ten years later Roussou (2001) wrote that virtual reality technologies mature, and the research is expanding from the military and scientific visualization realm into more multidisciplinary areas, such as education, art, culture, and the humanities. As stated by the authors Fisher & Unwin (2003) the term *virtual reality* has become a very trendy term, but neither "virtual" nor "reality" is either well defined or strictly appropriate. A more philosophical approach of the French philosopher Lévy (1998) pointed out that *virtual* in this context should be balanced against "actual" and "reality", which means; actual being or existence of anything, in distinction from mere appearance. Brodlie et al. (2003) explained that virtual reality is a form of human-computer interface (HCI). More specifically, in each case the process using virtual realities involves the creation of a construct on the basis of a source reality. In the case of this Master thesis this source of reality is ancient Pompeii and its geographical environment. A schematic representation of virtual realities is given in Figure 2.2.

Slater & Wilbur (1997) summarised and explained that when we look at a computer screen the scenario and events are now not "real" but computer generated. The environment

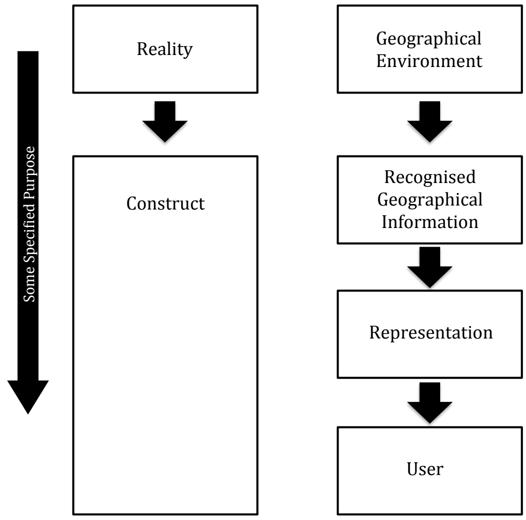


Figure 2.2: Schematic representations of virtual reality, based on Brodlie et al. (2003): left; VR identified as creation of construct from reality. right; Geographical information derived from the environment and the users themselves

that we are looking at is "virtual", it is a representation of something - some underlying process, or computation, rather than what it appears to be.

2.2.1.1 Virtual Environment

Slocum et al. (2010) defined a *virtual environment (VE)* as a 3D computer-based simulation of a real or imagined environment that users are able to navigate through and interact with. According to them VE's are normally experienced visually, although ideally it would be possible to utilize the full range of senses, including sound, touch, smell, taste and body movement. Further Slocum et al. (2010) stated that the term virtual reality seems inappropriate for certain models, therefore researchers have chosen to use the term virtual environment to encompass both tangible and intangible simulations. The Figure 2.3 shows the transition from the real world to virtual environment, whereby it should be noted that in this case the term virtual environment is equivalent to virtual reality. Rogers et al. (2009) argued that the term *virtual environment* is used more specifically to describe what has been generated using computer technology, but they point out that the terms *virtual reality* and *virtual environment* as well as *virtual reality environment (VRE)* are used interchangeably in the literature.

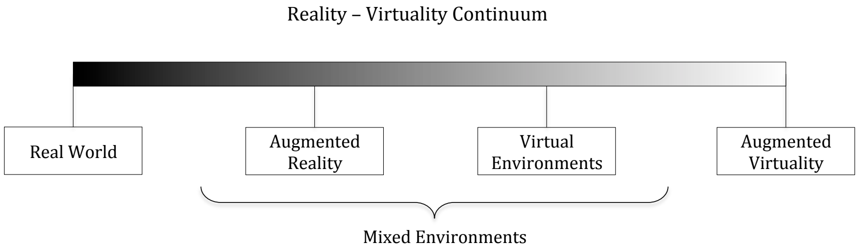


Figure 2.3: The real world to virtual environment continuum, based on Slocum et al. (2010)

2.2.1.2 Virtual Learning Environment

Virtual Learning Environment (VLE) is usually a network-based computer program in which user move and interact in simulated 3D spaces and conforming to Britain & Liber (2004) a VLE often involves a variety of tools for educational purposes. The term is sometimes also used as a synonym for virtual reality (Dickey, 2005).

2.2.1.3 Virtual World

A virtual or immersive world is an interactive environment often although not exclusively in 3D or animated graphics, for example virtual worlds often use animations rather than 3D representations. These immersive worlds can be used by many users at the same time (de Freitas, 2008). According to Allison et al. (2012) the term *virtual world* is often used for virtual realities. Other authors like Wiecha et al. (2010) argued that virtual worlds like Second Life[1], are more focused on socializing, exploring and building.

Serious Games

Serious Games (SG's) are simulations in which people have to learn to think about complex relationships and unintended outcomes in a critical and reflective way, if the players are to become any good at the game (Krotoski, 2005). The combination of curricular content and computer games is defined as serious games (Wrzesien & Alcañiz Raya, 2010). In her study de Freitas (2008) explained that serious games are games used for non-leisure purposes. According to the author virtual worlds, as the one of ancient Pompeii used for this thesis, can also be used for serious applications. With the growth of the serious games area in research and development, *serious virtual worlds* are being considered in many contexts as related media forms.

[1] Check: http://www.secondlife.com/

2.2.1.4 Virtual Archaeology

The term *Virtual Archaeology* means virtual reality used in archaeology, which encompasses the modelling of landscapes, excavations, buildings, cities and environments built with a variety of computer applications in order to test scientific questions, communicate impressions of the past to others and invite outside participation in the construction of the past (Morgan, 2009).

Throughout the presented thesis the terms *virtual reality environment*, *virtual environment*, *virtual learning environment* and *virtual world* are used interchangeably and as synonyms and these terms are often abbreviated as "VRE", "VE", "VLE" and "VW".

2.2.2 The Four I's of Virtual Reality

In 1998, Heim introduced the three "I"s of virtual reality; immersion, interactivity and information intensity. The researchers MacEachren et al. (1999), mostly of them from the GeoVISTA Center of the Department of Geography of the Penn State University in the USA, have added a fourth "I"; the intelligence of display objects.

2.2.2.1 Immersion

Roussou (2001), who holds a PhD in Computer Science and is an interaction and virtual reality designer, described immersion as the illusion of being in the projected world, being surrounded by the image and sound in a way, which makes one believe that one is really there. Slater & Wilbur (1997) gave a more application oriented definition, where immersion is a description of a technology and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant. In this definition *inclusive* indicates the extent to which physical reality is shut out and *extensive* indicates the range of sensory modalities accommodated. *Surrounding* indicates the extent to which this virtual reality is panoramic rather than limited to a narrow field. *Vividness* is concerned with the richness, information content, resolution and quality of the displays. In 2007, Bowman & McMahan clarified that a VR system's level of immersion depends only on the system's rendering software and display technology. It is objective and measurable how close the system's visual output is to real-world visual stimuli. Therefore one system can have a higher level of immersion than another. While immersion provides a realistic experience that enables applications like training and phobia therapy, Bowman & McMahan (2007) believed that immersion can potentially offer many other benefits as well. A higher level of immersion can also lead to greater spatial understanding, which can result in greater effectiveness for many applications such as scientific visualization, education and virtual prototyping.

Immersion and Presence

Immersion and Presence are closely tied together. The papers of Slater & Wilbur (1997) and Slater (2003) defined the terms this way:

- *Immersion* refers to the objective level of sensory fidelity a VR system provides.
- *Presence* refers to a user's subjective psychological response to a VR system. Presence is a state of consciousness, the psychological sense of being in the virtual environment and it is the potential psychological and behavioural response to immersion.

On the contrary to immersion, presence is an individual and context-dependent user response, related to the experience of "being there". Different users can experience different levels of presence with the same VR system (Bowman & McMahan, 2007). An user of a virtual reality can be totally engrossed by the experience and behave in a similar way how she/he would at an equivalent real event.

Telepresence

Telepresence is defined as the experience of presence in an environment by means of a communication medium. In other words, presence refers to the natural perception of an environment and telepresence refers to the mediated perception of an environment. Telepresence is the extent to which one feels present in the mediated environment (Steuer, 1992). Heim (1998) gave a good and simple example; The telephone produces a thin band of telepresence because the bandwidth (amount of information) remains limited to voice. Insofar as we can be with someone on the telephone, we are telepresent in the same artificial space.

2.2.2.2 Interactivity

Interactivity is not merely the ability to navigate in the virtual world, it is much more the power of the user to modify this environment and in a truly interactive system, the virtual world must respond to the user's actions in real time (Ryan, 1994). Roussou (2001) pointed out that interaction refers to the fact that members of the audience are not merely a viewer of the realistic scenery, but can actively participate in the program and determine what their experience is going to be. Heim (1998) argued that participants in a virtual experience are capable to change their viewpoint on the environment and to change their position in relation to other objects in the virtual reality environment.

2.2.2.3 Information Intensity

Information intensity deals with the level of detail (LOD) presented in the virtual environment. A level of detail is required that corresponds to what we expect of real worlds objects at particular distances. Additionally, increasing proximity to an object should allow a user to see increasing detail, as it does in the real world (MacEachren et al., 1999).

2.2.2.4 Intelligence of Objects

Slocum et al. (2010) explained that *intelligence of objects* refers to the notion that objects within a virtual environment should exhibit some degree of behaviour or intelligence, just as we would expect of real-world objects. According to MacEachren et al. (1999) achieving realism in a virtual world will be enhanced if display objects feature behaviours that correspond to those of animate objects in the world.

2.3 Pedagogical and Educational Aspects

According to Kebritchi & Hirumi (2008) the issue in current research on pedagogy is that little has been done to synthesize information on how established learning theories and instructional strategies are being applied to design educational games to guide research and practice. Hence for this study a pedagogical foundation was determined to design the virtual learning environment of ancient Pompeii and the knowledge of teaching and learning was applied to optimize game-based learning.

2.3.1 Learning

In the literature there are a lot of definitions of learning and learning psychology. The focus in the following sections is on definitions which are common practice in the German speaking curricula. *Learning* is a process whereby knowledge is created through the transformation of experience (Kolb, 1984). As believed by Mielke (2001) the origin of the word suggests that learning is a process in which one travels a way and thereby gains knowledge. Learning is acquisition, processing and conversion of information and learning is a lifelong process (Schilling & Zeller, 2012).

In a sentence: Learning means a change of experience and behaviour based on individual experience with the environment during the entire lifetime.

2.3.1.1 Engaged Learning

In their book Jones et al. (1994) defined *engaged learning* by giving indicators, which are briefly summarised in the following:

- Engaged learners are responsible for their own learning, and find excitement and pleasure in learning
- The tasks for engaged learning are challenging, authentic and multidisciplinary
- The assessment of engaged learning is performance-based and generative and it has equitable standards that apply to all students
- The instructional strategies for engaged learning are interactive and generative
- The context for engaged learning is a knowledge-building learning community, collaborative and empathetic and the grouping for engaged learning is heterogeneous, flexible and equitable

- The roles of teachers are facilitators, guides and co-learners; the roles students are explorers, cognitive apprentices and producers of knowledge

As reported by Ang & Wang (2006) and introduced in the next Subsection 2.3.4 the use of information and communication technology (ICT) can help to achieve some of the above indicators and hence has the potential to engage learners. As claimed by Chou (2003) ICT supports various types of interactions such as learner - content, learner - learner and learner - teacher. These types of interactions make the learning process more interactive and the learners more active and engaged.

2.3.1.2 Motivation for Learning

According to Lepper et al. (2005) students and children who report a desire for easy work and want to please the teacher (*extrinsic motivational factors*) perform worse in regular exams than students who report a desire for challenging, independent mastery and curiosity (*intrinsic motivational factors*). Prensky (2003) confirmed this result and stated that being interested and engaged in the curricular content results in fruitful learning and better achievement. As claimed by Jennett et al. (2008) successful computer games all have one important characteristic in common; the capacity to draw people in. This effect is hard to obtain by a teacher or a text during the traditional teaching process. As observed by Prensky (2003) students' attitudes toward classroom instruction were very different from their attitudes while playing games. Classes taught at school often have recourse to extrinsic motivational factors such as rewards, praise and punishment, while computer or video games seem to resort to intrinsic motivational factors (Wrzesien & Alcañiz Raya, 2010). Bellotti et al. (2009) summarised that the most successful feature for a video game, as well for a serious game, is the player's enjoyment.

2.3.1.3 Remembering

People process information in different ways and the pedagogue and professor Siegmund (2002) explained that there are three types of learners. The majority of them can be allocated to the so-called *visual type*, who processes the content primarily as images. *Linguistic types* store information preferably in the form of words, sentences or in any other linguistically coded way. People who memorize content primarily in the form of action sequences belong to the *action-oriented type*. These three type of learners occur rarely pure. In fact, people process information mostly with several of these possible ways. Furthermore, there is a considerable correlation between the type and number of sense organs addressed in the information transmission and the learning performance. As illustrated in Figure 2.4, when a topic is only absorbed with the sense of hearing, the quotient of remembering is just around 20% and when a person learns something by doing the remember quotient climbs up to 75%.

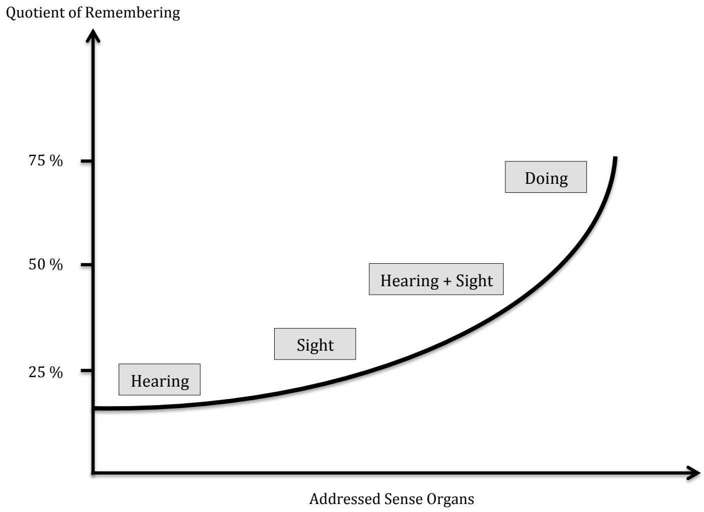


Figure 2.4: Connection between addressed sense organs and quotient of remembering, according to Siegmund (2002)

Another crucial aspect for a learner during the learning process is to construct knowledge from the foundation that she/he already has in order to reach a more complex level of understanding (Wrzesien & Alcañiz Raya, 2010).

2.3.2 Learning Theories

Learning theories can be divided into two main groups:

- Behaviourism
- Cognitivism

All processes which take place in an organism were ignored by the behaviourist, because they were not scientifically observable. For the strict behaviourist, human beings are passive beings, whose behaviour is exclusively controlled by the environment (Mietzel, 2009). Therefore *behaviourism* assumes a learner is essentially passive, responding to environmental stimuli.

Edelmann (2000) stated that while behaviourist learning theories focus on describing the external conditions of learning, the *cognitivist learning theories* bring the internal representation of the environment into focus. The human mind is valuable and necessary for understanding how people learn. Knowledge can be seen as schema or symbolic mental constructions and learning as change in a learner's schemata (Wessels, 1984). The term *cognition* refers to all processes of acquisition, organisation, memorizing and the application of knowledge (Mayer, 2000).

2.3.2.1 Constructivism

The cognitive approach is closely related to *constructivism*. The essence of constructivism is, that individuals do not respond to the objective world, but they form a subjective reality which is based on individual constructions and interpretations of the world (Gerstenmaier & Mandl, 1999). Kelly (1986), a founder of the constructivism called organised knowledge "constructs". From this the term *constructivism* was derived. According to Glaserfeld (1989) there are two main principles whose application has far-reaching consequences for the study of cognitive development and learning as well as for the practice of teaching, psychotherapy, and interpersonal management in general.

- Knowledge is not passively received but actively built up by the cognizing subject
- The function of cognition is adaptive and serves the organization of the experiential world

The author Mair (2005) gave a clear overview for better differentiation of cognitivism and constructivism in her work about models of learning theories.

- Cognitivist learning theories (perceive, think, realize): Information-centered learning, where the learning content is processed independently and is not conditioned in right or wrong.
- Constructivist learning theories (build, construct): Active, self-directed learning in problem-oriented context. The knowledge is not transported as in the cognitive approach, the learner constructs his own knowledge.

A more moderate (knowledge-based) constructivist view of learning, tries to connect principles of instruction and construction. This interprets learning as a personal construction of meanings, which can only be achieved if a sufficient knowledge base is available. This view is also well applied on geography (Haubrich et al., 2006). Mortara et al. (2013)

claimed that virtual environments are particularly suited to implement the "learning by doing" approach, which is related to the constructivism theory. The authors showed with playing history[2] a good example of a game which supports students in learning but also helps teachers in structuring their lessons. This statement is supported by Dickey (2005) who argued that the use of virtual environments supports a constructivist perspective by affording real-time communication and resources to support collaboration.

2.3.3 Experiential Learning

The crucial pedagogical theory used for this study is the experiential learning theory of Kolb (1984), who pointed out that the purpose of experiential learning theory is based on engaging learners in direct experience. As stated in the paper of Kolb & Kolb (2005) on page 194, experiential learning theory is built on six propositions given below:

- "Learning is best conceived as a process, not in terms of outcomes. To improve learning the primary focus should be on engaging students in a process that best enhances their learning"
- "All learning is relearning. Learning is a process that draws out beliefs and ideas about a topic so that they can be examined and integrated with new, more refined ideas. Learning is the process of creating knowledge. Social knowledge is created and recreated in the personal knowledge of the learner"
- "Learning requires the resolution of conflicts between dialectically opposed modes of adaptation of the world. Conflict, differences and disagreement are what drive the learning process"
- "Learning is a holistic process of adaptation to the world. Not just the result of cognition, learning involves the integrated functioning of the total person; thinking, feeling, perceiving and behaving"
- "Learning results from synergetic transactions between the person and the environment. Learning occurs through equilibration of the dialectic processes of assimilating new experiences into existing concepts and accommodating existing concepts to new experience"

According to Kolb (1984) experiential learning consists of the cycle constructed by the elements as shown in Figure 2.5. Winn (1993) stated that virtual reality environments

[2] http://www.playinghistory.eu/

can help to bridge the gap between experiential learning and information representation. For instance, the participants learn about Roman and about the environment of Pompeii by walking actively in the virtual city and collecting information (*active experimentation* and *concrete experience*), they reflect their observations and link it to their previous knowledge and create a concept about the topic (*abstract conceptualization*).

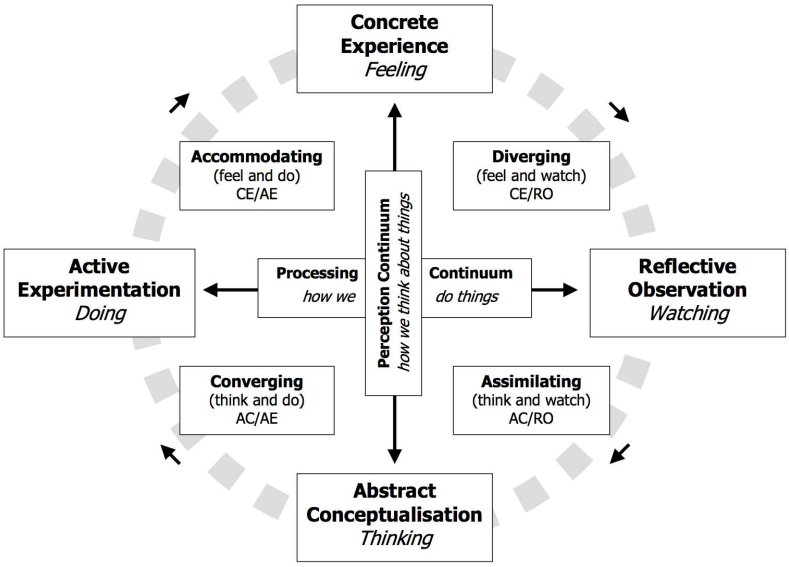


Figure 2.5: Kolb's Learning Styles (Kolb, 1984)

The experiential learning theory involves some passive instruction but it soon progresses to an experiential form of learning (Kebritchi & Hirumi, 2008).

2.3.4 Information and Communication Technology

Teaching is becoming one of the most challenging professions in our society where knowledge is expanding rapidly and modern technologies are demanding teachers to learn how to use these technologies in their teaching (Jung, 2005). *Information and communication technology (ICT)* can provide more flexible and effective ways for professional development for teachers and according to Soliman & Guetl (2011) the benefits of new ICT's for teaching are scalability, convenience and cost-effectiveness.

One of the commission of the Swiss grammar schools (*Gymnasium*) is to prepare the students for the demanding tasks in everyday life. Therefore the grammar schools are in charge of providing basic knowledge in the field of ICT and contributing to a solid basic education (Zulli et al., 2010). According to Petko (2009) notwithstanding there are enough computers at the school, they are used rather rarely in the classes. Zulli et al. (2010) recommended to every school to develop internally an ICT-concept and teach media competence to the students.

2.3.4.1 Teaching to Digital Natives

A person of the net generation has never known life without the internet, and on the report of Oblinger (2005) they are so called *digital natives*. Teenagers want new information and to learn more and to learn better from the internet. The use of the internet for learning is not limited to schoolwork. Students are often informal learners, seeking information on a variety of topics. Learning is participatory and knowing depends on practice and participation. Digital resources enable experiential learning which is defined in Subsection 2.3.3 and *net geners* would rather construct their own learning, assembling information, tools and frameworks from a variety of sources (Oblinger, 2005). Frand (2000) told that students nowadays take technology for granted and staying connected is a central part of their lives. Doing is more important than knowing, and learning is accomplished through trial and error as opposed to a logical and rule-based approach. These new generation of technology-savvy students possess unprecedented levels of skill with information technology. They think about and use technology very differently from earlier student cohort (Kvavik, 2005). The author McNeely (2005) stated that today typical students want more interactivity from learning, whether it is a computer, a professor or a classmate. Traditional lectures are not fulfilling the learning potential of typical students today. The technology and media used by the children during their formative years have an influence on how they learn (Dede, 2005). According to Barone (2005) technology and pedagogy are converging in the learning landscape, therefore virtual learning environments can support learning in an adequate and modern way. Virtual reality environments in general have become a significant phenomenon in many areas of research, but education is one of the most prominent disciplines where virtual worlds found many applications (Bogdanovych et al., 2012).

The emergence of new technology challenges our assumptions about the nature and circumstances of learning. In turn, advances in the learning sciences reveal new possibilities for the application of technology in support of educational goals centered on the engaged learner (Ramaley & Zia, 2005).

2.3.5 Concept of Learning in a Virtual World

Roussou (2000) reported in her paper the concept of the interactive learning environment developed for learners of all ages for institutions of informal education such as museums. Fällman et al. (1999) stated that virtual reality environments have been proposed as a technological breakthrough that holds the power to facilitate learning. The authors Fällman et al. (1999) explained how virtual worlds can help students as a learning method and the diversity in the education for which virtual learning environments can be used is also interesting. For example over 300 colleges and universities worldwide have so called "builds" in Second Life where they teach courses and conduct research (Wiecha et al., 2010). The concept of learning through experiences with virtual worlds is defined in terms of the literature about virtual reality environments used for education presented in the following Section 2.4. According to Kebritchi & Hirumi (2008) this concept is related to the experiential learning approach in which knowledge is constructed, not transmitted, as a result of experiencing and interacting with the environment. Throughout this thesis the terms *concept of learning* and *learning method* are used as synonyms and refer both to the presented concept in this chapter. As reported in the book of Rogers et al. (2009) this learning concept consists of a virtual world packed with information and opportunities for experiencing this world and enabling users to interact with objects and navigate in 3D space. Damarin (1996) brought into focus that virtual worlds help students to construct new knowledge rapidly by letting them experience a subject from several viewpoints and through self-directed exploration.

Generally it can be said that educational games are effective tools for teaching and learning because they use action instead of explanation, create personal motivation and satisfaction, accommodate multiple learning styles and skills, reinforce mastery skills, and provide interactive and decision making context (Holland et al., 2003; Charles & McAlister, 2004).

2.4 Related Research

Over the past years virtual reality environments have been developed to support learning and training for numerous skills. Researchers have designed virtual environments to help people learn to drive a vehicle, fly a plane as in the Microsoft Flight Simulator[3] and perform delicate surgical operations (Rogers et al., 2009). Virvou et al. (2005) described a virtual reality educational game that motivated students and improved their knowledge of geography, especially for those who used to have poor performance in geography.

