VIRTUAL REALITY AT SECONDARY SCHOOL – FIRST RESULTS

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ABSTRACT

This paper examines the use of Virtual Reality (VR) at Swiss secondary schools. Despite many years of research, no well-founded data are available on the effects of the technology on children's learning success. It is assumed that VR is compatible with the learning theory of constructivism through the possibility of immersion, interaction, 3D representation and the possibility of adopting several perspectives.

To investigate the topic, a vision has been developed for a learning unit within the competence area Nature and Technology on the subject "Plastics and its effects on the environment". Divided into five learning blocks, the learning unit provides the students with knowledge about the structure, production, recycling and environmental consequences with possible approaches to solutions. Ideas for possible VR applications were developed for each of these blocks. The vision was discussed in four interviews with teachers. The VR applications were commented and evaluated by 20 students of the same class. The topic "Environmental Problem Microplastics" selected for implementation is topical, fits into curriculum and is compatible with the specialist areas suitable for VR.

In summary, it can be said that VR is still a long way from a nationwide deployment at the Swiss elementary school. Nevertheless, the educational institutions should observe the technology and develop an understanding of its possibilities through pilot tests.

KEYWORDS

Virtual Reality, Education, K-12, Secondary School

1. INTRODUCTION

VR has received a great deal of media attention since the technological developments of the last three years. Currently, it is mainly private consumers who are in the virtual world for personal entertainment. In the future, however, the technology could increasingly be used in companies and public institutions. According to technology analysts, Virtual Reality will enter the classroom in five to ten years.

This paper examines the practical application of VR at a Swiss elementary school. For this purpose, a prototype of a VR learning environment has been developed for the Nature and Technology 3.3 competence area from Lehrplan 21 (Deutschschweizer Erziehungsdirektoren-Konferenz (D-EDK) 2016), a Swiss curriculum for primary and secondary school, and tested as part of a pilot project. The aim of this work is to examine whether VR can bring didactic added value to the Swiss primary school system.

Despite the subject's long research history, no scientific data is available on the long-term effects of VR learning environments on competence development and student motivation. Research to date has shown that scientific fields in particular are suitable for the use of VR.

The research paradigm is based on design science (Hevner et al. 2004). At the beginning, a learning unit on "Plastics and its effects on the environment", consisting of five learning blocks, was designed. Different ideas