2.4.1 Web Based Virtual Learning Environments

2.4.1.1 Second Life

On the report of de Freitas (2008), serious games are games that integrate gaming elements with learning or training objectives. The social interaction enabled by online games can contribute to improving engagement, participation and to maintaining a learner's interest (Corbit, 2002). For example, Bellotti et al. (2009) created SeaGame, a massive multiplayer online game (MMOG). SeaGame is a credible 3D model of a learning situation and is developed on top of a commercial game engine enhanced with several learning tools. SeaGame stresses the importance of game believability to create a "sense of place". In order to improve the "sense of place" the authors enhanced the game engine with conversational virtual humans (CVH). The aim is to provide content, to introduce backstories, assign tasks, give feedback on user performance and generally, offer information to the learner. The SeaGame player is involved in exploring the world, similarly to Grand Theft Auto (GTA), where the player wanders in a city and carries out several actions. In SeaGame, education and learning are embedded and hidden in several mechanisms, modules and situations that are pervasive in the game. Such features make SeaGame an educational game. The authors investigated whether and how the learning mechanisms embedded in an educational game have a (negative) impact on the overall entertainment. The authors concluded that the SeaGame was generally perceived as similar to state-of-the-art video games, which suggests that its educational mechanisms are integrated quite well in a meaningful and entertaining way. The few differences are not only due to SeaGame's learning mechanism, but also to the very high quality of the commercial video games to which SeaGame was compared. According to Bellotti et al. (2009) it is generally possible to support learning and entertaining experience, which

[3]Microsoft Flight Simulator: http://www.microsoft.com/games/fsinsider

is key to attracting a wide demographic that is currently not involved in educational activities during leisure time.

The authors Allison et al. (2012) concluded that virtual worlds have great potential for educational use. In particular they have noted how OpenSim has come a long way from Second Life in terms of its capability for supporting educational activities. In their work they created an OpenSim-based 3D reconstruction of Linlithgow Palace[4], combining cultural heritage, educational activities and virtual worlds. The development of the reconstruction was a collaboration between historians, computer scientists, educationalists and graphics designers. This immersive educational activity provided a focal point which energized pupils in investigating and exploring events, life and personalities that would have filled the Palace some 500 years ago.

The researchers Boulos et al. (2007) stated that virtual worlds such as Second Life are proving to be ideal for those studying at a distance from their parent institution, and entry into virtual reality environment seems to be a great leveller, proving a very popular and equitable method of interaction. Serious virtual worlds (SVW) can engage and motivate students and increase their performance and retention of knowledge (de Freitas, 2008). Morgado et al. (2010) envisioned and analysed the opportunity of using new e-learning approaches with virtual worlds in support of active and pragmatist learners, as a way to better provide real world training and education to professionals.

Second Life for Medical Education

Another interesting research field is the use of virtual worlds for medical education, where it is potentially dangerous to start learning with the real thing. In their study Wiecha et al. (2010) designed a medical education program in the virtual world of Second Life. The purpose of their project was to explore the potential of using a virtual world platform for medical education. The authors used a Second Life constructed by the Boston University School of Medicine, in which the participants could meet and sit down and listen to the seminar speaker, who was in real life a professor. The students could not carry out a simulated virtual surgery but among other things the professor could hold for instance a PowerPoint presentation about insulin therapy in the virtual world. For the evaluation an online survey that included clinical skill confidence questions were completed before and following the session in order to assess students reactions to the experience and evaluate learning transfer. The participants reported a statistically significant increase in confidence in their ability to select, initiate and adjust insulin for patients. All participants

[4]Linlithgow Palace in Scotland: https://www.historic-scotland.gov.uk/propertyoverview?PropID=PL199

agreed that this Second Life experience was superior to other online methods and most also felt that the Second Life method was as good as, if not better than, face-to-face methods. The results of this study suggest that virtual worlds offer the potential of a new medical education and offer an opportunity to provide a space for constructivist learning at its best and to enhance learning outcomes beyond that provided by more traditionally designed online courses (Wiecha et al., 2010). A further step would be to create a surgery simulation where medical students could utilize and develop their practical skills. Boulos et al. (2007) also concluded that virtual worlds offer great potential to creative medical and health educators and librarians.

Learning by Using Active Worlds

The authors Ang & Wang (2006) stated that active world[5] (AW) is one of the oldest virtual world available which provides social connectivity. It was first launched in 1994 and has changed several times since then. In their study, active worlds allowed its users to create their own private space inside the world, use communication facilities, create permanent content and personalized avatars. Through this process, a safer learning and teaching place was developed.

2.4.2 Educational Games - Teaching and Learning in Virtual Worlds

Osberg (1995) studied the effects of virtual reality environments as a learning tool during five years. She conducted research in the areas of learning, motivation, science and technology attitudes and found out how students' thinking was enhanced through the use of virtual worlds. In her opinion, virtual environments are a very special communication tool, that have the power to present information in three dimensions and in a manner that allows the participant to be an active part of the environment rather than a passive observer (Osberg, 1995). Her book "A Teacher's Guide to Developing Virtual Environments" focuses on helping teachers and students evaluate what is meaningful for virtual environments (Osberg, 1997).

Bogdanovych et al. (2012) showed how 3D virtual worlds can be utilised for teaching ancient history. They built an accurate replica of Uruk, one of humanity's first cities, in a virtual reality environment and provided history students with facilities to explore the virtual city and learn about its past in the simulated 3D environment. In order to test the learning effectiveness of using virtual worlds, the authors compared two different

[5] Active Worlds: https://www.activeworlds.com

ways of learning history with two different sample groups in a case study. One group (traditional group) was advised to read a history text describing the facts about the city of Uruk and its inhabitants and the second group (virtual group) visited the virtual Uruk to have an interactive learning experience. Both groups were aiming for the same learning objectives and contents. The quality of learning was evaluated through conducting a written exam with students in each study group. The study evaluation showed a clear difference in performance gained between the two groups. The evaluation outlined better performance achieved by the virtual group over the traditional group. Further the study of Bogdanovych et al. (2012) also revealed that the students of the virtual group were more engaged and willing to spend more time learning.

A similar study was conducted at the Polytechnic University of Valencia by Wrzesien & Alcañiz Raya (2010), who presented and evaluated a serious virtual world (SVW) for teaching children natural science and ecology, which they called E-junior application. It was designed according to pedagogical theories and curricular objectives to help children learn about the Mediterranean Sea and its environmental issues while playing. A class in a serious virtual world (virtual group) was compared with a traditional type of class (traditional group) that contained identical learning objectives and contents but lacked a gaming aspect. In contrast to the work of Bogdanovych et al. (2012) this evaluation showed no statistically significant differences in the learning performance between the traditional group and the virtual group. However, students from the virtual group reported enjoying the class more, being more engaged and having greater intentions to participate again in this type of class than students from the traditional group.

The aim of the study of Papastergiou (2009) was to assess the learning effectiveness and motivational appeal of a computer game for learning computer memory concepts, which was designed according to the curricular objectives and the subject matter of the Greek high school Computer Science curriculum. This group was compared to the group using a similar application, encompassing identical learning objectives and content but lacking the gaming aspect. The analyses showed that the gaming approach was both more effective in promoting students' knowledge of computer memory concepts and more motivational than the non-gaming approach. The results suggested that within high school Computer Science, educational computer games can be used as effective and motivational learning environments, regardless of students' gender.

The study of Ang & Wang (2006) compared primary school students learning science subjects in virtual world versus reading the same information from text. The outcome of this study was encouraging and indicated how for some students virtual and interactive environments can be more motivating and improve attendance and students' performance. The students became very active in the learning process as the learning task was authentic and rather challenging for them. Another study with primary study was conducted by Tüzün et al. (2009) who examined primary school students' achievement and motivation in geography learning through an educational computer game. The authors found a significant learning gain of the participants using the game-based learning environment and the pupils had fun exploring and learning in the virtual world. The interdisciplinary research team of Gabrielli et al. (2000) investigated whether children can learn to find their way around a real place before actually visiting it, by first navigating a virtual representation of it. Their results indicated that children were able to develop and display different levels of allocentric knowledge about the virtual environment depending on the way they had familiarized with it and on the characteristics of the task demands.

2.4.3 Virtual Reality Environments for Training and Exercise

Mattila et al. (2012) introduced a 3D learning environment, a Virtual-Mustiala, which is a extendable learning environment for training and learning. For that the authors chose a harvester as the main object for the learning module. The participants had to do several maintenance tasks, such as engine oil level check or tires air pressure check. The researchers noted that this kind of virtual environment provides a possibility to have initial training prior to actual use of the harvester in real conditions and repeat training without the need for the presence of instructor. When practice to use new and domain specific issues (e.g. use of harvester) it is useful and cost-effective to use of ordinary computer instead of expensive simulator device and real harvester. In addition, in virtual environments one can practice or do some virtual damage by accident that one can not do in real environment without consequences. Mattila et al. (2012) emphasised that learning has a role of social activity, and social interactions are important in virtual learning situations.

Stinson & Bowman (2014) investigated the feasibility and usefulness of using virtual reality environments for sport psychology training. The authors developed a virtual soccer goalkeeping application, in which users defend against simulated penalty kicks using their own body. Their results demonstrate that a VR sport-oriented system can induce anxiety in the participants and that this experience is close to reality. Solina et al. (2008) presented a virtual skiing game where users could stand on a pair of skis and perform the same movements as on real skis. Unfortunately, the authors did not conduct an user study, but they recommended further research and presented ideas like a virtual model of an existing slope which could be used as promotional means for that ski resort.

2.4.3.1 Virtual Reality Environments for Therapy and Mental Training

Virtual reality environments have also been designed to confront people with their phobias. An underlying assumption is that virtual worlds can be designed as a "safe" place to help people gently overcome their fears (e.g. spiders, talking in public) by confronting them through different levels of closeness and unpleasantness (Rogers et al., 2009). The authors Slater et al. (1999) explored in their work the effectiveness of virtual environments in psychotherapy for social phobias. They focused on public speaking anxiety and constructed a virtual seminar room where the participants had to give their talk to a virtual audience immersed with a head-mounted display. The authors stated, that real people do respond appropriately to negative or positive audiences, which are entirely virtual and they concluded that their participants rated themselves as being less anxious after speaking to a virtual audience.

Ruddle et al. (1997) demonstrated with their experiments, that users who navigate large-scale virtual buildings ultimately develop route-finding abilities and some survey-type spatial knowledge (direction judgements and relative straight-line distance judgements), which are as accurate as those abilities and spatial knowledge developed by people who were in real buildings. Hegarty et al. (2006) stated that the spatial layout from real world experience and virtual environments are similar, even though the field of view is greater in real-world navigation. Therefore it can be said that interacting and learning in a virtual learning environment demands a certain level of spatial ability and sense of direction.

2.4.4 Virtual Reality Environments for Cultural Heritage

The reconstruction of ancient landscape is a challenging research activity that implies the management of a high level of uncertainty and requires the cooperation of several different disciplines (Cerato & Pescarin, 2013). According to Cerato & Pescarin (2013), virtual reconstructions of archaeological sites, artefacts and buildings play an important role supporting scientific discussions among experts and bringing the past to broad audiences through virtual museums. Morgan (2009) argued for a more active role of archaeologists in virtual reconstruction and addresses issues of representational accuracy, personal expression in avatars and peopling the virtual past to relive the past as accurately as possible. Immersive technologies such as virtual environments and augmented reality have a clear potential to support the experiencing of cultural heritage by the large public, complementing the current tools and practices based on tangible goods such as museums, exhibitions, books and visual content (Mortara et al., 2013). Mortara et al. (2013) discussed the current situation of virtual worlds in the cultural heritage field, presenting examples of games, primarily structured according to their learning objectives. They highlighted the educational objectives of virtual worlds in the domain of cultural heritage.

Through the model of St Andrews Cathedral reconstruction illustrated in Figure 2.6a, the paper of Kennedy et al. (2012) presented an example of virtual reality environments as a technology for supporting the creation and use of virtual reconstructions as a platform that promotes understanding of and engagement with cultural heritage. According to Kennedy et al. (2012) virtual worlds offer the potential to reconstruct within a 3D computer environment the physical structures of the past and important aspects of the light, music and life that once filled those structures. Bringing together architecture, sculpture, illumination, stained-glass, music, procession and lighting into a scene which can be explored from multiple spatial perspectives enables a holistic experience and appreciation. Kennedy et al. (2012) concluded that their usage of open virtual worlds as a platform for supporting the exploration of cultural heritage, has been extensive and the experience has been overwhelmingly positive and demonstrates that with the right investment, history can truly be brought alive and made accessible to new generations.

(a) The East end of St Andrews Cathedral designed by Kennedy et al. (2012)

(b) Trading interactions between diverse virtual ethnic groups in the work of Lim et al. (2013)

Figure 2.6: Two examples of virtual realities used for cultural heritage

A more technical approach of reconstructing ancient landscape and cities is given by Dylla et al. (2009), who were working on the Rome Reborn project. Rome Reborn is an international initiative, based in the Virtual World Heritage Laboratory at the University of Virgina[6] and its goal is to illustrate the urban development of ancient Rome from the first settlements in the late Bronze Age to the depopulation of the city in the early Middle Ages. The first result of the project presented in the paper is a virtual reconstruction of the entire city of ancient Rome at the height of its urban development in 320 AD. The model of Rome Reborn consists of two kinds of digital reconstructions; Class I elements (whose position, identification and design are known with great accuracy) and Class II elements (whose building type and location are know only in a general way). The paper describes how the researchers utilized procedural and parametric modelling techniques to create visually compelling and detailed models of the Class II elements of the digital model of ancient Rome. The authors concluded that procedural modelling methods make the process very efficient without sacrificing detail or quality and provide a robust framework for virtual city reconstruction for scholarly models.

According to Styliani et al. (2009) museums are interested in the digitizing of their collections not only for the sake of preserving the cultural heritage, but to also make the information content accessible to the wider public in a manner that is attractive. Virtual museums enrich the museum experience by allowing an intuitive interaction with the virtual artifacts. Carrozzino & Bergamasco (2010) dealt with immersive virtual reality environments in real museums, which are nowadays considered as a privileged means for communication and play a central role in making culture accessible to the mass audience. They highlighted the use of new technologies such as virtual worlds to reach this. For that Carrozzino & Bergamasco (2010) analysed a series of live examples of virtual worlds installations. They concluded that immersive virtual environments have all the potential to become a very effective means to communicate cultural content. This is also confirmed by the work of Sequeira & Morgado (2013) who stated that virtual environments are worth considering as being part of any current and future attempts to preserve the memory of heritages sites. Gutierrez et al. (2007) presented in their paper a case study based on artificial intelligence crowd simulation which is being used by scholars to study the ergonomics of the Roman Colosseum. They focused on using crowds in cultural heritage sites, where the consequences of the actions of the virtual agents are uncertain. According to the authors it is precisely this uncertainty which allows scholars to test different hypotheses and draw conclusions based on the result of the simulation. A technological progress of this aspect is shown in the paper of Lim et al. (2013) which presented a method to simulate life in a local port in the 1800s, where

[6]Check: http://vwhl.clas.virginia.edu

various populations with very different social rules interacted with each other, as depicted in Figure 2.6. Already before the turn of the millennium Roussou (1999) noticed that of particular interest to museums in the use of virtual worlds and computer generated interactive experiences, is the fact that they can allow visitors to travel through space and time without stepping out of the museum building.

2.5 Research Gap

The related literature in Subsection 2.4 points out little doubt about the potential of virtual reality environments to achieve educational objectives, but in agreement with Wrzesien & Alcañiz Raya (2010) an empirical evidence using a rigorous methodological approach is still missing. The study of Kebritchi & Hirumi (2008) examined the pedagogical foundations of 55 modern educational games. As reported by the authors the pedagogical foundation of only 22 serious virtual games were based on learning theories, two reported not having any learning theory or instructional strategy base. For the rest of the games (31) no information concerning their pedagogical foundation was found. Even if the literature calls for the use of learning and instructional theories in educational game design, less than half of all designers follow these recommendations. This means that the lack of pedagogical standards and didactical methods is a weakness of most educational games. Another aspect is that on the current conferences (e.g. Malta, 2014; IEEE, 2014) the educational aspects of virtual reality environments are missed out and not a main issue. The collaboration between industry and academic research of virtual worlds play a much more important role, than virtual worlds for educational purposes.

Another issue, which is rarely discussed in the literature, is the importance of the spatial ability. According to Vinson (1999) navigation in a virtual environment such as virtual Pompeii is difficult and the spatial ability and the sense of direction of the user play important roles. Therefore it can be said that interacting and learning in a virtual learning environment demands a certain level of spatial ability. One aspect of human cognition that was studied using virtual reality technology is spatial ability. Dünser et al. (2006) claimed that few research investigated whether and/or how spatial ability can be improved by using virtual reality environments. However, there is little specific information in the literature whether a higher spatial ability leads to a better performance when learning in a virtual world. Further issues regarding the spatial ability and sense of direction are discussed in Section 7.1.

3 Aim of the Study

As previously shown in the related research in Section 2.4 virtual reality environments have been reported to play an important role for educational purposes. Although virtual worlds show promise towards making learning more successful, the number of studies is quite limited, especially studies which are based on pedagogical foundations. In this project we try to bridge the pedagogical aspects and learning theories with the use of virtual worlds for learning. For developing a virtual learning environment it is vital to ground the design on established learning theories.

3.1 Objectives and Research Questions

The proposed concept of using virtual worlds as a means of enhancing learning is investigated in the presented research, which aims at complementing the line of previous research by observing the learning effectiveness of two learning methods, learning through virtual learning environment and learning by reading a text. The objective of this thesis is focused on the pedagogical and educational values of virtual worlds.

In the presented user study the two learning methods are directly compared by using exactly the same exam for both test groups. A group of participants learning by reading a text was compared to a group learning through interacting in a virtual environment. For comparing the virtual group and the text group, the performance in the exam can be analysed and evaluated. The influence of the spatial ability and the sense of direction on the performance is examined with a Mental Rotation Test (MRT) and the Santa Barbara Sense of Direction Scale (SBSOD). In accordance with Hegarty et al. (2002) the SBSOD proved to be internally consistent and is predictive of environmental spatial abilities.

At the same time, another aim is to find out whether one of the presented learning methods is more motivating and engaging than the other and whether this result can be embedded in the literature proposing higher motivation is reached by using virtual worlds as in the projects of Wrzesien & Alcañiz Raya (2010) and Bogdanovych et al. (2012).

To tackle the issues listed above, following leading question is considered and for answering this, the research questions below were developed:

Leading Question: What is the value of virtual worlds for teaching and learning?

Research Questions:

1. Performance related questions

   1.1. How does the virtual learning method differ from the more traditional method of reading a text in terms of performance in a given exam?

   1.2. Exam tasks

      i. Does the type of question have an influence on the performance?

      ii. Does the question have an influence on the performance when it is visual or textual?

   1.3. Do high spatial participants of the virtual group perform better in the exam than low spatial participants of the virtual group?

   1.4. Does the sense of direction have an influence on the exam performance of the participants in the virtual group?

2. Preference related questions

   2.1. Do the participants of the virtual group have a higher satisfaction with the experiment and a higher engagement and motivation for learning than the participant of the text group?

   2.2. Do the participants of the virtual group recommend this learning method to others and for a future method?

In order to study these questions, an experiment with human subjects was conducted comparing two test groups. The results from the experiment will reveal whether the virtual or the text group performed better in the exam. Further, the students' evaluations and feedbacks will show which group had more excitement and appeal in learning history. The exam tasks and the participants' demographic attributes are described in Chapter 5. The importance of the spatial ability and the sense of direction are addressed in the Subsubsections 5.3.2.1 and 5.3.2.2

The following two chapters present the implementation and the method of the conducted experiment. The composition and definition of the concept of virtual realities as a learning method was already introduced in the Subsection 2.3.5.

4 Implementation

This chapter presents the materialisation of the experiment of this research work. To test the feasibility of the presented concept of learning in virtual worlds in Subsection 2.3.5, a virtual learning environment was created and a case study was conducted. The framework was aimed at re-creating the ancient city of Pompeii in the period of the Roman Empire before the volcanic eruption of Mount Vesuvius in 79 AD as a virtual world giving short facts and figures about the Romans in general and Pompeii in particular and letting the users experience it. Firstly, the data, software and lab is introduced. In the second section of this chapter the data processing and editing is explained and how the stereo effect was generated. Last but not least a brief introduction into the statistic software is given. In comparable studies (e.g. Boulos et al. (2007); Camara et al. (2009), to name but few) full modelling of the project was done in the Second Life platform. Second Life is a free, public virtual world created by Linden Labs[1], that features persistent content and which runs over any operative system. However, the presented study uses the virtual world of Pompeii which was built in Esri's CityEngine[2] and then further developed in Unity3D[3]. The next chapter (Chapter 5) focuses on the method.

4.1 Technical Setup and Implementation

As reported by Noellenburg (2007) an early focus on users and tasks, and empirical testing iteratively during the whole design process is a common principles in the literature on user-centred design approaches. On the basis of this idea, a virtual world was created and furnished with information regarding pedagogical aspects.

4.1.1 3D Software

4.1.1.1 City Engine

Cardoso & Oliveira (2013) explained that CityEngine is a procedural modelling tool, especially suited to deal with urban environments. One of its most important features is

[1]Linden Lab: http://www.lindenlab.com
[2]Esri CityEngine: http://www.esri.com/software/cityengine
[3]Unity - Game Engine: http://www.unity3d.com/unity

the CGA grammar core, which gives a language and syntax through which the designer can define her/his 3D buildings. Instead of manually creating geometry, CityEngine lets one describe, through procedures in a rule file, how simple shapes are transformed into complex geometries. When talking about large urban areas, describing geometry using rules allows to be more efficient by reusing the same rules into several base shapes, and effortlessly creating entire cities using parametric rules that adapt themselves to different basic geometries. CityEngine allows designers to efficiently create 3D urban landscapes using existing GIS data, as well as to do conceptual geodesign in 3D. Scenarios can be brought back into ArcGIS for further analysis or exported to high-end simulation engines or web clients (Esri, 2014).

4.1.1.2 Unity3D

Unity3D is a game development ecosystem. It is a powerful rendering engine fully integrated with a complete set of intuitive tools and rapid workflows to create interactive 3D content. Further the software involves easy multiplatform publishing and thousands of qualities and ready-made assets in the Asset Store and a knowledge-sharing Community (Unity Technologies, 2014). In the Unity3D game engine a virtual world can be explored by a first or third-person character. As stated by Cardoso & Oliveira (2013) Unity also allows creating games and 3D applications with a high-level of abstraction. This makes it easier and faster for developers to present their final products in a shorter period of time, and taking out of the equation many concerns such as object colliding, lighting, interaction, and so on. Currently (July 2014), the software supports three programming languages: C#, Javascript and Boo. The application does not need to be programmed in only one language. Therefore the game designer can mix them up.

4.1.2 Lab and Devices

The experiment for the virtual group was conducted in the *Geowall*, a room which is a 3D Visualization Lab belonging to the Geographic Information Analysis and Visualization (GIVA) unit. It is located at the University of Zurich's Irchel campus, in the Geography department. In this lab, there is a stereoscopic projection system based on polarization. The technical setup of the lab as seen in the picture 4.1a consists of a stereo projector set, a back projection screen and a workstation. The virtual reality is created using a wall-sized display, the GeoWall as shown on the image 4.1.

The 3D projection system used is the DepthQ Passive Bundle with a HDs3D1 Projector with 3D, 3500 ANSI lumens, 2700 lumens stereo mode, 2100:1 contrast ratio and a maximal resolution of 1280 x 720 WXGA. It has a vertical scan of 120 Hz and a horizontal scan of 77100 kHz.

The furnishing of the lab such as the screen, chair and table position as well as the room illumination were held identically throughout the entire investigation.

The lights were turned off so the stereoscopic virtual world was visible much better and clearer. For the other parts of one experiment round the room was lighten up to generate proper study conditions. This precaution makes sure that all participants meet the same conditions and have the same influence of external factors.

(a) The Geowall at the Irchel campus, picture of GIVA (2014) *(b) The wall-sized display*

Figure 4.1: Lab used for the experiment of the virtual group

4.1.2.1 Devices

Each participant used anaglyph glasses to perceive a stereoscopic 3D effect. The desired stereo effect occurs when two different images are projected to each eye. As reported by Dubois (2001) such anaglyph image allows the perception of depth when observed through colored glasses such as the familiar red/blue glasses as seen in picture 4.2a. This method is not as effective as an active stereo system, but it is well suited for large test groups, since each pair of glasses is quite cheap and therefore a damage is not so bad. As visible on the photograph 4.2b a conventional keyboard and mouse were used to navigate in the virtual city and interact with the wall-sized display.

(a) Anaglyph glasses *(b) Controlling*

Figure 4.2: Devices used for the experiment in the lab

4.2 Creation and Implementation of Virtual Pompeii

The design and creation of learning experiences in a virtual reality environment are a challenging undertaking, due to the particularities of context, such as the selection of colors or information presentation.

4.2.1 Data Procedure

4.2.1.1 Data Set of Pompeii

The data set is a reconstruction of ancient Pompeii and does not only include major monuments but also domestic buildings. Their appearance follows the aesthetic and statutory architectural rules of the corresponding epoch (Esri, 2013). Besides building footprints, additional GIS data such as population density, land usage and street networks were used. This reconstruction was completed by the research team of Maïm et al. (2007) at the Swiss Federal Institute of Technology in Lausanne and Zurich (EPFL and ETHZ). They revived the past of Pompeii by creating a 3D model with an extended version of CityEngine. The Pompeii grammar rules, based on Mueller et al. (2005), were enhanced with levels-of-detail capability which can be controlled with a single variable *LOD*, as showed in Figure 4.3. The shape grammar rules for the actual buildings were manually derived from photos and plans of remaining buildings, archaeological excavation data and historical paintings.

Figure 4.3: The Pompeii grammar rules with increasing complexity from left to right; LOD = 0 (quads only), LOD = 1 (doors and window elements), LOD = 2 (thick walls) and LOD = 3 (individual roof tiles), according to Maïm et al. (2007)

Data Processing in CityEngine

The provided data set[4] is made for the desktop application of CityEngine. Therefore the data needed first to be adjusted and prepared in City Engine to export it successfully into Unity3D. With a python script the scene consisting of terrain, roads and buildings was exported from CityEngine to the FBX format and saved on the computer. This format is suitable to be imported in Unity3D. For this step it is important that the offsets for the exported models (roads and buildings) are set up correctly or otherwise visual artifacts may occur, due to numeric imprecisions when the model is imported into Unity3D. For getting the exact offset the computer mouse is moved over the viewport of CityEngine and the current position of the model is located by coordinates in meters.

The python script does not export the terrain in 3D format from the CityEngine. It exports the terrain in CSV, PNG image and RAW image and provides a Unity script that reads the CSV and uses Unity "primitives" to generate a terrain. As claimed by Cardoso & Oliveira (2013) the created terrain asset in Unity has much more possibilities and performance, than just using a 3D mesh, which can cause some problems in Unity, due to the high number of vertices. Thanks to this preparation the model of Pompeii can be easily imported in Unity3D. In Unity further steps are done to make the world more realistic and immersive.

4.2.2 Preparation in Unity3D

The previously exported scene from CityEngine can now be dragged into Unity3D. This opens a main folder in Unity3D containing the subfolders buildings, roads and terrain. An Unity account was registered to have access to the Unity asset store, where thousands of ready-made assets are available and can be easily dropped into the own Unity project.

[4] Virtual Model of ancient Pompeii: http://www.arcgis.com/home/item.html?id=1f922a455be5441a9cf74042f94200d6

Mostly of the assets are with costs, but there are also some of good quality free of charge. As claimed by Vinson (1999) landmarks in general simplify the navigation and because of their navigational function, it is important to include landmarks in virtual environments. This was done by implementing trees, rocks, landscape, bushes and so on.

4.2.2.1 Settings of the Virtual World

Colliders

Colliders are meshes that prevent a first-person character from passing through objects. In Unity automatic colliders were generated for streets and special collider boxes for the buildings. This way, the first-person character was not able to penetrate any of the buildings and trees, nor go through the roads and pavements, as well as through the terrain.

Control

As stated in the design guidelines of Vinson (1999) a virtual environment will always be unfamiliar when the user first encounters it. Therefore the presented virtual world is intuitively understandable and the navigation self-explanatory. Disorientation in a virtual reality environment is upsetting and the motivation of test persons for the examination will probably decrease and the result of the user study could be falsified. The aspect of self-directed exploration is included in the concept of learning for the presented study. The participants will have a first-person perspective where they move through the virtual world of ancient Pompeii without seeing a representation of themselves.

From the standard asset folder in Unity3D the first person controller was dragged directly into the scene window and the coordinates for the starting position were entered. The controlling had to be adjusted. It was set up for using computer mouse and keyboard. With the arrows the avatar can be conducted forward, sideways and backwards. With the mouse the user can turn the "body" of the first person view to left or right and also make more than 360 degrees turns. For navigating in the city it is actually enough to press the forward key and rotate the "body" to the correct walk direction with the mouse. The maximum forward speed is limited to approximately walking pace, and the person can walk sideways and backwards, but slower, as in reality, too. The first person can also jump on pavements and in the terrain, so it will not get blocked by small steps and obstacles.

Terrain

The terrain was adjusted and the Mount Vesuvius had to be fine-tuned, that the model looks more vivid and exciting. After importing the model of Pompeii into Unity3D it did not match exactly with the terrain. Around the city the terrain needed to be modified to the height of the ground of the city. Otherwise the first person character would fall down on the terrain, when the user left the city ground. This procedure ensures that the transitions between the city and the terrain are fluid. The Figure 4.4 shows a adjusted border between city and terrain.

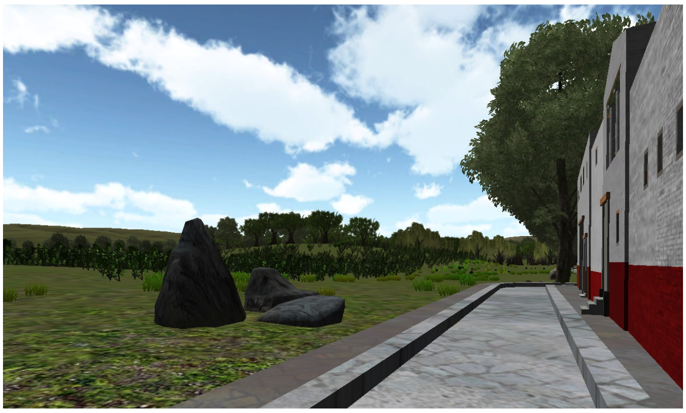


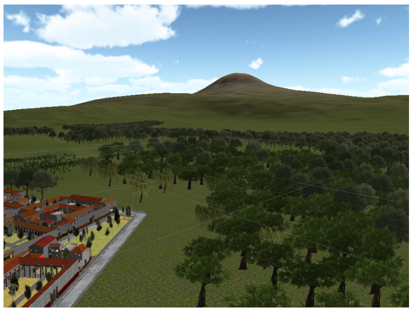
Figure 4.4: Border between city and terrain of the virtual Pompeii model

Further the texture height of the terrain had to be customized for different levels of altitude. Five different levels were set up, each with a different type of vegetation and color. These levels alter from meadows and fields around Pompeii to a forest on the horizon and to the rocky landscape of the Mount Vesuvius. The higher the altitude of the terrain, the less green and more alpine the landscape looks. The various texture were chosen from the asset store and customized with the Pompeii model as can be detected in the Figures 4.5.

In a further step the landscape needed to be grassed and planted with vineyards, meadows, bushes, rocks and various trees. These were free available from the asset store and were saved and edited in the terrain asset folder of Unity3D.

Finally, a realistic looking blue sky with white clouds was imported from the asset store and adjusted to fit the 3D model as can be seen in Figure 4.5b.

(a) Streets of ancient Pompeii with the Vesuvius in the background



(b) Textures and vegetation for different levels of altitude and blue sky

Figure 4.5: Textures for different altitudes levels

4.2.2.2 Creation of the Learning Environment

The idea was that each participant should spent 15 minutes in the virtual world and get an impression of ancient Pompeii and learn about its history. As a learning aid a so called *learning path* through the city was defined.

(a) Yellow arrow as a direction sign

(b) Pointer on an info box

Figure 4.6: Arrows and info box of the learning path

There were 15 yellow direction arrows (signs) created to guide the participant (Figure 4.6a). They were created using rectangular quads (GameObject -> Create Other -> Quad) and the mesh renderer in the inspector of Unity3D was adjusted with an yellow arrow, which was drawn before in Adobe Illustrator[5]. Further twelve info boxes marked with a blue pointer symbol (defined as explanation arrows) were created as can be seen in Figure 4.6b.

[5]Adobe Illustrator: http://www.adobe.com

The direction signs made sure that the participants followed the right roads to find the info boxes, which were spread over the city at certain points of interest as showed in Figure 4.7.

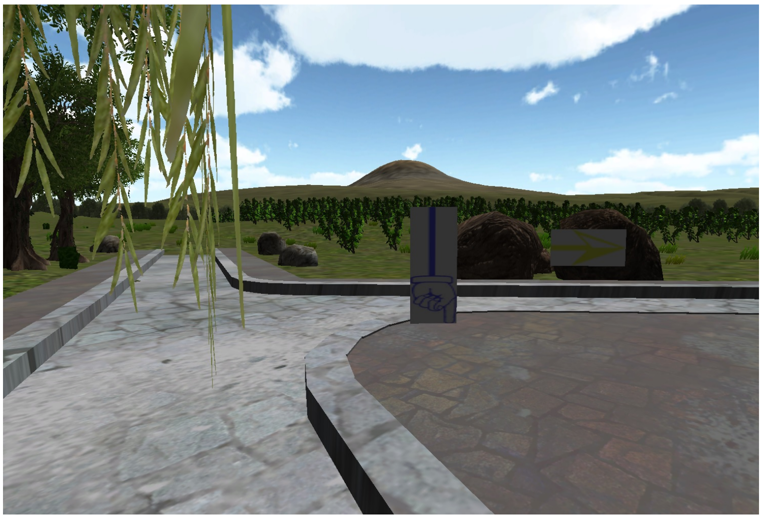


Figure 4.7: An info box (left) and a direction sign (yellow) with the Vesuvius in the background presented in the virtual world of Pompeii

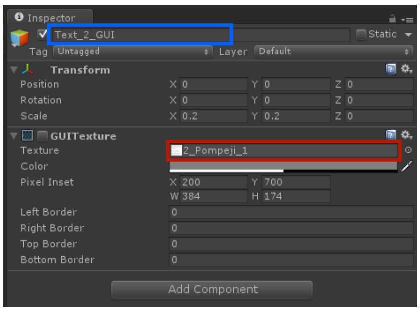
Info Boxes

For the creation of the info boxes two main steps in Unity needed to be done; The generation of a GUI texture and the design of a cube and eventually assemble these together.

Firstly, the text for one info box was written on one page in a word document and saved as a pdf file. It was important to make sure that for each info box there was one pdf file with the correct information and appropriate font size. This was also the procedure for including graphics or pictures. They were imported into a word document, adjusted and exported as pdf. After that the pdf files could be imported into the created folder "Text" in Unity3D.

GUI Texture

The next step was to generate a GUI Texture (GameObject -> Create Other -> GUI Texture) which references to the text that will be used as the texture's display. Their position and scaling are measured in screen coordinates, so the text file can be positioned where it should appear on the screen. The above imported pdf file can now be dragged on the GUI Texture, it is now connected to it in one object (GUI Object). The red framed box in Figure 4.8a highlights the text file (pdf) in the GUI Object (blue framed box).



(a) *Text GUI setup*

```
using UnityEngine;
using System.Collections;

public class Mouseclick_Text : MonoBehaviour {

    public GameObject Text1 = null;

    private void OnMouseDown()
    {
        if (Text1 != null && Text1.guiTexture != null)
            Text1.guiTexture.enabled = ! Text1.guiTexture.enabled;
        }


}

```

(b) *Mouse command in C#*

Figure 4.8: Implementations and procedure in Unity3D

Cube

In another step a cube was created in the scene window in Unity (GameObject -> Create Other -> Cube) and set to a suitable size. For the rendered cube the material with a blue pointer was taken, which was designed before in Adobe Illustrator. Besides a script (depicted in Figure 4.8b) for a command of the computer mouse was written with C# in the text editor MonoDevelop[6] and saved in the script folder on the Unity3D workspace. This script executes, that on mouse click the file connected to the script will open. This created script was attached to the cube and the GUI Object was dragged into the field below the C# script. The GUI Object (Text 2 GUI) in the red framed box in Figure 4.9 will open when the script is activated by a left mouse click on the cube. Now the first info box was finished and in the gaming mode it can be clicked to display the information. By clicking again on the box the information is switched off.

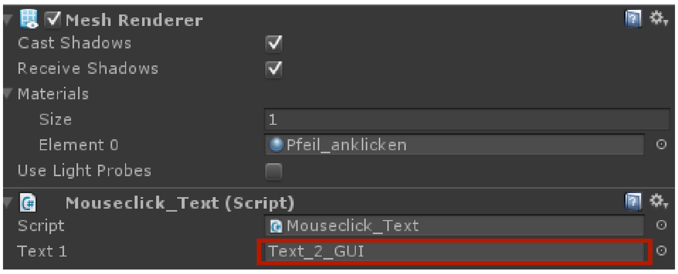


Figure 4.9: Connecting the GUI Texture to a Cube

These steps had to be repeated for all twelve info boxes. Therefore twelve individual pdf files, GUI textures and cubes were created.

[6]MonoDevelop: http://www.monodevelop.com

Lighting and Sky
A directional light was inserted with a low intensity, and quite far from the terrain. This way it gives a realistic lighting on the surface.

Stereo Effect and Standalone Game
The anaglyph glasses use colors to control which images go to which eye. The created Unity scene of Pompeii was exported to a game file. For that, out of the main scene a standalone platform was built. The game scene of virtual Pompeii can now directly be opened without opening Unity. During this export also the anaglyph options were set to have a stereo view of the virtual city as can be seen in Figure 4.10. According to Slater & Wilbur (1997) for a virtual environment user study, the participants should experience the VE as more engaging reality than the surrounding physical world and they should experience the environment as a place visited rather than as images seen. This was reached with the stereoscopic view as good as possible.

Figure 4.10: Virtual Pompeii configured for anaglyph glasses

4.2.3 Colour Blindness

The criteria of color-blindness was set prior to the experiment by simple asking the participants when the evaluation started. According to Ishihara (1972) most cases of colour deficiency are characterized by a red-green deficiency (protanopia) and secondly a deutan type (deuteranopia), which is a reduced sensitivity to green light. The Color-Blind-Awareness (2014) also describes Tritanopia, which is a reduced sensitivity to blue light and is extremely rare. None of the participants stated to have any type of colour blindness.

4.2.4 Pilot Study

Noellenburg (2007) explained that determining the characteristics of the target user group in an user analysis is one of the first steps. Prototypes with still limited functionality can be tested in a situation where one of the designers acts as a user and who performs her/his actions verbally. After the desired level of usability for all parts of the product can be ensured, the final implementation takes place. In order to avoid last minute flaws, which can cause timely repair, the implementation and procedure was checked from a participants perspective right early stage of the development of the virtual world of Pompeii. Further a pilot study was conducted to define a constant and equivalent method of the procedure for the virtual group participants. For the procedure of the text group a trial run was completed as well.

4.3 Statistical Software

The data obtained from the experiment were analysed and statistically computed with the free software R[7]. RStudio, an open source integrated development environment (IDE), was additionally installed to use R more productive and efficient (RStudio, 2014). Besides few charts generated in Microsoft Excel[8] most of the graphics were done with R.

The performance of the exam was expressed in percentage of the maximum reached score. Therefore the reached score is used as interval data, because the difference between 60% and 80% is equivalent to the difference between 50% and 70%, which is in accordance with the explanation of Field et al. (2013). Further ordinal as well as nominal data were used for the analysis. One part of the analysis of this thesis is looking whether two variables are associated and another part is looking at differences. The choice whether to take a parametric test or a non-parametric test was based whether data are normally distributed or not. In order to test whether a distribution of scores is significantly different from a normal distribution, the scores were investigated with a Shapiro-Wilk test. The results are seen as statistically significant at a p-value of +/- 0.05. If the test is non-significant ($p > 0.05$) it tells us that the distribution of the sample is approximately normally distributed. If the test is significant ($p < 0.05$) then the score is significantly different from a normal distribution.

[7]R Project for Statistical Computing: http://www.r-project.org

[8]Microsoft Excel: http://office.microsoft.com/de-ch/excel

5 Method

The research design for this experiment is a quantitative and qualitative exploratory case study focusing on the unique learning opportunity afforded by a virtual learning environment. The main aspect of this thesis is reviewing the concept of virtual worlds as a learning method. To conduct a comparative study, this method was compared with a more traditional way of learning in form of text reading. For this comparison between the virtual group and text group, the best possible approach and procedure according to skills, knowledge and capacities needed to be found and these are presented in the following sections.

5.1 Participants

The participants for this study were selected randomly from a self defined list containing 100 of possible test persons from the personal environment including many students from the University of Zurich and Lucerne and at the Swiss Federal Institute of Technology in Zurich (ETHZ), as well as working people from the circle of acquaintances. Further also flyer were hung in libraries of the university. Each person was randomly assigned to either the virtual group or the text group and then the persons were asked by e-mail if they want to take part in the experiment. Much more people than needed were asked to take part to make sure there will be enough in the end. There was no need on focusing on a certain type of people, branch of study or age category. It was even preferable to have a heterogeneous sample in order to represent the population structure and to evaluate the effect of gender or age. The recruited test persons were told that they participate in an experiment regarding the learning effectiveness of virtual worlds and that they were allocated to one of the two test groups.

In total 40 persons (19 females and 21 males) from various backgrounds ranging in age from 18 - 32 to 50 - 65 were recruited for the experiment. However, this sample is clearly biased because there are much more younger than older participants. For each test group 20 persons were assigned. The virtual group (VG) has eight females and twelve males and the text group (TG) consists of eleven women and nine men.

5.2 Experimental Design - Evaluation of Students' Learning Effectiveness

This study mainly aimed at comparing two different ways of learning. For this purpose, there were two participating groups in this study. The text group was advised to read a history text describing Pompeii and Roman history. This text can be looked up in the appendix. Participants in the virtual group were asked to visit the virtual city of Pompeii to have an interactive learning experience about the same facts as the text group. All participants in one group found the same conditions and process of the user study for minimizing the external factors. For every test person the experiment was conducted individually regardless of the test group.

5.2.1 Examination Aspects

The Figure 5.1 shows in a simple form the investigated variables and impulses of the conducted experiment. The *stimuli axis* shows the two study conditions to which the participants of the experiment were assigned, virtual group and a text group. On the *participants axis* the individual characteristics of each participant (participants' demographic attributes explained in Subsection 5.3.2) are recorded in various variables, as spatial ability, age, gender, etc. The *axis of the tasks formulation*, classifies the tasks according to the type of question and if the questions are visually or not.

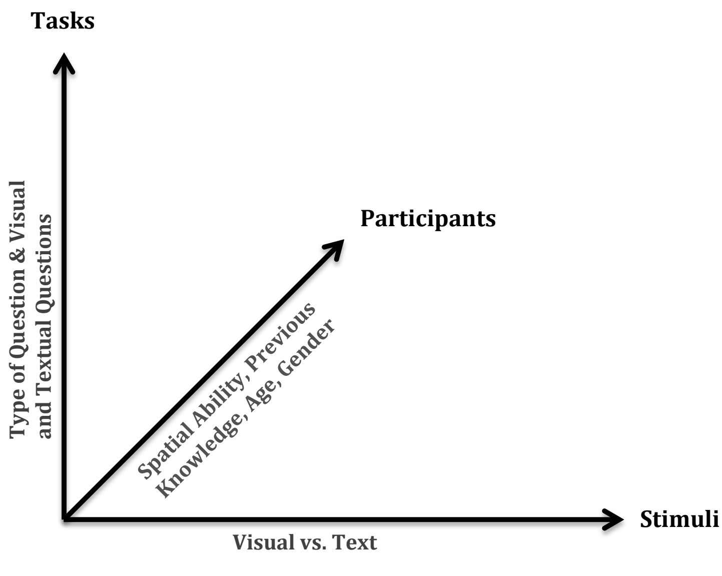


Figure 5.1: The defined examination variables

5.2.2 Variables to Manipulate and Measure

5.2.2.1 Independent Variables

In his book Martin (2008) described, that the independent variable is independent of the participant's behaviour and it is the one that the experimenter manipulates. The purpose of the experiment is to find the effect of the independent variable on behaviour.

The independent variables for this experiment are learning with a text and learning in a virtual world. These two conditions are represented as stimuli in the Figure 5.1. The participants were divided into these two circumstances as will be explained in Subsubsection 5.2.2.4.

5.2.2.2 Dependent Variable

The behaviour which will be measured in response to manipulations of the independent variable is called the dependent variable, because it is dependent on what the participant does (Martin, 2008).

The dependent variable of the presented experiment is the performance (reached score) in the exam. For every task in the exam the participants could get points for the right answer. Totally 30 points could be reached in the exam. The variable is the percentage of the participant's reached score. The mark was calculated conforming to the Department of Education of the Canton of Zurich (MBA, 2014). The calculation of the mark is secondary and it has the same meaning as the score, but it gives an idea and reference how good the test persons performed comparing to a normal high school exam.

5.2.2.3 Main Effect

The author Krantz (2011) explained that a main effect is the effect of one of the independent variables on the dependent variable, ignoring the effects of all other independent variables. In general, there is one main effect for every independent variable in a study.

5.2.2.4 Between-Subjects Design

The design chosen for assigning the participants is conforming to Martin (2008) a between-subject design. As already explained in the introduction to this section, the participants were exposed to only one level of the independent variable, either they took part in the text group or the virtual group. Thus, different people were exposed to different experimental manipulations. The two groups were aiming for the same learning objectives and contents. It was assumed that any variation in the learning outcomes could be attributed to the group type factor. However, it has to be considered that different people took part in the two groups and the groups might not be equivalent to each other on some dimension. In the following subsections the approach for each group is explained.

5.2.3 Procedure Virtual Group

The participants of the virtual group were informed that their experiment sessions will take place in the 3D visualization lab at Irchel campus of the University of Zurich. In the sessions the participants had to visit the virtual city of Pompeii individually and all participants were given guidelines to interact with the system to successfully complete the study. The participants were welcomed in the lab and a brief introduction to the study objectives was given. They had to do two sample questions of the Mental Rotation Test before completing the test itself. After an introduction to the navigation control the participants completed a trial run in a small version of the virtual Pompeii and followed a predetermined path, which is in another district of the city than where the actual experiment takes part. Thus the participants could not see or learn anything crucial concerning the learning objectives while doing the trial run. In the Figure 5.2 the procedure of the experiment of the virtual group is shown. The black boxes are the steps where data is collected and the time written in red in brackets are binding time limits. The time above the boxes give approximately an idea how long the experiment takes.

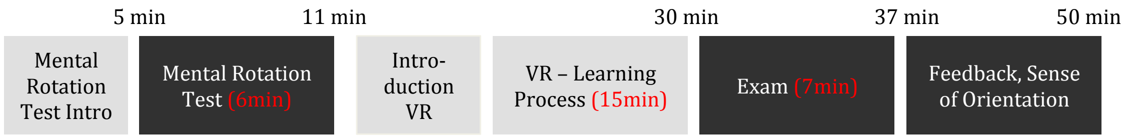


Figure 5.2: Procedure of the experiment of the virtual group

During the visit to the virtual city of Pompeii participants could learn about the city by navigating, observing and exploring the various places in the virtual city. They had to follow a learning path which was highlighted with signs and learn about different historic facts, places, landscapes, constructions and artefacts. These various places, where the participants could get more information and learn something, were identified with pointers as explained in Chapter 4. On mouse click an information field was displayed and the participants could learn the presented and visualized facts as for example seen in

Figure 5.3. Theses information boxes contain the same facts as were given to the text group in the text document.

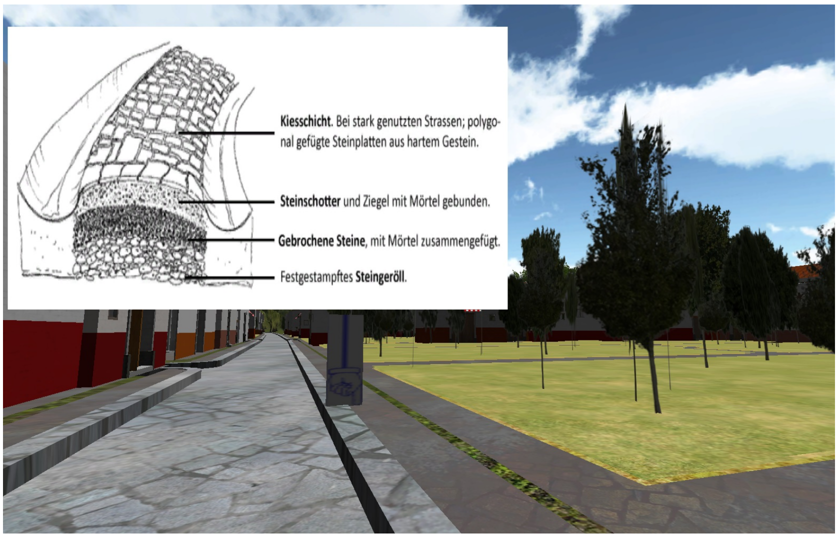


Figure 5.3: Information in the virtual reality

5.2.3.1 Methods of Conducting the User Study for the Virtual Group

The method for conducting the user study for the virtual group participants is uncontrolled and supervised for any technical questions. The participant was provided with full control of the system. During the session the researcher accompanied the participant and the participant was also allowed to seek any technical help needed for visiting the virtual city. This supervision also gave an opportunity to observe the participant closely during his interaction. After the interaction in the virtual city, the participant was given the exam and was left alone during this part of the study but the researcher stayed in the same room. The pilot period showed that this approach has a good repeatability. Therefore all the participants met the same conditions and procedure.

5.2.4 Procedure Text Group

The text group read a text describing ancient Pompeii, Roman Empire, volcanic eruption, daily life and Roman roads. The text and also the information in the virtual world is based on reliable literature and references (Bringmann, 2008; Pesavento Mattioli et al., 2004; Gibbon, 2006; Pohanka, 2012). In the Figure 5.4 the procedure of the experiment of the text group is explained. The black boxes are the steps where data is collected and the time written in red in brackets are the binding time limits. The text group did not complete a pre-test part containing the Mental Rotation test. They started right away reading the text after a brief welcoming. The time above the boxes give approximately an idea how long the experiment takes.

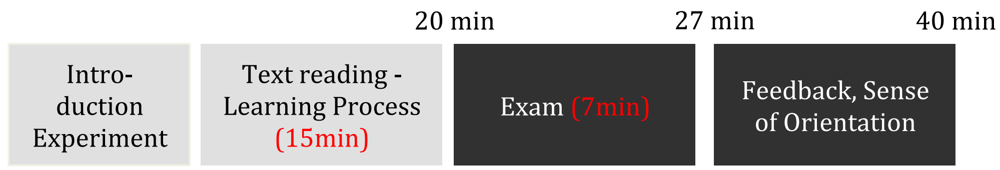


Figure 5.4: Procedure of the experiment of the text group

5.3 Test Material

The motive of this research study was to collect both quantitative and qualitative data. Rogers et al. (2009) explained that quantitative data is data that is in the form of numbers, or that can easily be translated into numbers. Qualitative data on the other hand is data that is difficult to measure, count, or express in numerical terms in a sensible fashion.

The information about the examined variables depicted in Figure 5.1 had to be collected with several test materials. For that the experiment contains several parts: The pre-test part of the virtual group examines the users spatial ability with a Mental Rotation Test (MRT). The second part was the interaction in the virtual world and the exam, which was aiming to test the knowledge gained about the city of Pompeii. The post-test part collected the users' demographics and their background knowledge about Pompeii and the Romans in general, as well as previous experience with virtual reality environments. In this part also qualitative data were collected by answering a feedback questionnaire and writing optionally suggestions for improvements. Furthermore the participants answered the questions of the Santa Barbara Sense of Orientation Scale, for examining their opinion of their sense of directions.

5.3.1 Creation of the Exam

The exam checks whether and to what extent the participant achieved certain substantive and methodological objectives of the virtual world or the text (Haubrich et al., 2006). The process of solving the exam tasks requires different intellectual work and mental benefits. According to the author Haubrich et al. (2006) there are following taxonomies:

- Reproduction; the students just reflect their knowledge
- Reorganization; the students represent connections and work up an issue
- Transfer; the students transfer their knowledge to review similar facts and issues
- Problem solving

In a written exam questions should be asked from possibly all categories. Already remembering and reproduction of knowledge can differ in difficulty. Key factors concerning the difficulty of the content are on one hand the number of sense-unit that need to be processed in the working memory at the same time and on the other hand the level of abstraction of the content. On the task axis in Figure 5.1 there were used two kinds of taxonomies for the task form in the exam; *Type of Question* and *Visual and Textual Questions*.

5.3.1.1 Types of Questions

There are several different types of questions, each of which requires a particular kind of response. For example, closed questions require an answer from a set of possibilities while open questions are unrestricted (Rogers et al., 2009). As stated by Haubrich et al. (2006) a balanced proportion between closed and open questions is important, because different complex tasks determine the degree of objectivity as well as the degree of freedom of the students. The presented examination about the Romans is comprised of totally ten open and 15 closed questions.

Open Questions
For the ten open questions the participants have to answer the questions in a few words. For this kind of questions the degree of objectivity is low and the degree of freedom high (Haubrich et al., 2006).

Closed Questions
For the closed questions the degree of objectivity is high and the degree of freedom low. The closed questions are further divide into three classes based on Haubrich et al. (2006):

- *Alternative tasks*; there are only two possible answers (e.g. right or wrong), therefore the likelihood to get the right answer is 50%
- *Multiple choice tasks*; in this exam there are questions with four possible answers and the one right solution has to be ticked

- *Regulatory/order tasks*; the participant should bring the terms and statements into the right order

Among these 15 closed questions there is one alternative task, one is an order task and the remaining 13 questions are multiple choice questions.

5.3.1.2 Visual and Textual Questions

Besides the separation of the questions into open and closed questions, they can also be divided into more visual task and more textual tasks. Totally there were six visual and 19 textual questions in the exam.

5.3.2 Participants' Demographic Attributes

This subsection focuses on the influence of the participants' demographic attributes on the performance. These are on the participants axis in Figure 5.1. On the listing below all evaluated participants' demographic attributes are presented:

- Spatial Ability
- Sense of direction
- Previous Knowledge about Romans
- Gender
- Age
- Mother Tongue
- Qualification and Profession
- *VG only;* Experience in using VR

As explained the Mental Rotation Test was only done by the virtual group and before the interaction with the virtual world. In the post-test part information about the participant were collected and all did the Santa Barbara Scale where they answered some questions about their sense of direction.

5.3.2.1 Mental Rotation Test

Vandenberg & Kuse (1978) suggested that the Mental Rotation Test (MRT) may be useful in studies of the development of spatial ability and also the authors Caissie et al. (2009) stated that MRT is one of the most commonly used measures of spatial ability. Hoyek et al. (2012) defined Mental Rotation (MR) as the ability to make the mental image of a given 2D or 3D object turning in space. Spatial knowledge is acquired by individuals as a function of their experience within a given environment. At the simplest level, an individual must have knowledge of important objects and/or places. Spatial knowledge also includes information about the relationships among objects. The general assumption is that an individual's permanent knowledge structures provide the basis for interpreting objects, actions and events in the external environment. It is also commonly assumed that people's decisions and behaviours within the spatial environment are some function of the cognitive representation of that environment. Geographers distinguish between spatial behaviour and the a priori decision-making process that culminate in spatial activity (Golledge et al., 1985).

The used Mental Rotation Test contains 20 tasks (MRT items) in which (two-dimensional) drawings of three-dimensional geometrical figures are to be compared. Each MRT item, as depicted in Figure 5.5, consists of a row of five line drawings, including a geometrical criterion figure in the left most position followed by four response-choice figures, two correct alternatives and two incorrect ones or "distractors". The correct alternatives are always identical to the criterion in structure but are shown in a rotated position.

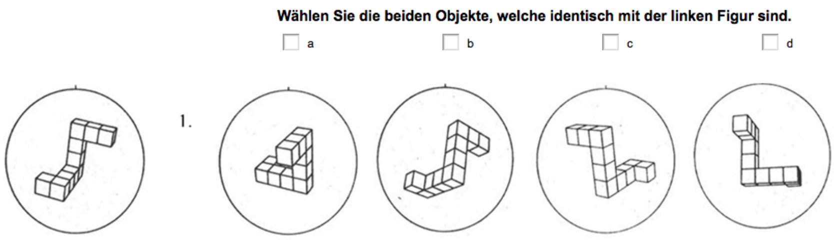


Figure 5.5: Mental Rotation Test as tested on Survey Monkey, based on Vandenberg & Kuse (1978)

Only the participants of the virtual group completed the designed Mental Rotation Test on SurveyMonkey[1], which is a web survey program. All participants of the VG followed the same procedure and they had the same administration instructions. Accordingly, the test persons of the VG were instructed to indicate for each MRT item which two of the four response figures are rotated reproductions of the target figure. At first they had to solve two trial MRT items. After that participants were allotted to a six minute

[1]SurveyMonkey: http://www.surveymonkey.net

time limit to complete the Mental Rotation Test, and were informed when there were 3 minutes remaining.

The recommended procedure for scoring according to Vandenberg & Kuse (1978) is to count each item as correct when both choices are correct and to give no credit otherwise. In the opinion of Hoyek et al. (2012) this kind of evaluation discourages and reduces guessing. This scoring method was taken into account and one point was given when the participants gave two correct answers per item and no point was attributed when one or both selections were wrong or the participants did not give an answer at all.

5.3.2.2 Santa Barbara Sense of Direction Scale

The Santa Barbara Sense of Direction Scale measures people's judgments about their own environmental spatial and navigational skills. It is important to note that it is not an objective measure of ability, although it is correlated with objective measures of performance in a number of environmental spatial cognition tasks (Hegarty et al., 2002). The questionnaire consists of several statements about the participants spatial and navigational abilities, preferences, and experiences. For the experiment a German version of the Santa Barbara Sense of Direction Scale was used, according to the Center for Cognitive Science of the University of Freiburg (Freiburg, 2014). It was performed as a part of the post-test questionnaire and both test groups completed it.

The scoring procedure for the scales was conducted as recommended by the Hegarty Spatial Thinking Lab from the Department of Psychological and Brain Sciences of the University of California (Hegarty & Stull, 2014). First the positively phrased items were reversed to ensure that all items coded such that a high number indicates more ability and a low number indicates less ability. After that, the score for all of the items was summed together and then divided by the number of items to compute the average score across items. Using this technique, the reached score will be a number between 1 and 7 where the higher the score, the better the perceived sense of direction.

5.3.2.3 Previous Knowledge and Virtual Reality Experience

In the post-test, which was carried out with SurveyMonkey, the user's level of familiarity with virtual world and the previous knowledge about the Romans were asked in order to determine the influence on the results. The interest in history is different for every person and history is perceived differently by every person. Therefore it is important for this study to ask the participant's understanding of history. The post-test was similar for both groups. The virtual group was moreover asked to give response to statements about their experience with the virtual reality and what is there opinion related to the learning effectiveness. The text group gave a feedback about their satisfactions and what they think about the possibility of using virtual worlds as an alternative learning method.

5.3.2.4 Remaining Participants' Demographic Attributes

In the post-test part the participants of both test groups gave personal details such as gender, age and mother tongue. Further they ticked the box with the suitable occupation title and education level.

The experience in using virtual realities, experience in video- and computer games as well as computer skills were only asked to the test persons of the virtual group.

5.3.2.5 Additional Variables of the Virtual Group

In the post-questionnaire the participants had to answer some statements about their overall impression which was evaluated with one question asking the participants to rank their overall impression from one to five. Other aspects asked for the qualitative data were; user friendliness, imagination of ancient Pompeii, learning effectiveness, presence in the virtual world and the understandability of the information.

6 Results

In order to answer the lead question and the several research questions the collected data were analysed and statistically evaluated. The results of the experiments were processed in R Statistics and the results are organized according to the variables affected, which were introduced in Chapter 5, illustrated in Figure 5.1 and examined in the experiment. The next Section 6.1 presents the analysis of the two test groups. The attributes of the participants and the task formulation are evaluated in the Subsection 6.2.1 and 6.2.2, respectively.

6.1 Performance of the Test Groups

The raw data from the Mental Rotation Test, the exam score and the survey were first cleaned up and brought into an analyzable data set which is implementable for RStudio software. There the data could be filtered according to the chosen variables. This allowed analyses to be conducted on subsets of the data and hence do draw detailed conclusions for more specific goals.

6.1.1 Comparison of the Reached Score

This subsection compares the performance of the two test groups. In addition to comparing the average mark, also the percentage of the reached score and the maximal and minimal learning achievements were compared. There was a visible difference in performance between the participants of the virtual group and the text group. As shown in Figure 6.1 participants of the virtual group outperformed with an average mark of 3.95 the participants in the text group who achieved an average mark of 3.34. The average percentage of the reached score was 58.42% for the virtual group and 46.71% for the text group.

A boxplot displays the range of the data in a really useful way. According to Field et al. (2013) the line at the centre of the plot is the median, which is surrounded by a box, in which the middle 50% of scores fall, the so called interquartile range. Sticking out of

Comparison: Virtual Group vs Text Group					
	Average Mark	**Average Mark (rounded)**	**Reached Score (%)**	**Lowest Score (%)**	**Highest Score (%)**
Virtual Group	3.92083333	3.95	58.42	36.7	81.7
Text Group	3.33541667	3.34	46.71	10	60
Total	3.628125	3.64	52.56	10	81.7

Figure 6.1: Average mark and score of the virtual group and text group

the top and bottom of the box are two whiskers that extend to one and a half times the interquartile range.

The boxplot (Figure 6.2) also reveals that the virtual participants (a) had a much higher top score and the text group (b) had a lower low score. Further also the lower quartile of the text group is much lower. The distance between the bottom of the vertical line and the lower quartile is larger for the virtual group, which means that there is a more variability in the lowest 25% of the virtual group. The same also applies for the distance between the top of the vertical line and the upper quartile. The virtual group varies much more than the text group. The median for the virtual group is much higher, which tells us that the middle participant of the virtual group scored higher than the one from the text group. The two whiskers of each boxplot are more or less the same length. This means the distribution is symmetrical and each group has an outlier below the boxplot.

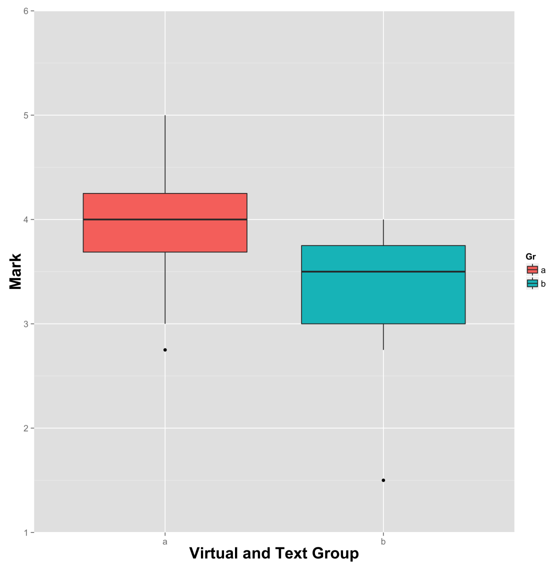
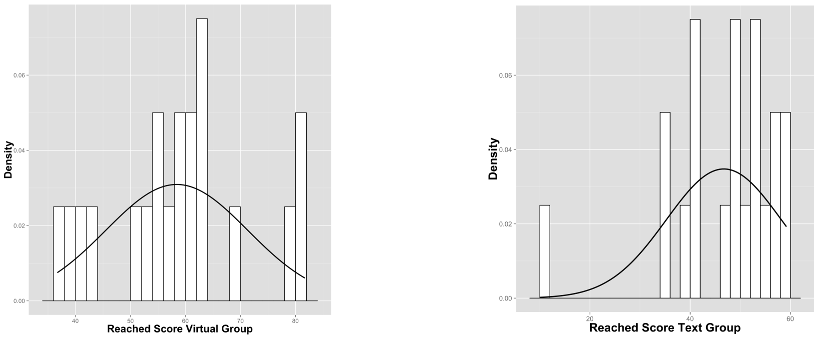


Figure 6.2: Boxplot of exam scores for each test group (a; virtual group, b; text group)

The two histograms in Figure 6.3 depict the distribution of the reached scores for both groups. Only two participants of the text group (Figure 6.3a) reached an adequate mark of four (equal to the score of 60%). In the virtual group (Figure 6.3b) there were at least 12 persons adequate, but the average of the group was still inadequate.



(a) Histogram virtual group *(b) Histogram text group*

Figure 6.3: Histograms of the scores for the two test groups

6.1.1.1 Distribution

For a normal distribution the values of skewness and kurtosis should be zero. Figure 6.4 depicts that the text group reached values over one for both measures. This indicates that it is quite likely that the data are not normally distributed, while the virtual group is much closer to a normal distribution. The clear negative value for the skewness of the text group (SK = -1.519) indicates a build-up of high scores. This means a pile-up of scores on the right side of the distribution, which confirms the histogram 6.3b. The high value for the kurtosis of 2.582 indicates a pointy and heavy-tailed distribution of the text group data. In other words there is more "data" on the tails than in a normal distribution, whereas the virtual group (kurtosis = -0.758) has more a flat and light-tailed distribution with a positive skewness of 0.131.

Distribution of the Reached Score for Virtual Group and Text Group								
	Mean	Median	Standard Deviation	Range	Skewness	Skewness - 2SE	Kurtosis	Kurtosis - 2SE
Virtual Group	58.42	58.3	12.898	45	0.131	0.128	-0.758	-0.381
Text Group	46.71	48.75	11.476	49.2	-1.519	-1.483	2.582	1.301

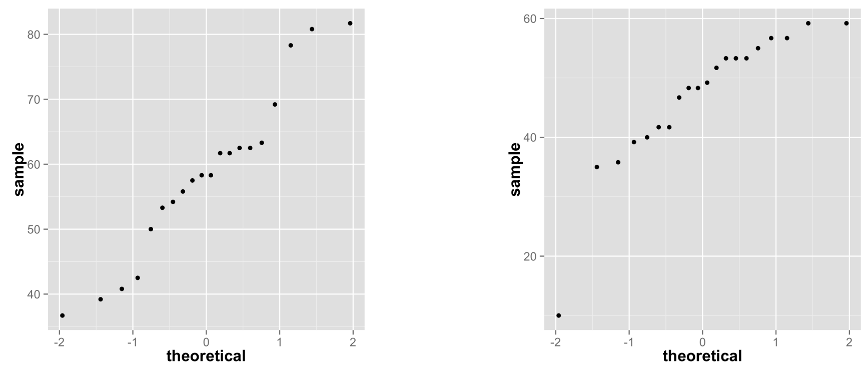
Figure 6.4: Distribution of the data for the two test groups

A descriptive analysis of the two test groups based on their achieved score helps to identify the statistical difference between the two groups, also because the number of participants being the same in both groups. As can be seen in the Figures 6.1 and 6.4 for the text group these statistics indicate; Mean = 46.71, Standard Deviation (STD) = 11.476, Minimum score = 10 and Maximum score = 60. The virtual group outperform this with statistical values; Mean = 58.42, Standard Deviation (STD) = 12.898, Minimum Marks = 36.7 and Maximum score = 81.7. These descriptive statistics confirm the better performance of the virtual group.

The Shapiro-Wilk test compares the scores of the two test groups to a normally distributed set of scores with the same mean and standard deviation. A significant value, when the p-value is less than 0.05, indicates a deviation from normality. The Q-Q plots in the Figures 6.6 help to interpret the results of the Shapiro-Wilk test presented in table 6.5.

Shapiro-Wilk test		
	W	p-value
Virtual Group	0.9483	0.3424
Text Group	0.8438	0.0042
Total	0.9501	0.07666

Figure 6.5: Shapiro-Wilk test for the data of the two test groups



(a) Q-Q plot VG *(b) Q-Q plot TG*

Figure 6.6: Q-Q plots for the reached score of the virtual group and the text group

If the data are normally distributed, the dots in the Q-Q plot should fall exactly along a straight line. For the text group in Figure 6.6b the dots consistently rise above the diagonal, this shows that the kurtosis differs from a normal distribution, whereas the dots of the virtual group in Figure 6.6a follow roughly a diagonal. This confirms the description about the data before.

The reached score for all exams together (N = 40, M = 52.56) is approximately normally distributed, because the Shapiro-Wilk test is not significant, W = 0.9501, p = 0.07666. However, for comparing the two test groups the distribution in each group is important. For the virtual group the Shapiro-Wilk test is not significant, W = 0.9483, p = 0.3424, indicating that the distribution is approximately normal. On the contrary the text group is significant, W = 0.8438, p = 0.0042 and indicates that the score is significantly different from a normal distribution.

6.1.1.2 Wilcoxon Rank-Sum Test

Because of the non normal distribution of the data of the text group the Wilcoxon rank-sum test, which is non-parametric, was used for testing the differences of the means between the two groups.

The score of the virtual group (Mdn = 58.3) did differ significantly from the text group (Mdn = 48.75), W = 308, p = 0.0036, r = -0.46.

This interesting observation that the virtual group performed considerably better is also recognizable in the Figure 6.7 which compares the group performance for each exam task.

The text group outperformed the virtual group in six out of 25 tasks, though the better performance in these questions vary slightly between 2 and 10 percent and the mean difference is 5 percent. In 18 questions the participants of the virtual group were better and the range of this better performances lies between 4 and 65 percent with an average of 19 percent per question.

6.1.1.3 Outliers

The outliers from both data sets were removed and analysed and plotted again in a boxplot (Figure 6.8) to make sure that the evaluation does not depend on the performance of a single participant. After removing the outliers in both groups, the score of the virtual group (M = 59.56) was still normal distributed, W = 0.9359, p = 0.2223 and the score of the text group (M = 48.65) was still not normal distributed, W = 0.8937, p = 0.0375. The difference between the two groups was also without the outliers significant, W = 286, p = 0.00215.

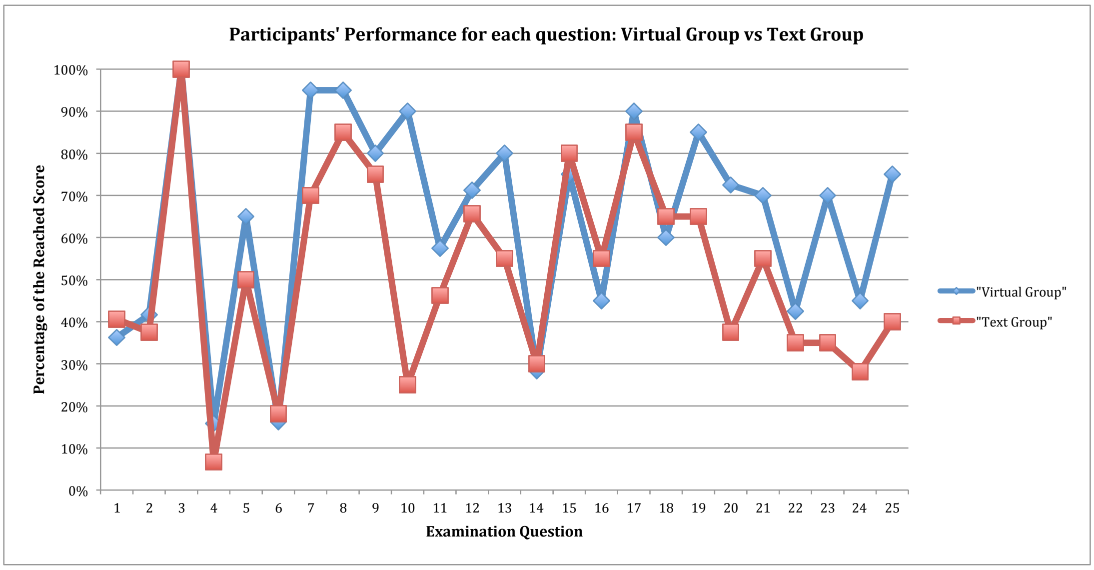


Figure 6.7: Participants' performance for each task, according to the test group

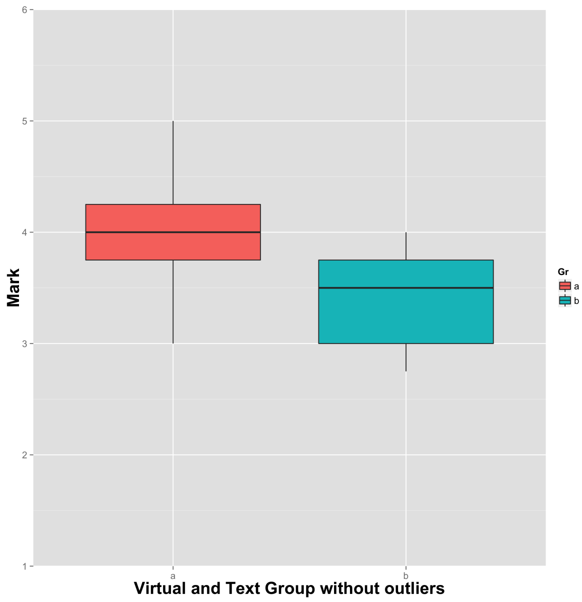


Figure 6.8: Boxplot of exam scores without outliers for each test group (a; virtual group, b; text group)

6.2 Impact of Relevant Factors

6.2.1 Qualities and Characteristics of the Participants

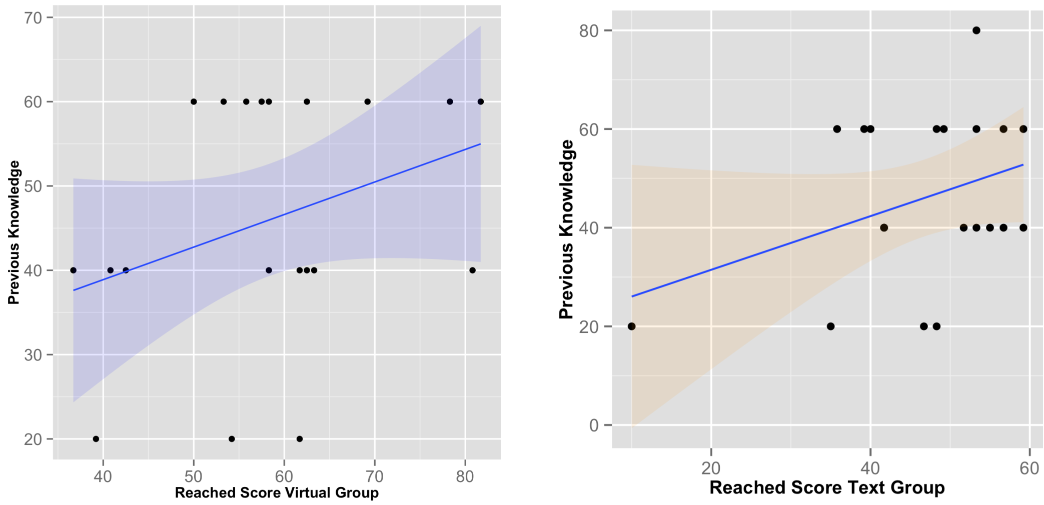
This subsection focuses on any possible impact of any participants' demographic attributes on performance in the exam. All the statistics to measure the effect of those attributes were gathered for both test groups. In the following subsubsections the effects of these attributes on the dependent variable (reached score) are investigated, starting with the previous knowledge about Romans.

6.2.1.1 Effect of Previous Knowledge about Romans on Performance

All participants had some basic knowledge about Romans and/or the city of Pompeii itself, but only few valued their knowledge as adequate. It was analysed whether this previous knowledge about Romans may have any effect on the performance of the participants. It has to be mentioned that the variable previous knowledge is only based on a self-assessment of the participants.

The Spearmans' correlation coefficient was used to determine the effect, which is according to Field et al. (2013) a non-parametric statistic and can be used when the data have violated parametric assumptions such as non-normally distributed data. The scatterplot 6.9a illustrates the correlation coefficient between the virtual group and the previous knowledge, which is fairly large (0.278) and the significance value of this coefficient is p = 0.235. Therefore, it can be concluded that there is no significant relationship between the two variables. The correlation coefficient between the reached score of the text group (Figure 6.9b) and the previously knowledge is similar (0.251) and the amount of the p-value is 0.2866, which is also above 0.05 and means that there is no significant relationship between the reached score of the text group and their previous knowledge about Romans.

In a sentence: The previous knowledge about Romans did not correlate with the reached score in the exam, therefore the its influence can be neglected.



(a) Previous knowledge of the VG

(b) Previous knowledge of TG

Figure 6.9: Self-assessment of the participants about their previous knowledge about Romans

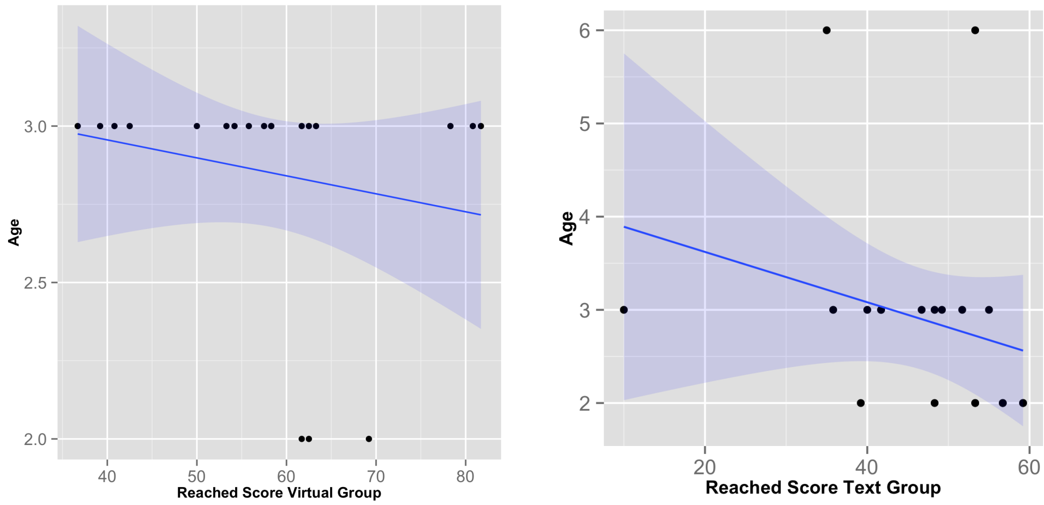
6.2.1.2 Effect of Age on Performance

The participants of both groups had to declare in which of the seven age categories they fall.

The correlation coefficient analysis (-0.304) for the age factor depicts no significant impact of participant's age of the virtual group on the reached score, p = 0.193, which correlation is illustrated in the scatterplot (Figure 6.10a). The negative relationship correlation coefficient means as age increased, the reached score decreased.

The scatterplot in Figure 6.10b shows the correlation between the reached score of the text group and the age. The significance value correlation coefficient (-0.525) is p = 0.01753, which is less than 0.05. Therefore it can be concluded that there is a significant relationship between the reached score and the age of the participant in the text group. However, this could be due to the participation of two persons much older than the other participants.

It should be generally noted that there were only two age classes participating in the virtual group. The first from 18 to 24 years and the second from 25-32 and only three participants were in the first age group. In the text group 90% of the persons fall into these two categories, only two participants were older, namely between the age 50 and 65.



(a) Correlation of age and reached score for the virtual group

(b) Correlation of age and reached score for the text group

Figure 6.10: Correlation of age and reached score

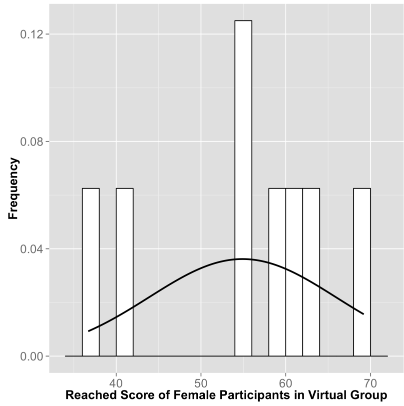
Therefore a truly influence of the age can not be explored, for that a broader range of age of the participants would be needed.

6.2.1.3 Effect of Gender on Performance

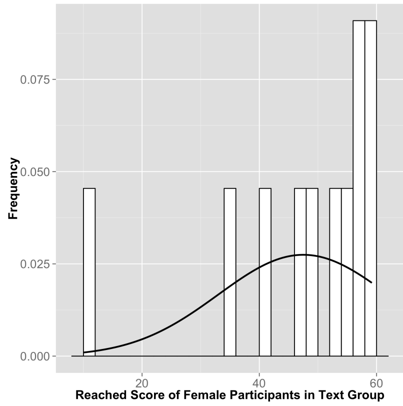
There was no major difference of gender of the participants in the performance in the exam. The 19 female participants of both test groups achieved a mean score of 50.62% and the 21 male persons a mean of 54.32%.

The following histograms in Figures 6.11 and 6.12 show the performance opposed to the gender of the participants. The first two histograms depict the performance of the eight women who took part in the virtual group (Figure 6.11a) and the eleven women who took part in the text group (Figure 6.11b). Below there are the histograms for the male participants of the virtual group (12 men) in Figure 6.12a and text group (9 men) in Figure 6.12b.

Looking for differences between gender in the virtual group, the output from the Wilcoxon test shows the reached score of the male (M = 60.8) did not differ significantly from the female (M = 54.9), W = 58.5, p = 0.4399, r = -0.122. The gender (female = 47.51 and



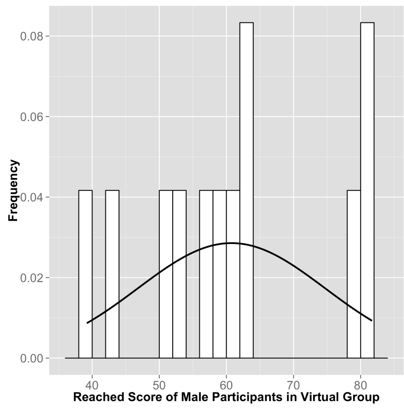
(a) Histogram women VG



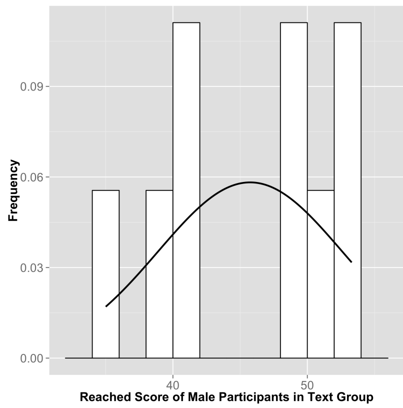
(b) Histogram women TG

Figure 6.11: Performance of women according to their test group

male = 45.74) did also not significantly affect the performance in the text group, W = 33, p = 0.223 with an effect size of r = -0.193.



(a) Histogram men VG



(b) Histogram men TG

Figure 6.12: Performance of men according to their test group

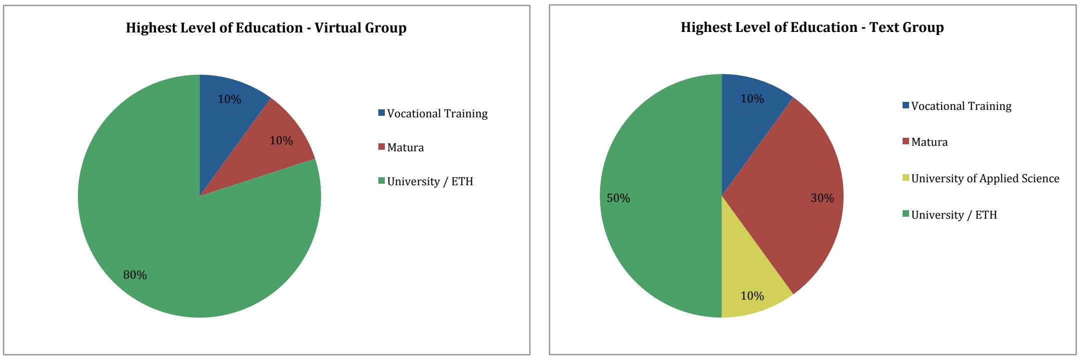
The differences between the performance of women and men are explained more in detail in the descriptive statistics in table 6.13. It shows that the male participants outperformed the female participants in the virtual group, but in the text group the females were slightly better than the males.

Gender: Diferences between Gender and Groups											
Gender	Group	Mean (%)	Median (%)	Standard Deviation	Minimum	Maximum	Range	Skewness	Skewness-2SE	Kurtosis	Kurtosis-2SE
Female	Virtual Group	54.9	57.1	11.03	36.7	69.2	32.5	-0.477	-0.317	-1.338	-0.452
	Text Group	47.51	53.3	14.53	8.75	59.2	49.2	-1.459	-1.104	1.193	0.466
Male	Virtual Group	60.8	60	13.97	39.2	81.7	42.5	0.148	0.116	-1.263	-0.512
	Text Group	45.74	48.3	6.85	35	53.3	18.3	-0.222	-0.155	-1.767	-0.631

Figure 6.13: Statistics for participants according to gender

6.2.1.4 Effect of Qualification and Profession

In the post-test of both test groups the participants were asked to give information about their highest educational attainment (Figure 6.14) and in which field of study or profession they are working in (Figure 6.16). Participants in this experiment mainly belong to two levels of qualification; University and Matura. *Matura* is the diploma from Swiss grammar schools. As can be seen in the pie chart (Figure 6.14a) four fifths of the virtual group have an university degree, whereas only half of participants of the text group (Figure 6.14b) had such a degree. It has to be taken into account though, that 30% of them have completed the Matura. Most of them have probably already begun with their studies but are still in the bachelor's programme.



(a) VG Education *(b) TG Education*

Figure 6.14: Highest level of education of the participants of both test groups

The bar chart in Figure 6.15 illustrates the mean score in the exam with regard to the highest educational attainment. It should be noted that there is a bias in the amount of participants with a university degree, because 65% had one. One fifth of the participants completed the *Matura* and at least 10% completed the vocational training. Only two persons from a University of Applied Science took part. Generally it can be concluded that all four levels of qualification performed inadequately in the exam.

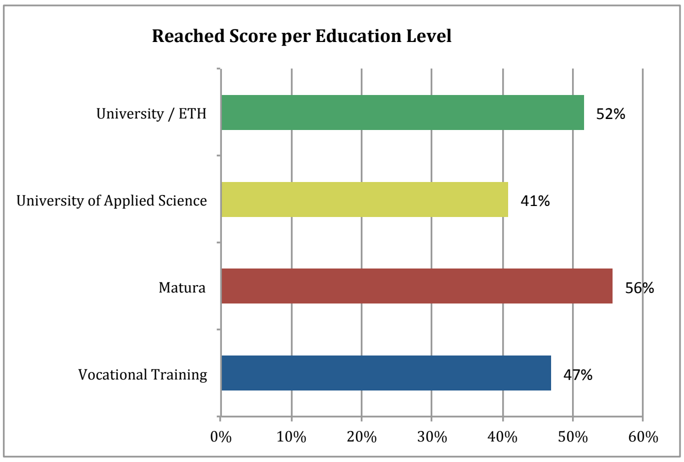
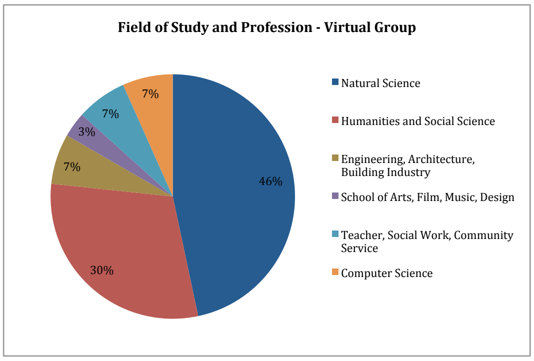
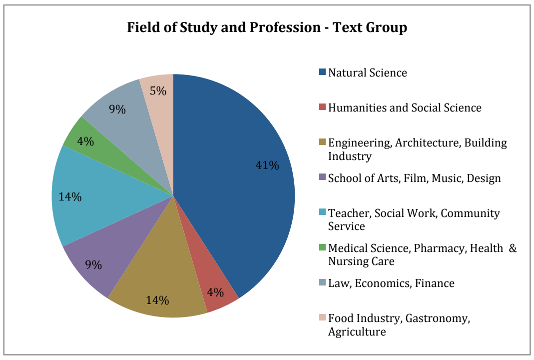


Figure 6.15: On average reached score according to the highest level of education

The participants could choose several options and also describe briefly what they are doing. As seen in the Figures 6.16 the majority of respondents have a background in natural science. The participants of the text group (Figure 6.16b) have a more heterogeneous background, whereas over three quarters in the virtual group (Figure 6.16a) come from the field of natural science or humanities and social science. No statistical evaluation was done, because one participant could have a multiple field of study and there were too little participants for representing each field of study adequately.



(a) VG Profession



(b) TG Profession

Figure 6.16: Profession of the participants of both test groups

6.2.1.5 Effect of Sense of Direction

In the Santa Barbara Sense of Direction Scale the two test groups had almost the same average with a slightly better performance of the virtual group. In most tasks both groups reached a similar score, as illustrated in Figure 6.17. For both, virtual group (p = 0.27) and text group (p = 0.579), the Shapiro-Wilk test is not significant, indicating both distributions are normal. An independent t-test revealed no statistical significant difference between the sense of direction of the virtual group (M = 63.6, STD = 11.3), and the sense of orientation of the text group (M = 62.1, STD = 15.86), t(34.33) = 0.3446, p = 0.7325, r = 0.059.

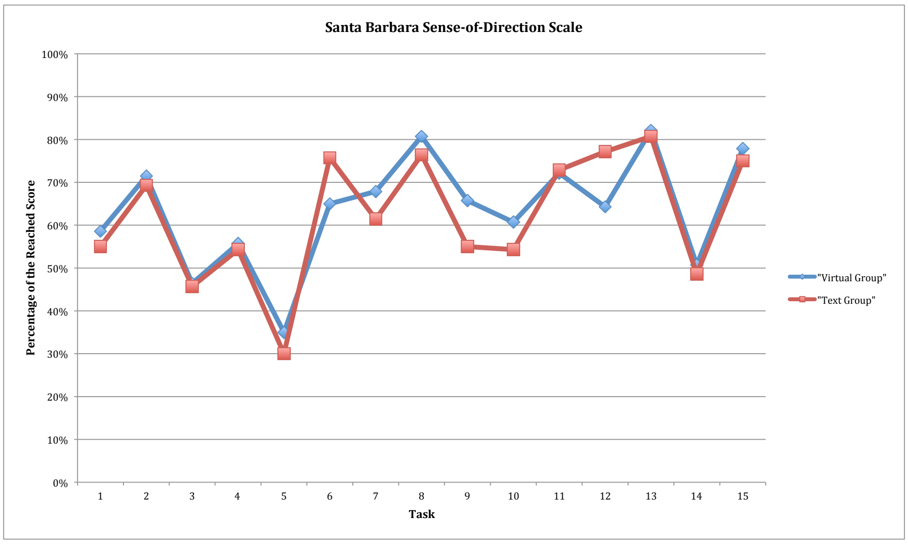


Figure 6.17: Results of each task of the Santa Barbara Sense of Orientation Scale according to the two test groups

Further the difference of the score in the Santa Barbara Sense of Direction Scale between the gender was evaluated and an independent t-test disclosed that scores of the females (M = 56.5, STD = 13.54) and males (M = 68.6, STD = 11.1) are significantly different, t(34.9) = 3.1, p = 0.004, r = 0.461. However, this finding does not matter in this study.

6.2.2 Question Types of the Exam Tasks

This subsection focuses on task axis of the diagram 5.1 presented in the method chapter (Chapter 5).

6.2.2.1 Effect of the Type of Question

As described in the Subsection 5.3.1 there were multiple choice questions and open questions. In general the scores for the multiple choice questions were higher (M = 67.5 versus M = 35.5). This observation can be confirmed by comparing the two test groups by using descriptive statistic as shown in Figure 6.18. For both types of question the virtual group performed better than the text group. For the multiple choice questions the virtual group even reached a score over 75%, whereas the text group did not complete with an adequate mark. The score for the open questions were low in both groups.

Open Questions vs. Multiple Choice Questions for each Group												
	Mean (%)		Mean (%)	Median (%)	Standard Deviation	Minimum	Maximum	Range	Skewness	Skewness-2SE	Kurtosis	Kurtosis-2SE
Open Question	35.5	Virtual Group	38.8	36.6	12.61	14.3	60.7	46.4	0.0577	0.0563	-0.7	-0.353
		Text Group	32.2	33	12.227	7.1	60.7	53.6	0.152	0.146	-0.151	-0.076
Multiple Choice	67.5	Virtual Group	75.6	79.7	15.713	51.6	100	48.4	-0.058	-0.057	-1.429	-0.72
		Text Group	59.4	64.1	16.1	12.5	78.1	65.6	-1.26	-1.23	1.16	0.58

Figure 6.18: Open questions versus Multiple choice questions

6.2.2.1.1 Effect of the Open Questions The scores of the open question of both groups were analyzed for normal distribution with the Shapiro-Wilk test. The score of the virtual group, W = 0.9626, p = 0.597, and the score of the text group, W = 0.9829, p = 0.965, were both approximately normally distributed. On average for the open questions, the virtual group reached a higher score (M = 38.8), than the text group (M = 32.2). This evaluated difference between the test groups for the open questions is not statistically significant, t(37.963) = 1.68, p = 0.1, r = 0.264.

6.2.2.1.2 Effect of Multiple Choice Questions The score of the multiple choice questions of the virtual group, W = 0.9268, p = 0.134 was approximately normally distributed, but the text group, W = 0.8664, p = 0.0102 indicates a deviation from normality. Thus, for further investigations a Wilcoxon rank-sum test was done. The output shows that the score of the virtual group for the multiple choice questions (Mdn = 79.7) differs significantly from the text group (Mdn = 64.1), W = 303, p = 0.00549.

In summary it can be said, that the two groups performed significantly different only for the multiple choice questions.

6.2.2.2 Visual and Textual Questions

In the visual tasks the participants had to know for example something about a landscape, a sketch and in the textual task some facts etc.

Visual Questions vs. Textual Questions for each Group												
	Mean (%)		Mean (%)	Median (%)	Standard Deviation	Minimum	Maximum	Range	Skewness	Skewness-2SE	Kurtosis	Kurtosis-2SE
Visual Question	47	Virtual Group	55.74	57.35	14.123	26.5	76.5	50	-0.339	-0.331	-0.969	-0.488
		Text Group	38.25	41.2	13.527	11.8	55.9	44.1	-0.422	-0.412	-1.24	-0.625
Textual Choice	54.77	Virtual Group	59.47	60.5	15.091	33.7	88.4	54.7	0.112	0.109	-0.747	-0.376
		Text Group	50.1	54.1	13.874	9.3	69.8	60.5	-1.225	-1.196	1.416	0.714

Figure 6.19: Visual questions versus Textual questions

In general the textual questions (M = 54.77, STD = 15.078) were solved better than the visual questions (M = 47, STD = 16.271). As can be seen in Figure 6.19 especially for the visual questions the virtual group (M = 55.74, STD = 14.123) outperform the text group (M = 38.25, STD = 13.527) by 17.49%. The distribution of both scores were approximately normal (VG: W = 0.963, p = 0.611 and TG: W = 0.9125, p = 0.071). The output of the t-test reveals a significant difference between the scores of the test groups for the visual exam questions, t(37.93) = 4, p = 0.0003.

Regarding the textual questions the means for the virtual group (M = 59.47, STD = 13.527) and for the text group (M = 50.1, STD = 13.874) were more similar and the output of the Wilcoxon rank-sum test, done due to the abnormality of the textual questions of the text group (W = 0.89, p = 0.03), reveals no statistical significant difference between the test groups for textual questions, W = 269, p = 0.066.

This section presented each of the participants' demographic attributes for any possible influence on performance (Subsection 6.2.1) and the effect of the task formulation on the performance for each group (Subsection 6.2.2). This user study concludes that just age had some effect on participants performance and the open questions as well as the multiple choice questions disclose some significant differences in the performance between the two test groups. All other demographic factors and task types had insignificant influence on performance.

6.3 Performance of the Virtual Group

As explained in the Subsection 5.2.3 the virtual group completed two additional tasks compared to the procedure of the text group. In a first step the participants of the virtual group did a Mental Rotation Test before visiting the virtual world and in the post-test they answered some questions regarding their experience about virtual realities in general, as well as computer skills.

6.3.1 Effect of Spatial Ability

As expected many test persons were unable to respond to all items of the Mental Rotation Test within the time allotted to complete the test. The evaluation was done as explained in the Subsubsection 5.3.2.1 and recommended by Vandenberg & Kuse (1978).

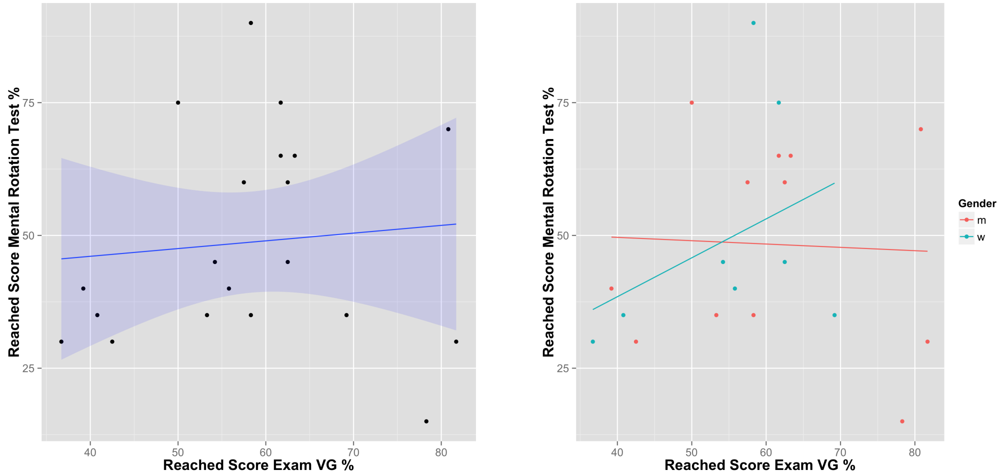
The data of the reached score in the Mental Rotation Test was like the exam score of the virtual group also approximately normally distributed, W = 0.9363, p = 0.204. The output of Pearson's correlation between the performance in the MRT (M = 48,75) and the reached score in the exam (M = 58.42) is t(18) = 0.4, p = 0.691. Therefore it can be concluded that there is no significant relationship between exam score and how well someone of the virtual group did in the Mental Rotation Test. The scatterplot in Figure 6.20a visualizes the correlation between the reached score in the exam and MRT. The second Figure 6.20b illustrates the correlation between the MRT and reached score of the male and female participants.

6.3.1.1 Gender Differences in the Mental Rotation Test

The dataset of the Mental Rotation Test of the male is approximately normal distributed, W = 0.913, p = 0.232, but the females' dataset is significantly different from a normal distribution, W = 0.81, p = 0.034. The outcome of the Wilcoxon rank-sum test indicates that the spatial ability of the female participants (N = 8, Mdn = 42.5) did not differ significantly from the male participants (N = 12, Mdn = 50), W = 45, p = 0.85.

6.3.1.2 Subdivision in a Low and a High Spatial Group

The participants of the virtual group were divided into two groups regarding their scores in the Mental Rotation Test. The low spatial group consists of participants with a score below the adequate score of 60% and the high spatial group comprises the persons above 60%. Twelve persons, six women and six men, fall into the low spatial group and eight



(a) Scatterplot MRT vs Reached score

(b) Scatterplot MRT vs Reached score, male = red, female = green

Figure 6.20: Scatterplots of the Mental Rotation Test

participants reached the high spatial group, from whom two were female. This corresponds to a quarter of the female participating reached the high spatial group and a half of the male.

The reached score of the exam in the low spatial group, W = 0.9368, p = 0.4577 and the data of the high spatial group, W = 0.8429, p = 0.081, are both approximately normal distributed. An independent t-test revealed no statistical significant difference of the reached exam score between the low spatial group (M = 56.04 %, STD = 14.95) and the high spatial group (M = 61.98 %, STD = 8.73), t(18) = -1.01, p = 0.327, r = 0.256. Therefore the difference in the exam of approximately 6% between the low and high spatial participants of the virtual group is statistical not significant.

6.3.2 Effect of Experience with Games and Virtual Worlds

The data set of experience in virtual realities is composed of; concrete experience in creating or handling with VR's, experience with video or computer games, use of computer in general and computer skills such as programming skills. This data set is plotted against the reached score in the exam in Figure 6.21. The data set of the experience in virtual worlds is approximately normally distributed, W = 0.9301, p = 0.1554. The output of the Pearson's correlation between the experience and the reached score in the exam is t(18)

= 1.2522, p = 0.2265. Consequently the computer skills and the experience with games and virtual realities did not have a significant influence on the performance in the exam.

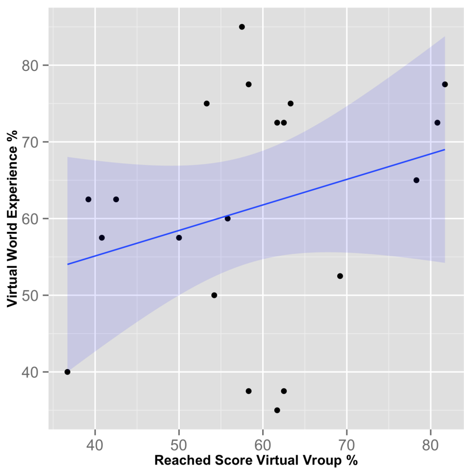
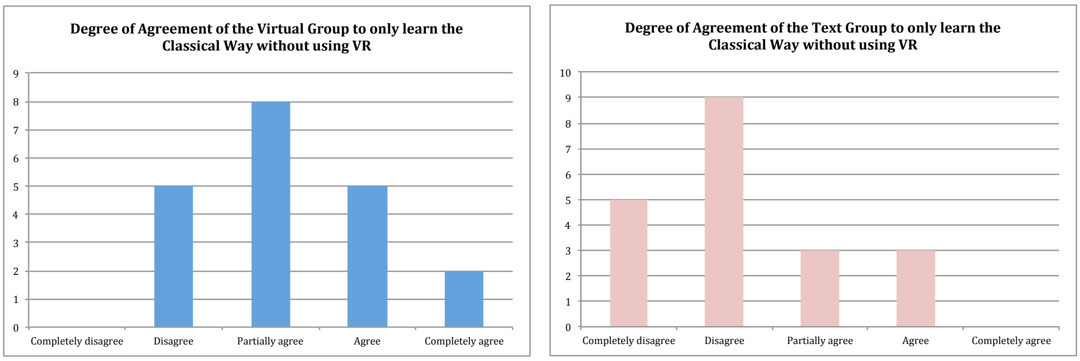


Figure 6.21: Correlation of the experience with virtual worlds and reached score

6.4 Qualitative Data

In the elicitation phase the research aims at finding out the basic and commonly shared criteria that users use in evaluating the virtual world. To this end, the collected data was analyzed and grouped the users' personal constructs into clusters - called dimensions - according to a semantic similarity principle. The feedback and participants' opinions were collected in the post-test, were they had to respond to some statements and answer open-ended questions. With the feedback questions the engagement and interest taken by participants in both groups was investigated.

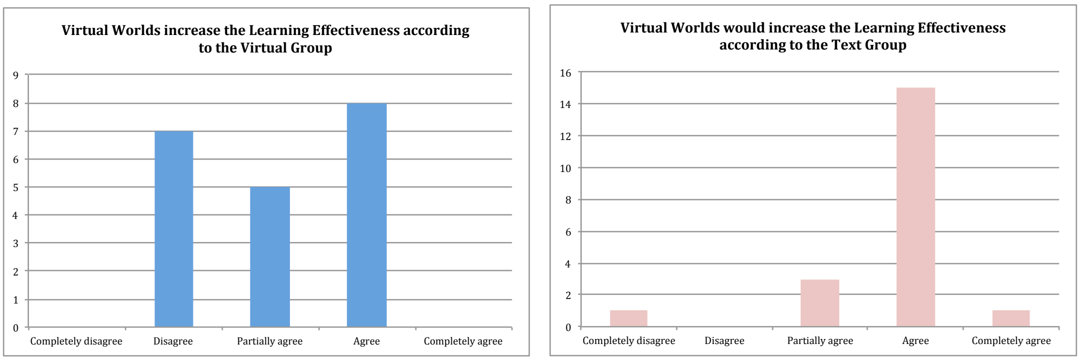
The evaluation of the feedback about the exam difficulty shows that the participants found the exam medium difficult. Between the virtual group and the text group there is no considerable difference. This is different for the statement "I prefer to learn the classical way with books, papers, etc., instead of using virtual worlds as a learning aid". As visible in Figure 6.22b the text group mostly disagreed with this statement and a quarter even completely disagreed. In contrast, most of the participants of the virtual group partially agree and one third even agrees or completely agrees to the statement as illustrated in the bar chart 6.22a.



(a) Agreement of the virtual group *(b) Agreement of the text group*

Figure 6.22: Level of agreement to use virtual reality as learning aid

The feedback questions about the learning effectiveness shown in the charts 6.23 are not comparable one to one, because the virtual group has gotten a first experience with virtual worlds as a learning method, but the text group can rate this statement only with reservations. 40% of the participants of the virtual group agreed that using a virtual environments increases the learning effectiveness, but also 35% disagreed and the remaining 25% agreed partially. On the other hand the text group reveals a different feedback, they agreed at least to 80% to the statement about learning effectiveness.



(a) Learning effectiveness according to the virtual group

(b) Learning Effectiveness according to the text group

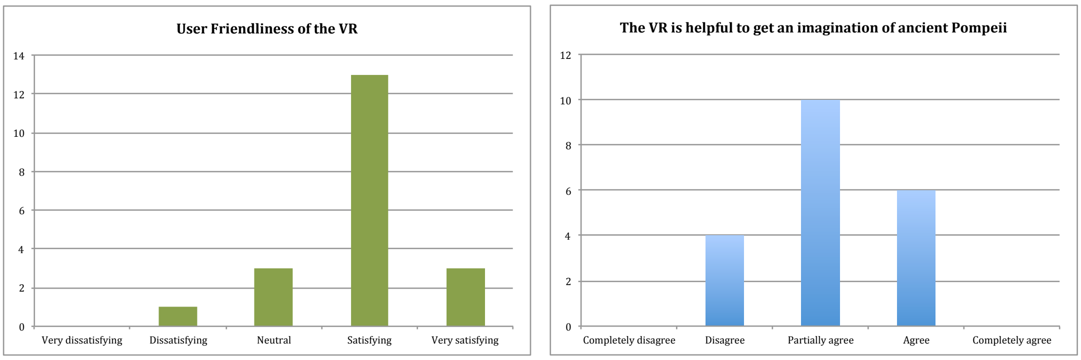
Figure 6.23: Learning effectiveness from the point of view of the test groups

6.4.1 Evaluation and Feedback of the Virtual Group

In the post-test the virtual group participants had to answer some questions about their satisfaction of the virtual world. The satisfaction was figured out of following six questions; the overall impression, user friendliness, imagination of ancient Pompeii, learning effectiveness, presence in the virtual world and understandability of the information. Over these questions the median is at the second highest possible gradation out of five possible classifications, ranging from "very dissatisfying" to "very satisfying". Long story short, the participants were generally satisfied with the virtual world of ancient Pompeii.

In regards to the navigation and user activities in the virtual world the researcher did not notice any problems during the experiment. As seen in the charts of Figure 6.24a 80% found the user friendliness of the virtual reality at least satisfying and only one person was dissatisfied by the ease of use. Hence it can be assumed that the navigation and control in the virtual city was not disrupting the learn process.

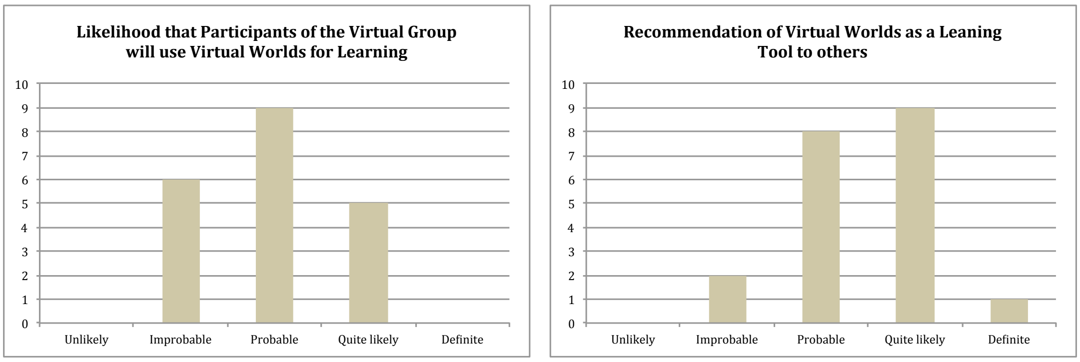
Further, 80% of the virtual group participants at least partially agree that the virtual learning environment was very helpful to get an imagination of the ancient city of Pompeii and the Romans. One fifth disagrees with this statement and did not consider the virtual world any helpful for imagining Pompeii, as can bee depicted in the Figure 6.24b.



(a) User friendliness *(b) Using of VR to get an imagination*

Figure 6.24: Level of agreement to use virtual reality learning aid

The answers to the question how likely it were that the participants would use and recommend virtual worlds as a learning method are seen in Figures 6.25. 70% of the participants would at least probable use virtual realities if they had the chance to learn with it and about a quarter would quite likely use it, which can be seen in the bar chart 6.25a. In this context it is fairly interesting to note that almost half of the test persons would recommend virtual worlds as a learning tool to others quite likely or even definite. Even 90% would at least probable recommend virtual reality environments (Figure 6.25b).



(a) Likelihood of using VW *(b) Likelihood of recommendation of VW*

Figure 6.25: Feedback of the virtual group about virtual reality

On the whole the researcher's informal observations noted that the participants of the virtual group were very engaged and focused during the interaction with the virtual environment and they were enthusiastic and largely immersed in the virtual ancient city of Pompeii.

6.4.1.1 Suggestions for Improvement of the Virtual World

Most of the participants of the virtual group had a great and excellent impression of the experiment and of the virtual world of Pompeii. In the post-questionnaire the participants could write suggestions for improvement and they provided encouraging comments. A lot of persons took the chance and gave a lot of interesting and constructive ideas and proposal how the virtual reality environment could be improved and enhanced.

A participant wrote: "Pompeii seems a bit empty. It was quite possible that the presence of residents would exert a positive effect on the learning effectiveness, because it would seem more realistic." This statement is supported by other participants, who suggested more reality is reached with important people such as emperor Augustus or governor and with conversations and actions with the local population. More activity and vividness could also be generated with stray dogs and other animals and also with marketplaces where the virtual people meet and chat. One person wanted more action in the form of simulated scenes of the volcanic eruption and what was happening to the population and how they escaped from Pompeii. Another person suggested including pictures from the real world and show short video clips about various events such as the outburst of Vesuvius. A student wrote there should be more time left to truly explore the virtual city and there should be more labelling about certain structures or roads and even some more detailed 3D visualizations about certain buildings. Another interesting idea is addressing more senses like acoustic in the form of an audio file on which the user has to click or talks with residents.

Adverse comments made by the participants of the virtual group were not large. Some minor technical issues are to mark better the learning path in the virtual world. The signs should be more distinctive and at some locations brighter and the text in larger letters. When pressing the forward and the left or right arrow keys simultaneously the game slows down and flickers a little.

The lack of residents, so called virtual agents, was a conscious choice of the researcher, because it would have been a much greater effort to create such a world and it would have gone beyond the scope of this thesis. This massive engagement in feedback shows that the participants were really interested and excited about the idea of learning in a virtual reality environment.

6.4.2 Feedback of the Text Group

One aspect which was more important for the participants of the text group than for the virtual group was the time limitation for reading the text. The time required for reading is individually different, so around 65% of the test persons stated they had little but enough time. Only one had too little time to read and study the text content. For 30% the amount of time was sufficient.

Three quarters of the text readers agreed to the statement "the text about Pompeii and Rome was very understandable and clear". All of them at least partially agreed and 35% even completely agreed to the claim, therefore it can be concluded that the participants did not have trouble in understanding the text document. The influence of the mother tongue to the comprehensibility of the text can be neglected, because the only person with another mother tongue than German found the text completely understandable and clear.

6.5 Summary of the Results

This chapter has described the experimental evaluation of two learning methods; reading a text comparing to learning through a virtual worlds. The concept of learning in a virtual reality environments was introduced and tested to its improvements of learning effectiveness. The user study outlined a significant better performance achieved by the virtual group over the text reading group. The participants' demographic attributes as described in Section 5.2 and the formulation of the tasks revealed no generally significant effect on participant's performance in the exam.

7 Discussion

This Master's thesis creates, presents and evaluates a virtual world of ancient Pompeii based on pedagogical theories and shows how it is used for studying history about Romans. Within this thesis, an experimental evaluation of the learning effectiveness of a virtual reality environment was conducted. A text group who read a text document was compared with the virtual group learning through the virtual world in order to examine its learning effectiveness. This was evaluated with a written exam for every participant in each group. This Chapter discusses the results, interprets them and takes up the leading question and research questions of this thesis defined in Chapter 3 and tries to link this findings into the literature and current issues. As described in the related literature in Section 2.4 a virtual environment should ideally facilitate learning. This is indeed the case for the conducted experiment and the presented study can be embedded in the educational technology research, which is conforming to Winn (2002) concerned with the study of learning in complete, complex and interactive virtual learning environments. The researchers Mortara et al. (2013) highlighted the educational objectives of games in the domain of cultural heritage and analysed the complex relations between genre, context of use, technological solutions and learning effectiveness.

The educational objectives of this thesis can also be embedded in the domain of cultural heritage. Virtual learning environments as the one generated could also be used as an informal learning tool in museums or cultural centres. For further research on virtual agents the authors Bogdanovych et al. (2009) even suggested the development of virtual heritage applications as normative multiagent systems.

7.1 Virtual Worlds versus Traditional Learning

The experiment of comparing the two learning methods was motivated by a contribution of virtual worlds for teaching in high schools. Our prediction was deduced from the literature and assumed that the stimuli (VW or Text) of learning the facts about history would affect the performance in the exam. This prediction is packed in the first research question of Section 3.1. The evaluation revealed a statistical significant difference in the performance between the text group and the virtual group. The virtual group outperformed the text group in the reached score of the exam. This outcome confirms findings from previous studies (e.g. Bogdanovych et al., 2009; Winn & Windschitl, 2002). The difference between the two groups could be due to the stimulation of more senses when visiting a virtual reality environment. It is also possible that the historical information in the virtual world is clearer and it comes in portions not as a whole like in the text. The user walks and acts in the virtual world and then learns something about a fact and then walks and acts again. This variety of actions of the users could influence the process of receiving the information and affect that the users learn more efficient. Participants in each group had the same procedure of experiment and they learnt on their own, wrote the exam on their own and had an equal amount of time. Therefore the influence that test persons from one group met utterly other conditions and procedure than the test persons from the other test group can be excluded. This is not the case for the study of Wrzesien & Alcañiz Raya (2010), where the students of the text group learnt and wrote the exam in one large group. For our study we followed their advice that same group size of the test groups should be applied for future experimental design. The statement of Papastergiou (2009), that the attractiveness and complexity of the virtual world could be a distraction from the learning objectives, is not true for this study. We assume the navigation in the city and the immersive world did not distract the participants but rather the participants appreciated the visual features and could focus on the information presented about Pompeii at the same time. Thus, the connection of the received information with the visual input seems to have a positive and constructive impulse on the learning performance.

7.1.1 Type of Question

The participants of the virtual group performed significantly better in the multiple choice questions than the participants who read the text. For the other questions the two groups reached similar scores. When classifying the questions into visual and textual questions also no statistical significant difference was identified. No such virtual world study analysing the type of question of the exam has been conducted so far, therefore comparable results from the literature are lacking. A reason why there is a significant difference only for the multiple choice questions could be that the virtual group persons could identify better the right answer, because they learnt the information in portions and in activities. On the other hand the participants of the text group were not able to pick out the right answers, because maybe they received too much information at once when reading the text. The similar score for the other questions could be that the text group participants could express themselves better or at least equally good in the open questions. For the open questions the ability how to express themselves is more important than they way the person receives the information. As a matter of course these are just personal assumptions and ideas. However, further research is needed to determine these assumptions.

7.1.2 Spatial Ability

According to Thurstone (1973) spatial ability is one of the main components of human intelligence. Conforming to Eliot (2002) spatial ability is especially important for several educational programs and trainings and he even stated that spatial ability is pervasive, which means that we need it for almost every activity in everyday live. Dünser et al. (2006) argued that virtual worlds are very useful tools for training spatial ability. The general importance of spatial ability was taken into account for this study and tested. The research question whether high spatial participants of the virtual group would perform better than low spatial people can be denied. One possible reason for this result might be related to the fact that the participants are following a predefined learning path and therefore the visit of the virtual city does not require a well trained spatial ability and orientation. On the other hand, the conducted Mental Rotation Test might not fully query the skills needed to cope with such a virtual reality environment. The conducted Mental Rotation Test revealed no significant difference between females and males, although Moffat et al. (1998) stated that numerous studies had indicated that males tend to outperform females on a diverse set of spatial tests that require manipulations and transformations of geometric figures and forms as in the study of Dabbs et al. (1998).

7.1.3 Sense of Direction

In agreement with Darken & Peterson (2002) navigation tasks are essential to any environment that demand movement over large space and in the opinion of Hegarty et al. (2002) the Santa Barbara Sense of Direction Scale (SBSOD) predicts these abilities very well. Sense of direction can be useful in a virtual learning environment, because according to Darken & Sibert (1996) people have generally severe problems wayfinding in virtual worlds. The results of this study show no significant difference between the two test groups, therefore it can be excluded that that the virtual group reached a higher score in the exam due to a better sense of direction. However, the male participants had a significantly higher score than the female participants. On the report of Coluccia & Louse (2004) this is not unusual, because most of the time males perform better than females in spatial orientation tasks in virtual environments, but according to the authors males generally estimate themselves to be more able in orientation and they show greater confidence in their own ability than females. On the contrary Schmitz (1997) explained that females report a higher level of spatial anxiety than males, related to the fear of getting lost.

7.2 Preference and Motivation

A further research question dealt with the statement that the participants of the virtual group would show more engagement and satisfaction, in accordance with Ang & Wang (2006) who explained that virtual learning environments enable the teacher to present scientific knowledge in a way that is more appealing to students than traditional textbooks. The authors Payne et al. investigated already in 1992 the instructional potential of a pure version of animated demonstrations, which are used in video games and they noted the intrinsic motivation inherent in games. This statement is confirmed by the authors Tüzün et al. (2009) who compared the motivation of two learning methods and found that students demonstrated higher intrinsic motivations learning in the game-based environment. These findings are consistent with the presented user study. Contrary to Tüzün et al. (2009), in this thesis no quantitative and statistical evaluation of the motivation and feedback was completed. However, the motivation of the participants was observed directly by the researcher, which was also done in the work of Ang & Wang (2006). After the expiration of the learning time in the virtual world, the participants were keen on experiencing more of the city and they asked a lot of questions out of curiosity after the experiment and they optionally and diligently wrote suggestions for improvement. In our opinion these many written comments and interests, even after 50 minutes of an exhausting user study, shows clearly a high motivation for experiencing the virtual world for educational purposes. On the contrary the most participants of the text group found their experiment a demanding and monotonous procedure. They were not really motivated to complete it, even though all agreed that the text was very understandable and clear to read. The people that took part in the virtual group reported enjoying learning much more than reading a text. Further they can imagine using this type of learning method again. This findings are very similar to the study of Wrzesien & Alcañiz Raya (2010) who reported that students from the virtual class enjoyed the class more and were more engaged than students from the traditional class. However, in the work of Wrzesien & Alcañiz Raya (2010) the traditional group performed their learning class in one large group and the virtual group existed as group of four. Therefore the perception and experience in the virtual world is influenced by others and the students were not able to learn on their own. The different size of the test groups is also not ideal for comparing learning effectiveness of the two test groups. In our opinion the preference of the virtual class in the study of Wrzesien & Alcañiz Raya (2010) could be due to the fact that the students experienced the virtual world as a group and also because this learning approach was an exciting novelty. As stated in Prensky (2003) the motivational aspects of a virtual learning environment are essential during the learning process. Therefore we think this method of learning can be a really good way of teaching historical issues to children, students and adults in general.

With this concept of learning in a virtual world one can kill two birds with one stone, on one hand the persons will enjoy the virtual world and on the other they will also learn from it. To measure the motivation of the participants and make it more comparable, a motivation scale could be developed based on the work of Lepper et al. (2005) and used in the research of Tüzün et al. (2009). However, we think we can safely say that such a motivation scale would confirm the higher motivation for the virtual learning approach.

The last research question analyses if the participants of the virtual group will recommend this learning method. Over 90% of the virtual group participants would recommend to use virtual learning environments as a learning tool. In related projects the participants were not directly asked to give a statement about their recommendation. Therefore an one-to-one comparison to other literature is not possible, just a linkage to similar findings, like the work of Wrzesien & Alcañiz Raya (2010), in which the students were disappointed when the virtual learning class was over and they were very keen on experience more topics in virtual environments. Also Bogdanovych et al. (2012) stated that the virtual group was more engaged and willing to spend more time learning in such a virtual world.

7.3 Limitations and Improvements

As a matter of course this study has limitations. For example the text group could also have done a Mental Rotation Test to truly make the two groups comparable regarding the spatial ability and the experiment procedure of the two test groups were even more similar.

7.3.1 Feedback Statement

As seen in the Section 6.4 most of the participants of the virtual group at least partially agreed that they would prefer learning the classical way with using virtual worlds as a learning aid, rather than without using virtual environments. The agreement and enthusiasm of the text group for using virtual worlds as a learning aid is even higher, even though they did not utilize and learn in the virtual city of Pompeii. This finding is peculiar and means that the participants are a little less confident about this method after interacting and learning in the virtual world, than persons who did not learn through the virtual reality environment. We think the persons who read the text have the misconception that in a virtual world the learning process goes very smoothly and well and happens by the way. The virtual group participants realized that learning in a virtual world also needs concentration and full attention of the user, as traditional methods. Still, this finding needs further investigations so that comparisons can be made.

Further, we consider that the post-test questionnaire and feedback statements should be more detailed in future user studies. It should be noted that the most negative feedback comments from the virtual group concerned the control system of the first person controller. Further the reading parts of the learning path in the virtual world could be reduced and more graphics, videos, visualization should be included. The application could be improved by transforming some more of the important information into an interactive game, so the user feels a "sense of place". Conforming to Bellotti et al. (2009) this is important in order that the user can experience the interactions, roles and narratives more realistically and perceive the notions provided by the game as credible.

7.3.2 Other Limitations and Particularities

7% of the participants of the virtual group had, among other fields, a background in computer science and they reached a mean score of 71.7% in the exam. This clearly reveals a trend that these persons could be better by learning using a virtual learning environment. However, for verifying this finding further investigations focusing on this aspect are needed.

7.3.3 Improvement of the Virtual World

As explained in the Subsection 6.4.1 the participants of the virtual group could give a feedback and write some suggestions for improving the virtual world of Pompeii and educational aspects. In conjunction with these ideas and own thoughts some useful additions for the virtual environment are summarised. According to MacEachren et al. (1999) the four I's factors introduced in Chapter 2 contribute to the virtuality of a virtual reality environment. For further investigations the presented virtual learning environment of Pompeii could be developed and improved by the factor of the intelligence of object. The authors Bogdanovych et al. (2012) progressed the idea of Maïm et al. (2007), who had simulated an ancient city life by populating the scene and the crowds were able to exhibit particular behaviours relatively to their location in the city. Bogdanovych et al. (2012) included so called virtual agents in their virtual world of Uruk which were capable of simulating everyday life of ancient inhabitants, which among other things included communicating with other virtual agents. Further the agents acted as autonomous tutors and were capable of sensing the user through their avatars and interact with them both in terms of performing joint actions and through written communications.

We believe, that the number of items, events and situations (more objects on the streets like signs, garbage, animals, etc.) should be increased and virtual agents in the form of virtual humans with intriguing and authentic roles (e.g. blacksmith, soldier, senate) should be added. These implementations make the environment richer and more challenging and exciting to explore. A rewarding upgrade would be that the participants could also converse with these virtual humans present in the virtual city. These virtual humans could be aware of their daily routines and tasks and interactions with the participants could act as learning source. The presented learning path in the virtual city of Pompeii can definitely be improved and more interactivity implemented. In addition, based on the idea of the cybercampus of Prasolova-Förland et al. (2006), social interactivity with other learners could be enabled and virtual meetings with others could be arranged. As claimed by Corbit (2002) activity and social interaction are important for education. The author stressed the relevance of the work that must still be done in virtual reality environment design and game-using education to exploit all potential of virtual learning environments and make them useful in supporting knowledge acquisition and skill development.

Further also so called microGames (mGs) could be integrated to increase the dynamism and address the stimulation. MGs are simple, short games that focus the player's attention on a particular item that she/he may find during exploration of the virtual world. Such microGames can vary in content and be placed at different locations and situations. The idea is that they can be played immediately, so that the player can focus on their content rather than on learning how to play them (Bellotti et al., 2009).

Generally new technologies used in education must be carefully chosen and applied in order to help students not only enjoy the aesthetical aspect but also to learn while playing. As believed by Noellenburg (2007) a visualization system that is too complex for its users has rather negative than positive effects. As reported by Wrzesien & Alcañiz Raya (2010) evaluations are the best way of confronting the developed application with reality. Last but not least the results may also further depend on factors that may not be directly detected and analysed. It is just not possible to analyse a virtual world in a vacuum if its educational impact has to be determined.

7.3.3.1 Learning Objectives

Other issues related to the evaluation of the learning effectiveness should also be studied further. In the presented study mostly a *declarative type of knowledge* (facts) was considered although the learning process does not only involve facts but also *procedural knowledge* and *strategic knowledge*. According to Wrzesien & Alcañiz Raya (2010) *procedural knowledge* is how to do the described action and *strategic knowledge* refers to the transformation of learned information to other situations.

Affective learning objective could also be taken into account for further studies using virtual worlds as a learning method. *Affective learning objectives* deal with attitudes, motivation, values, willingness and interests in human behaviour (Haubrich et al., 2006; Zenke & Schaub, 2007). For the presented study this could be the promotion of the protection of the archaeological excavations in Pompeii and its importance of preserving it for future generations. James Paul Gee is one of the primary proponents for games in education and in the interview with Krotoski (2005) he explained that nowadays the idea that learning an area such as biology is all about learning a bunch of facts and repeating them back on tests. For James Paul Gee learning an area like biology should be about learning how to play the game of biology, that is, learning to think, act and value like a biologist (of a certain sort) by doing biology with support and mentorship from people who really know how to be and do biology. As claimed by Bellotti et al. (2009) it is possible to support learning through an entertaining experience, which is key to attracting a wide demographic that is currently not involved in educational activities during their leisure time. However, in our thesis we focused on the possibility of using a virtual world for teaching and learning in a school additional to the usual lessons and the findings of Bellotti et al. (2009) are also useful for this kind of study.

7.3.3.2 Long Term Memory

The conducted user study only makes use of the working memory, which is defined in the work of Baddeley (2012). For testing the influence of the learning method on the long term memory the same exam could be handed out to the participants one or two months after exploring the virtual world or reading the text. In this manner, it could be examined whether the virtual group also performed better after some time has passed, or if the participants from the text group could memorise the read text longer. It would be also interesting to see if learning in the virtual environment concerned the episodic memory. As claimed by Clayton et al. (2007) the episodic memory refers to our ability to recall specific past events about what happened where and when and this memory is explicitly located in the personalised past and accompanied by the feeling of remembering. Due to the lack of time, this thesis could not investigate these aspects.

7.4 Virtual Reality Environments for Teaching and Learning

In 1996, McGrenere reported that the common theme in the literature for educational games for both electronic and non-electronic was, that these games were considered successful only, if they are at least as effective as traditional classroom education. This trend in research was confirmed by Virvou et al. (2005) who stated that this kind of comparison implies that games are not meant to be included in traditional classroom education, but rather they are meant to replace it. As well as the work of Wrzesien & Alcañiz Raya (2010), in our thesis we did not assume that the new technology is determined to replace traditional learning. On the contrary, virtual learning environments can be used to complement the traditional method and it can be used purposeful to make learning objectives easier and clearer to understand. The virtual world of Pompeii is not meant for an every day classroom use, but rather it can be used in an ICT lesson as an addition to the facts learnt in the classroom. In our opinion there is no single best way to teach, therefore such a virtual world can contribute to a diverse, rich and stimulating learning and teaching environment.

This statement is consistent with other authors who explained that a virtual learning environment should serve only as a supplement to its real prototype and the corresponding educational and administrative facilities (Prasolova-Förland et al., 2006). Prasolova-Förland et al. (2006) argued that the challenge in this context is in choosing educational topics and concepts where 3D visualization and simulation will have clear advantages compared to the more traditional presentation modes. Ang & Wang (2006) reported that virtual worlds could be used to support practical teaching methods, where visualization in such environments may provide a more memorable learning experience, because the user is not a passive information receiver any more. The participants of the virtual group learnt the information independently and in a self-paced mode. Using this virtual world for an ICT lesson in a computer room with several students, the role of the teachers became guide and manager rather than lecturer (Tüzün et al., 2009). The professor Baum (2002) stated that teachers will do best when they use styles with which they can be successful. This means that first the teachers have to get to know the concept of using virtual worlds as a learning method and they have to become acquainted with it. Of course teachers do not have to learn the implementing techniques and creating skills of such virtual worlds. For that, manuals for designing a virtual reality environment should be created by professionals, as the one proposed by Dylla et al. (2009), who concluded that procedural modelling methods provide a robust framework for virtual city reconstruction for scholarly models.

In the opinion of Wrzesien & Alcañiz Raya (2010) a virtual environment can be utilized as a virtual field trip with a class. In the case of ancient Pompeii it is not possible to organize a real field trip, just to the excavations and ruins. Therefore a virtual Pompeii visit could be an interesting option to consider. Such a virtual learning environment can also be developed to a platform for educational purposes, where students can meet and chat and learn with each other, similar to the work of Wiecha et al. (2010) presented in the related literature in Section 2.4. The mentioned issue of Boulos et al. (2007) to use virtual reality environments for distance universities is arguable, but we think that a virtual world like the one of Pompeii is not applicable for this issue, because we think virtual worlds are more of a learning aid than a substitute. However, for that further investigations are necessary. Virtual worlds can also be used in a geography lesson hold as an ICT lesson at a grammar school. Typical physical geography topics as glaciology or geomorphology are definitely possible to teach and learn in a virtual reality environment. For example, the student is located in a alpine region and can walk along a hiking trail towards a glacier and learn about different natural phenomena.

8 Conclusion

The conducted study shows that virtual worlds are an effective method for satisfying and engaging people for learning. The defined and presented concept of learning in a virtual world was tested with a case study using the recreated virtual city of ancient Pompeii and compared to a more traditional learning method. For that a group of participants read a text document and the other test group received the same information by exploring the virtual environment. After learning, both groups had to complete the exact same exam for getting comparable data. The result revealed that the virtual learning method has crucial aspects for successful learning. The experiment outlined a statistical significant better performance achieved by the virtual group over the text group. Participants of the virtual group reported high enjoyment and motivation and they estimated a considerable learning effectiveness. By this means the users not only enjoy a fantastic graphical representation but also the users' learning effectiveness are increased. Even though the statistically significant higher learning effectiveness of the virtual environment, there is still a need for improvements in this area. New technologies and approaches with virtual reality environments used for educational purposes must be applied carefully after profound scientific research is completed. The virtual learning environment does not necessarily need the latest and the most impressive software and hardware. It is much more important that the learner can concentrate on the content that the virtual world is really created for.

James Paul Gee stated in the interview of Krotoski (2005) that the US military uses very sophisticated games to teach their soldiers. This means that governments already know about the benefits of virtual worlds, they just have to begin encouraging educationalists to use such serious games. This formal discussion about embedding virtual worlds as a learning method in the curriculum and using such learning environments in information and communication technology (ICT) lessons is connected to other discussions (e.g. Ang & Wang, 2006; Bogdanovych et al., 2009; Wrzesien & Alcañiz Raya, 2010). It will be needed to do thorough analysis on what opportunities this learning method provides for modern teaching, like ICT lessons. Further also the limits or maybe even dangers of this approach have to be assessed. In agreement with Allison et al. (2012) a successful realization of such a concept of learning requires a collaboration of various disciplines like pedagogue, graphic designer, computer scientist, education authorities, and many more.

As already noted by Fuhrmann & MacEachren (2001) further research on cognitive aspects of virtual worlds and on pedagogical correct implementation and presentation are required. However, current studies and conferences referring to virtual worlds focus on how the research can be applied into industry (Malta, 2014). As can be taken from the literature (e.g. Carrozzino & Bergamasco, 2010; Cerato & Pescarin, 2013) and as can be concluded from the conducted user study, virtual learning environments, as the one in this thesis, can provide a collaborative environment for history students, high school students and museum visitors.

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9 Appendix

Declaration of Consent

Procedure of the User Study of the Virtual Group

Text of the Text Group

Exam about Romans for both Test Groups

Santa Barbara Sense of Orientation Scale - German Version, as used for the User Study

Mental Rotation Test

Einverständniserklärung zur Teilnahme an der Studie: Lernwirksamkeit von virtuellen Welten

Ich ______________________________ (Nr.) erkläre mich damit einverstanden, an diesem Forschungsprojekt teilzunehmen, welches von folgender Person durchgeführt wird:

Matthias Mahrer
matthias.mahrer@uzh.ch

Ich wurde vom unterzeichnenden Testleiter mündlich und schriftlich über die Ziele, den Ablauf der Studie, über die zu erwartenden Wirkungen, über mögliche Vor- und Nachteile sowie über eventuelle Risiken informiert.

Ich habe verstanden, dass der Zweck dieser Studie, die Untersuchung der Lernwirksamkeit einer virtuellen Welt im Vergleich zu herkömmlichen Lernmethoden ist. Weiter habe ich verstanden, dass meine Studienteilnahme eine 15-minütige Interaktion mit einer virtuellen Welt und weitere zehn Minuten für das Ausfüllen eines Fragenkatalogs mit sich bringt.

Meine Fragen im Zusammenhang mit der Teilnahme an dieser Studie sind mir zufriedenstellend beantwortet worden und ich fühle mich bereit für die Interaktion auf dem Geowall-Screen.

Ich hatte genügend Zeit, um die Entscheidung zu treffen, an der Studie teilzunehmen und ich weiss, dass meine persönlichen Daten nur in anonymisierter / pseudonymisierter Form gespeichert werden. Diese Studie bleibt völlig anonym. Daher werde ich später nie in irgendeinem Prozess dieser Forschung identifiziert werden können.

Ort: _________________________ Datum: _____________

E-Mail-Adresse Teilnehmerin / Teilnehmer: ______________________________

Unterschrift (Teilnehmerin / Teilnehmer): ______________________________

Unterschrift (Testleiter): ______________________________

Einverständniserklärung zur Teilnahme an der Studie: Lernwirksamkeit von virtuellen Welten

Ich ______________________ (Nr.) erkläre mich damit einverstanden, an diesem Forschungsprojekt teilzunehmen, welches von folgender Person durchgeführt wird:

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Ich habe verstanden, dass der Zweck dieser Studie, die Untersuchung der Lernwirksamkeit einer virtuellen Welt im Vergleich zu herkömmlichen Lernmethoden ist. Ich habe verstanden, dass ich in der Textgruppe bin und meine Studienteilnahme ein 15-minütiges Lesen und Lernen eines Textes beinhaltet. Weiter bringt das Experiment zehn Minuten für das Ausfüllen eines Fragenkatalogs und das Beantworten von Feedbackfragen mit sich.

Meine Fragen im Zusammenhang mit der Teilnahme an dieser Studie sind mir zufriedenstellend beantwortet worden und ich fühle mich bereit für das Experiment.

Ich hatte genügend Zeit, um die Entscheidung zu treffen, an der Studie teilzunehmen und ich weiss, dass meine persönlichen Daten nur in anonymisierter / pseudonymisierter Form gespeichert werden. Diese Studie bleibt völlig anonym. Daher werde ich später nie in irgendeinem Prozess dieser Forschung identifiziert werden können.

Ort: ______________________ Datum: ______________

E-Mail-Adresse Teilnehmerin / Teilnehmer: ______________________

Unterschrift (Teilnehmerin / Teilnehmer): ______________________

Unterschrift (Testleiter): ______________________

Procedure of the Pompeii User Study - Virtual Group

By Matthias Mahrer, April 4 2014

Preparation - Before Participant arrives (10min)

- Turn on the computer in the Geowall
- Check if the VR and the VR Trial is working
- Turn off the screen (the participant should not see the visualization)
- Prepare the form sheets and the test sheet
- Open the Mental Rotation Test on SurveyMonkey on the MacBook

Welcoming the participant (1min)

- Let the participant into to Lab
- Cell phone in silent mode
- Assign the participant an ID (relevant! Write it on the consent form)
- Briefly explanation of the topic and procedure
- Explain that we start with a Mental Rotation Test

Step 1: Mental Rotation Test on Survey Monkey (8min)

- Let the participant sit down in front of the MacBook
- Do the Intro Test on SurveyMonkey (*MM - Mental Rotation Test, Intro*)
- Ask if there are any questions
- Open the Mental Rotation Test on Survey Monkey and insert the ID of the participant in the beginning (*MM - Mental Rotation Test*)
- Do the Mental Rotation Test (**6min**)
- After 6 min finish and save the test by closing it

Step 2: Trial Run in Virtual Reality: Set up computer, Introduction and Training period on Unity (3min)

- Participant takes a seat on the provided chair (in front of the geowall screen)
- Hand out the 3D glasses
- Explanation how to move around in the VR
- Follow the yellow arrows and click on the blue hand-arrow (pointer) to get information
- Turn on the screen, if needed log in again
- Open the *Trial Pompeii*, the participant puts on the 3D glasses
- Start the VR, make sure the control system is working
- Let the participant do the parkour in the VR Trial (ca. 3min)
- Stop the trial period
- ***Signing the Declaration of Consent***

Step 3: Experiment, Learning process in the VR (17min)

- Make sure the participant is at the starting point in the VR and she/he has the 3D glasses on
- Let the participant walk around the VR following the learning path (yellow arrows) and collect information (**17min**)
- Stop the learning phase after 17 minutes, participant takes off the 3D glasses
- Turn off the screen

Step 4: Written test (7min)

- Participant takes a seat at a table
- Hand out the ***Test sheet about Pompeii***
- The participant answers the question by writing on the test sheet (**7min**)
- Stop the test after exact 7 min

Step 5: Feedback and Personal information (12min)

- Open Survey Monkey on the MacBook
- Open (*MM - Virtuelle Realität - Allgemeine Fragen*)
- Participant fills in the Feedback and does the Santa Barbara Sense of Orientation Scale

See off Participant (1min)

- Note if participant wants to be informed about the findings of this study
- Check the forms and SurveyMonkey again
- To thank the participant and say good bye

Final Part, after Participant left

- Deposit the test sheet correctly in the folder (numerically according to the ID)
- Turn on the screen and make sure the avatar is at starting point
- After VR is ready for the next experiment round, turn off the screen again
- Make a copy of the test
- Download the results from SurveyMonkey, back it up

Pompeji eine Stadt im Römischen Reich

Pompeji - Geschichte und Ausgrabung

Aufstieg von Pompeji

Pompeji lag am Golf von Neapel und am Fusse des Vulkans Vesuvs, wurde von den Griechen gegründet und stand bis 525 v. Chr. unter ihrem Einfluss und kam danach unter den Machtbereich der Etrusker, um diesen nach fünf Jahrzehnte wieder an die Griechen zu verlieren. Von 420 v. Chr. bis 290 v. Chr. stand Pompeji unter samnitischer Herrschaft. Nach den Samnitenkriege mussten sich jedoch sämtliche samnitische Städte dem römischen Bündnissystem anschliessen und aus den Pompejanern wurden loyale Bürger, die den Interessen Roms dienten. Rom war zu diesem Zeitpunkt noch keine Grossmacht, doch beherrschte die Stadt am Tiber ganz Mittelitalien und übte durch ihre staatliche Geschlossenheit Einfluss auf die umliegenden Gebiete aus.
Pompeji lag in der Nähe des Flusses Sarno, an welchem ein kleiner Hafen entstand, in dem Waren aus dem fruchtbaren Umland verschifft wurden, welches durch frühere Ausbrüche des Vesuvs zustande kam und Getreide, Weintrauben und Olivenbäume wuchsen.
So entwickelte sich die kampanische Stadt Pompeji innerhalb weniger Jahrhunderte zu einer wohlhabenden Handelsstadt, was unter anderem durch Bauten ersichtlich wurde.

Jeden Sommer flüchteten reiche Bürger aus der schwülen Enge Roms nach Pompeji. Die befestigte Stadt wuchs. Es wurden Thermenanlagen errichtet und Wasserleitungen verlegt. Pompeji verfügte über ein Theater, ein Odeon und eine Arena. Die Römer sprachen auch der fleischlichen Lust zu, was bei den Ausgrabungen durch die Entdeckung von 13 öffentlichen Bordellen dargelegt wurde. In den Garküchen - den Thermopolia - nahmen die Bürger eine schnelle Mahlzeit im Stehen zu sich.

Der Untergang von Pompeji

Im Jahre 62 n. Chr., als Pompeji circa 8'000 bis 10'000 Einwohner hatte, wurden weite Teile der Stadt durch ein Erdbeben zerstört. Das Geld aus Rom floss spärlich und so zog sich der Wiederaufbau über Jahre hin. Für die nächsten 17 Jahre war Pompeji quasi eine Baustelle ohne fliessendes Wasser, da auch die Aquädukte zerstört worden waren. Es war ein lauer Sommermorgen an jenem 24. August 79, als der Boden in Pompeji erneut schwankte. Der Donner einer gewaltigen Explosion riss die Bürger jäh aus ihrem Alltag. Der Gipfel des Vesuvs war weggesprengt worden und an seine Stelle war ein Krater getreten, aus dem Feuersäulen schlugen. Eine graue, pinienförmige Wolke aus Staub und Gesteinsstrümmern verdunkelte innerhalb von Minuten den Himmel. Die verstörten Menschen fürchteten den Zorn der Götter. Fackeln wurden entzündet, Gebete wurden gesprochen, doch es half nichts. Der Vesuv spie ein Gemisch aus Asche, überhitztem Gas und Magma, das überschallschnell hoch in die Atmosphäre vordrang. Eine halbe Stunde später prasselten vulkanische Aschen, Staub, Lapilli und schaumige Bimssteinstücke auf Pompeji nieder. Nach ihrem ersten Berichterstatter dem Schriftsteller Plinius der Jüngere wird diese Eruption eine "plinianische" genannt. In seinen Briefen an den Geschichtsschreiber Tacitus schildertet er minutiös den zeitlichen Ablauf der Katastrophe, in welcher auch sein Onkel, Plinius der Ältere, sein Leben verlor.

Während des Höhepunktes des Ausbruches drangen jede Sekunde über 100'000 Tonnen Asche-Gas-Gestein-Gemisch ans Freie. Glühende Brocken und Felstrümmer polterten zu Tal und verbrannten die Vegetation am Vulkanhang. Die Stadt hatte das Pech, dass der Wind aus der Richtung des Vesuvs wehte und die Eruptionswolke zu ihr trieb. Die Ablagerungen in Pompeji wuchsen mit einer Geschwindigkeit von 20 Zentimetern pro Stunde in die Höhe. Die Menschen gerieten in Panik, viele rafften Hab und Gut zusammen und versuchten zu fliehen. Andere suchten Schutz in ihren Häusern. Doch den bot die nach oben hin offene Bauweise der Atriumhäuser nur unzureichend. Giftige Gase drangen in die Zimmer ein, und die Menschen wurden unter einem Berg aus Dachziegel und Lava begraben. Brände brachen in der Stadt aus, welche vermutlich eher durch verschüttetes Öl aus Lampen verursacht wurden, als durch glühende Lavabomben.
Nach achtzehnstündigem Ausbruch beruhigte sich der Vesuv wieder, jedoch waren zu diesem Zeitpunkt die meisten Menschen in Pompeji bereits erstickt oder von herabfallendem Gestein erschlagen worden. Die wenigen Überlebenden fielen kurze Zeit später pyroklastischen Strömen zum Opfer, welche neben Pompeji auch die Städte Herculaneum, Stabiae und Oplontis vollständig bedeckten.

Archäologie, Ausgrabung

Bereits kurz nach dem Untergang der Stadt wurden aus verschiedenen Gebäuden Wertgegenstände geborgen. In den folgenden 1700 Jahren hatten vor allem Grabräuber in den einfach zu erreichenden Ruinen nach wertvollen Stücken gesucht und diese geplündert. Doch der grösste Teil von Pompeji lag in dieser Zeit unter einer bis zu 20 Meter hohen Decke aus vulkanischer Asche und Bimsstein begraben. Erst im 16. Jahrhundert kamen bei Kanalbauarbeiten diverse Inschriften, Marmortafeln, Münzen und Ähnliches zum Vorschein, welche aber noch auf kein Interesse stiessen und in die Hände dubioser Sammler gelangten.
Erst im Jahre 1748 wurden die Ausgrabungen vom spanischen Ingenieuroffizier Oberst Rocque Joaquin de Alcubierre mit Genehmigung des neapolitanischen Könighauses offiziell begonnen. Dieses beanspruchte das exklusive Vorrecht auf die gefundenen Schätze und verschenkte diese oft an andere europäische Königshäuser. 1763 wurde mit dem Auffinden eines Schildes mit der Inschrift respublica Pompeianorum die Stadt eindeutig als Pompeji identifiziert.

Einen weiteren bedeutsamen Fortschritt bei der Erforschung gab es, als die Franzosen Neapel und Italien von 1806 bis 1815 beherrschten. Die Ausgrabungen waren besser or-

ganisiert, gingen planmässiger vonstatten und bei den Grabungen wurden viele Arbeiter eingesetzt. Dadurch konnte erstmals ein Eindruck von der Grösse und dem Erscheinungsbild der antiken Stadt gewonnen werden.
Nach einer Baisse wurde erst wieder in der zweiten Hälfte des 19. Jahrhunderts intensiv gegraben und die Arbeit wurde immer wissenschaftlicher und kontinuierlich verbessert. Die Leichen und Gegenstände wie Möbel hinterliessen im erhärteten Gestein Hohlräume, welche nun mit Gips ausgefüllt wurden und anschliessend als Gipsmodelle dienten. Insgesamt wurden mehr als 2000 Leichen gefunden.

Zu Beginn des 20. Jahrhunderts wurde mit der Restaurierung und Rekonstruktion begonnen. Heutzutage kann man bei den Mauern kaum noch zwischen Originalteilen und neuen Mauerteilen unterscheiden. Doch das grösste Problem ist mittlerweile die Baufälligkeit der Rekonstruktionen aus dieser Zeit.
In den 1920er-Jahren und nach dem Zweiten Weltkrieg fanden die letzten Grabungen in grossem Stil statt. Diese wurden jedoch nur unzureichend wissenschaftliche dokumentiert und die Konservierung wurde sträflich vernachlässigt. Dieser Bereich der Stadt wurde in den 1980er -und 1990er Jahren fragwürdig wieder aufgebaut. Diese Tatsachen stellt die heutigen Archäologen vor grosse Schwierigkeiten. Mittlerweile sind etwa zwei Drittel der Stadt freigelegt und weitere Ausgrabung im grossen Stil sind derzeit nicht absehbar, da die Archäologen momentan vor allem dokumentieren und rekonstruieren und versuchen den schneller voranschreitenden Verfall aufzuhalten.

Römische Geschichte

Das antike Rom wurde im Jahre 753 v. Chr. von den Brüdern Romulus und Remus gegründet. Die Gründungsgeschichte beruht hauptsächlich auf Sagen und Legenden. Es sind wenige schriftliche Quellen vorhanden. Das Wissen über die Königszeit erhalten wir aus archäologischen Funden und aus den überlieferten Institutionen. Der letzte der sieben legendären römische Könige war schliesslich Lucius Tarquinius Superbus, welcher wegen seiner Tyrannei etwa 509 v. Chr. aus Rom vertrieben wurde.

Römisches Reich

Nachdem der letzte König gestürzt war, übernahm der Senat (Ältestenrat), welcher vorwiegend aus adligen Männern bestand, die Herrschaft in Rom. Die römische Republik wurde ausgerufen und die Staatsgeschäfte waren nun als res populi, Sache des Volkes. Die neue Staatsform war republikanisch und orientierte sich an griechischen Vorbildern. So wurde beispielsweise eine Kodifizierung des geltenden Rechts vorgenommen, wessen Ergebnis die Zwölf-Tafel-Gesetze waren. Dadurch konnte die herrschende Rechtsunsicherheit grösstenteils beseitig werden und eine Rechtsgleichheit zwischen Patriziern und Plebejern (Kleinbauer, Handwerker etc.) wurde geschaffen. Über 200 Jahre lang kämpften die Plebejer um eine Besserstellung, welche ihnen schlussendlich durch unterschiedliche Ämter gewährt wurde. Das herausragendste Amt war jenes des Volkstribunen, der rechtlich unverletzlich sein Veto gegen Beschlüsse des patrizischen Senats einlegen konnte. Der Staat funktionierte nur, weil sich die Römer darüber im klaren waren, dass sie einem höheren Prinzip, dem Gemeinwohl, dienten. Die geschickte Führung des Staates durch Patrizier wurde ergänzt durch den Aufstieg tüchtiger Plebejer.

Die Entstehung des Römischen Reiches war nicht das Ergebnis planvoller Eroberungspolitik, sondern eines fast 200 Jahre dauernden Prozesses. Jeder Schritt, der letztlich zur Bildung des Weltreiches beitrug, beruhte auf einer Einzelentscheidung, die auf eine bestimmte Herausforderung reagierte. Zwischen 474 v. Chr. und 264 v. Chr. entstand die politische Ordnung des republikanischen Rom und das italische Bundesgenossensystem, welches Rom die Verfügungsgewalt über das Wehrpotential der Halbinsel sicherte. Beides bildet die Grundlage für den Aufstieg Roms zur Weltmacht. Rückblickend lassen sich vier Hauptphasen unterscheiden. Im 3. Jh. v. Chr. ging es um die Sicherung Roms gegenüber Karthagern, Kelten und Illyrern. In dieser Zeit konnte sich Rom, trotz mancher Rückschläge, als die führende Macht auf der italienischen Halbinsel beweisen. In einer zweiten Phase (201 - 188 v. Chr.) führte die Erfahrung des 2. Punischen Krieges und der Intervention in Griechenland dazu, dass die gegnerischen Grossmächte der römischen Kontrolle, u. a. durch Souveränitätsminderungen, unterworfen wurden. Zwischen 168 und 146 v. Chr. wurden die alten Gegenspieler Makedonien und Karthago vernichtet. In der vierten Phase kam es, zunächst zögerlich, später mit einem klaren Konzept, zur Errichtung eines römischen Herrschaftsverbandes (Imperium Romanum).

Mit dieser enormen Ausweitung des Römischen Reiches hielt das Führungspotential der regierenden Klasse nicht Schritt und die Zahl der Amtsträger reichte nicht mehr aus, weswegen Amtszeiten verlängert und übergeordnete Kommandos errichtet wurden. Einzelne Mitglieder der regierenden Klasse wie Pompeius und Caesar stellten das kollektive Regiment ihres Standes in Frage und sie waren die Schöpfer grosser neuer Herrschaftsbezirke. Dank Caesar wurde dem Römischen Reich das riesige Gallien einverleibt und enge Beziehungen zu Ägypten geknüpft. Als solche verkörperten sie die Gefahren, die der Republik durch die Existenz des Reiches drohten. Das Römische Reich zerstörte quasi die Römische Republik. Die Verwaltung dieses Weltreiches überforderte im 1. Jh. v.Chr. die staatliche Struktur und so kam es zum Bürgerkrieg. Nach der Ermordung Caesars ging aus dem Bürgerkrieg Oktavian als Sieger hervor, der unter dem Namen Augustus ab 27 v.Chr. das Reich grundlegend reformierte und in seiner Existenz sicherte. Forthin war Rom eine Militärmonarchie mit republikanischer Tradition und einem Kaiser an der Spitze (Prinzipat).

Kaiserzeit

Mit dem römischen Kaisertum wurde die Form gefunden, in der das Römische Reich die Gewähr einer lang dauernden Existenz fand. Unter den Nachfolgern von Augustus expandierte das Reich immer weiter, bis es von Schottland nach Ägypten und von Spanien

bis Armenien reichte. Der Kaiser nahm für sich in Anspruch, der zivilisierten Welt den äusseren und den inneren Frieden zu sichern. Das bedeutete zunächst den Schutz der Reichsangehörigen vor Einfällen von aussen, dann die Aufrechterhaltung von Ruhe und Ordnung im Inneren und schliesslich die Wahrung des Rechtsfriedens. Die über 200 Jahre währende Pax Romana wurde durch den Einfall von Germanenstämmen und einem erstarkten persischen Reich im Osten beendet.
Ende des 3. Jh. n.Chr. konnte jedoch wieder eine einigermassen stabile Ordnung errichtet werden und Kaiser Diocletian passte das Reich den neuen Umständen in Verwaltung und Organisation an. Er teilte die Macht zwischen einem Hauptkaiser im Westen und einem Mitregenten im Osten.

Der westliche Teil zerfiel allmählich unter dem Druck der Völkerwanderung, konnte sich aber noch bis 476 n.Chr. halten. Ostrom konnte unter Kaiser Iustinian im 6. Jh. n.Chr. einige der weströmischen Provinzen für sich gewinnen, das Reich jedoch nicht mehr einen. Als Byzantinisches Reich überdauerte es nochmals 1000 Jahre bis es schlussendlich 1453 dem Ansturm der Osmanen unter Muhammed II erlag.

Kultur und Freizeit

Ab dem 3. Jh. v. Chr. unterlag die Gesellschaft einer Veränderung, welche durch die Begegnungen mit der hellenistischen Welt angeregt wurden. Griechischer Lebensstil, griechische Kunst und Literatur wurden als Herausforderung, als Bereicherung und als Gefährdung in einem erfahren. Römische Armeen, Administratoren und Diplomaten trugen ihre Einstellung und Ideen nach aussen in ihr expandierendes Reich. Der Term "römische Kultur" darf nicht als räumlich und zeitlich begrenzt und als eine monolithische Einheit betrachtet werden. Ausgehend von der Stadt Rom hat sich diese immer weiter entwickelt und unterlag diversen Einflüssen aus den besetzten Gebieten. In der Architektur passten die Römer die übernommenen Bauformen ihren eigenen Bedürfnissen an und entwickelten sie weiter, so dass ein eigener architektonischer Stil entstand und zugleich der römische Mittelmeerraum um zahlreiche Bautypen bereichert wurde. Neben dem geschlossenen Forum, welches als Mittelpunkt des gesellschaftlichen, ökonomischen und religiösen Lebens galt und dem Amphitheater für Gladiatorenkämpfe, gehörten dazu Basiliken, Thermen, Theater, Triumphbögen und typische Formen des Strassen-, Brücken- und Wasserleitungsbaus. In grossen Palästren wurde der körperlichen Ertüchtigung nachgegangen und Thermen dienten nicht nur er Hygiene, sondern auch der Freizeitgestaltung. Während der augusteischen Zeit um Christi Geburt ging die griechisch-hellenistische Kunst endgültig in die römische über. Die heute noch erhaltenen Reste römischer Baukunst zeugen von hochentwickelter Architektur und Stadtplanung.

Strassenbau

Die erste von Römern gebaute Staatsstrasse (via publica) geht auf das Jahr 312 v. Chr. mit dem Bau der Via Appia zurück. Sie verband Rom mit Brundisium, der Hafenstadt, die das Tor zum Osten war. Römische Strassen verliefen generell möglichst geradlinig, bei vergleichsweise geringer Steigung und bestanden aus einem vierlagigen Unterbau. Die unterste Schicht war aus festgestampftem Steingeröll, darüber lagen gebrochene Steine, die mit Mörtel zusammengefügt waren, in der dritten Lage war Steinschotter und Ziegel mit Mörtel gebunden, den Abschluss bildete eine Kiesschicht. Bei stark genutzten Abschnitten legte man noch eine Decke aus polygonal gefügten Steinplatten aus hartem Gestein wie Granit, Lava oder Basalt darüber. Alle 1000 Doppelschritte standen Meilensteine, sogenannte Miliaria, welche den Abstand von Rom angaben. Dank diesem technischen Aufbau waren die Strassen weitgehend unabhängig von der Feuchte des Bodens passierbar.

Im Laufe der Zeit entstand ein leistungsfähiges Strassensystem, von ungefähr 78'500 km, primär für die Bedürfnisse der Administration und Armee,was die Verschiebung von Truppen erleichterte, um mit den Krisen an den weit ausgedehnten Grenzen fertig zu werden.

In Städten wie Pompeji war die mit Steinplatten gepflasterte Fahrbahn leicht bombiert und wies regelmässige erhöhte Übergänge für Fussgänger auf, dazwischen liessen Öffnungen die Fahrspuren für die Wagen frei. An den Seiten der Strassen befanden sich ab dem 1. Jahrhundert v. Chr. erhöhte Gehsteige.

Prüfung zu Pompeji

Name: ____________________________________

Ziel dieser Untersuchung ist es, die Lernwirksamkeit einer virtuellen 3D Welt mit dem herkömmlichen Erarbeiten eines Textes zu vergleichen. Ihre Rückmeldung wird alleinig dazu benutzt, die Eignung einer virtuelle Welt für das Lehren und Lernen von geschichtlichen und kulturellen Aspekten und Fakten zu untersuchen. Diese Studie benötigt keine persönliche Daten und ihre Angaben werden in keiner Weise identifizierbar sein.

1. Wo lag das antike Pompeji? (Beschreiben Sie in Stichworten die Lage so genau wie möglich)

____

____

2. Was können Sie über das Gelände, die Umgebung und die Umwelt sagen, in welcher die Pompejanerinnen und Pompejaner lebten? (Stichworte)

____

____

____

3. Wie hiess der Vulkan, bei dessen Ausbruch Pompeji unterging?

____

4. Nenne weitere Städte, welche verschüttet wurden.

____

____

5. Bis zu wie viel Asche-Gas-Gestein-Gemisch kam während des Ausbruchs jede Sekunde ans Freie?

☐ 10'000 Tonnen

☐ 1 Mio. Tonnen

☐ 200'000 Tonnen

☐ 100'000 Tonnen

6. Von wann bis wann gehörte Pompeji dem Römischen Reich an?

☐ Ich weiss es nicht

---

7. Was beschreibt ein Miliarium?

☐ Römische Masseinheit

☐ Distanzsäule an einer Römerstrasse

☐ Beschreibt einen Zeitabschnitt

☐ Waffe eines römischen Legionärs

8. "Pompeji lag am Tiber."

☐ falsch

☐ wahr

9. Wer hielt die Katastrophe schriftlich fest?

☐ Statthalter von Rom

☐ Geschichtsschreiber Tacitus

☐ Plinius der Ältere

☐ Plinius der Jüngere

10. Was ist ein Thermopolium?

- ☐ Bar
- ☐ Thermen
- ☐ Villa des Statthalters
- ☐ Warmwasserzufuhr

11. Wie lange dauerte es bis das Römische Reich letztlich ein Weltreich wurde?

____

12. Ordne die vier Hauptphasen des Römischen Reiches in die richtige zeitliche Reihenfolge (1-4):

- ☐ ____ Errichtung des Imperium Romanum
- ☐ ____ Punischer Krieg
- ☐ ____ Schutz gegen Karthager und Kelten
- ☐ ____ Zerstörung Makedoniens

13. Aus wem bestand der Senat vorwiegend?

- ☐ Volkstribunen
- ☐ adligen Männern
- ☐ Ritter und Patrizier
- ☐ Gelehrte und Ritter

14. Was wurde mit den Zwölf-Tafel-Gesetzen erreicht?

____

____

____

15. Staatsform des Römischen Reiches

- ☐ republikanisch
- ☐ demokratisch
- ☐ monarchisch
- ☐ kommunitaristisch

16. Was bildet die Grundlage für den Aufstieg Roms zur Weltmacht?

- ☐ Städtekönigtum
- ☐ Die Eroberungsfeldzüge Caesars
- ☐ Republik Rom und italisches Bundesgenossensystem
- ☐ Aristokratische Republik

17. Wer war der erste römische Kaiser?

- ☐ Tiberius
- ☐ Augustus
- ☐ Caesar
- ☐ Pompeius

18. Wie lange währte Pax Romana?

- ☐ 200 Jahre
- ☐ 100 Jahre
- ☐ 220 Jahre
- ☐ 250 Jahre

19. Was war der Hauptgrund für die verbesserten Ausgrabungen und Erforschungen 1806?

- ☐ Leitung und Führung der Ausgrabungen durch einen spanischen Ingenieuroffizier
- ☐ Das neapolitanische Königshaus begann sich für die Ausgrabungen zu interessieren und es wurde mehr investiert
- ☐ Die Besetzung und Beherrschung Neapels durch Frankreich
- ☐ Von den Toten und Hohlräumen konnten nun Gipsabgüsse gemacht werden

20. a) Was erkennen Sie auf dem linken Bild?

- ☐ Kaiserpalast
- ☐ nobles Villenviertel
- ☐ einfaches Wohnviertel
- ☐ Landvilla

20. b) Was erkennen Sie auf dem rechten Bild?

- ☐ Römisches Thermalanlage
- ☐ Atrium
- ☐ öffentlicher Brunnen
- ☐ Gartenanlage

21. Bis wann überdauerte Ostrom als Byzantinisches Reich?

- ☐ 476
- ☐ 846
- ☐ 1453
- ☐ 1145 Jahre

22. Wie hiess die erste Römerstrasse und wann wurde diese gebaut? Welche Städte verband sie?

____

____

23. Was waren die Hauptgründe für den Bau von Strassen? (Stichworte)

____

____

24. Beschreibe kurz den Aufbau der Strassen (von unten nach oben, pro Linie eine Schicht, Linie entsprechen nicht zwingend der Anzahl Schichten)

____

____

____

____

____

25. Wie viele Kilometer umfasste das römische Strassennetz in etwa?

- ☐ 80’000 km
- ☐ 35’000 km
- ☐ 60’000 km
- ☐ 100’000 km

FSBSOD

VP-Code: ________

Dieser Fragebogen besteht aus verschiedenen Aussagen über Ihre räumlichen Fähigkeiten, Vorlieben und Erfahrungen sowie Ihre Fähigkeiten, Vorlieben und Erfahrungen beim Finden von Wegen. Nach jeder Aussage sollen Sie einen Kreis um diejenige Zahl ziehen, die den Grad Ihrer Zustimmung mit dieser Aussage am besten ausdrückt. Markieren Sie die „1“ wenn Sie stark zustimmen, dass diese Aussage für Sie zutrifft, markieren Sie „7“ wenn Sie dies stark ablehnen oder markieren Sie eine Zahl dazwischen, wenn Ihre Zustimmung dazwischen liegt. Markieren Sie die „4“ wenn Sie weder zustimmen noch ablehnen.

1. Ich bin sehr gut im Geben von Wegbeschreibungen.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
2. Ich kann mir nur schlecht merken, wo ich Dinge liegen gelassen habe.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
3. Ich bin sehr gut im Schätzen von Entfernungen.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
4. Mein „Orientierungssinn“ ist sehr gut.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
5. Wenn ich über meine Umgebung nachdenke, verwende ich meist die vier Himmelsrichtungen (N,S,O,W).
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
6. In einer neuen Stadt verlaufe ich mich sehr leicht.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
7. Landkarten lesen macht mir Spaß.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab
8. Ich habe Probleme, Wegbeschreibungen zu verstehen.
   stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

9. Ich bin sehr gut im Kartenlesen.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

10. Als Beifahrer im Auto erinnere ich mich nicht sehr gut an die gefahrenen Strecken.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

11. Ich gebe nicht gerne Wegbeschreibungen.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

12. Für mich ist es nicht wichtig, zu wissen wo ich bin.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

13. Normalerweise überlasse ich anderen die Wegeplanung für längere Fahrten.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

14. In der Regel kann ich mich an einen neuen Weg erinnern, wenn ich ihn lediglich einmal zurückgelegt habe.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

15. Ich habe keine sehr gute „innere Karte“ meiner Umgebung.

stimme stark zu 1 2 3 4 5 6 7 lehne stark ab

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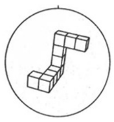

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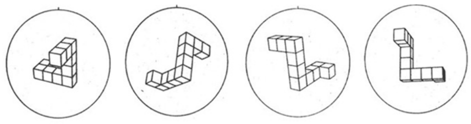

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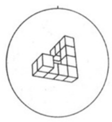

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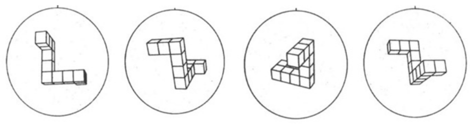

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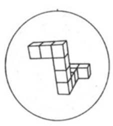

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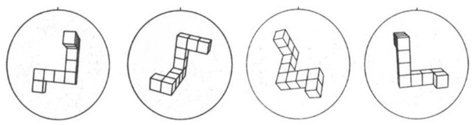

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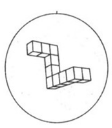

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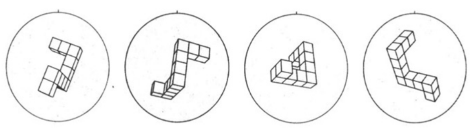

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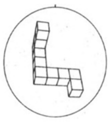

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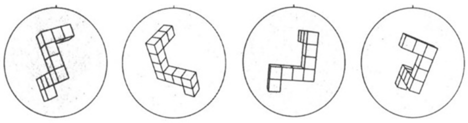

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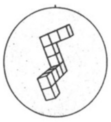

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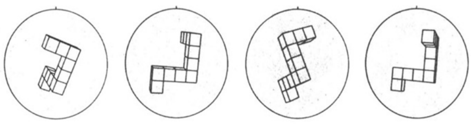

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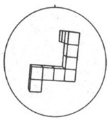

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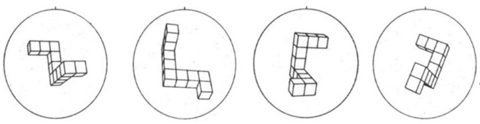

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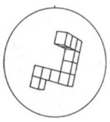

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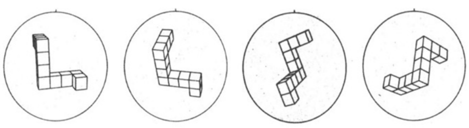

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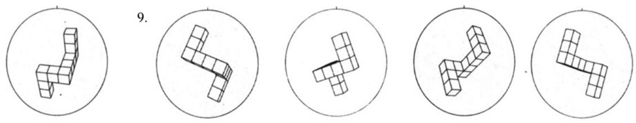

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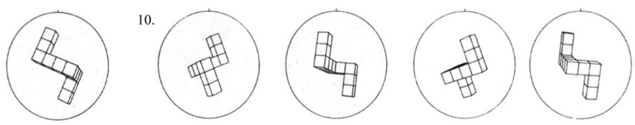

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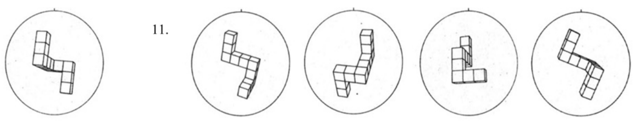

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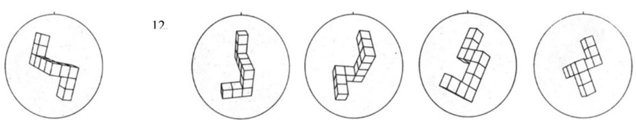

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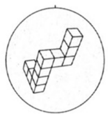

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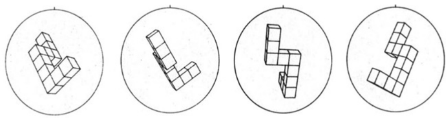

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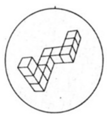

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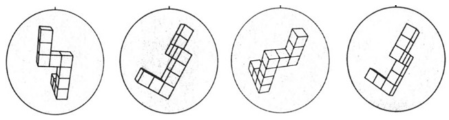

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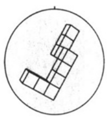

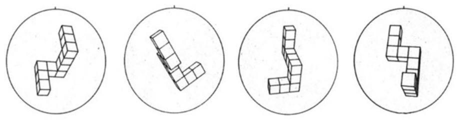

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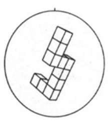

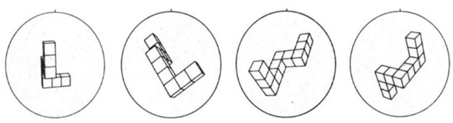

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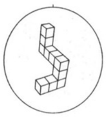

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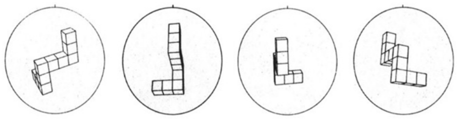

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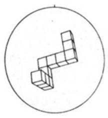

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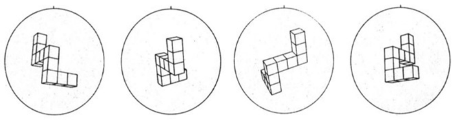

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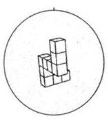

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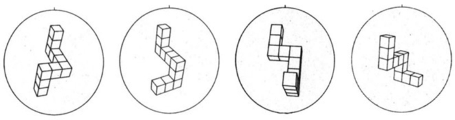

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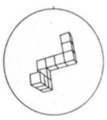

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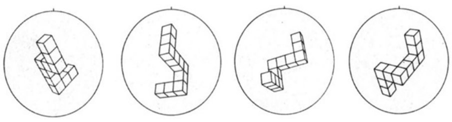

Personal Declaration

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

Zurich, 12 September 2014

Matthias Mahrer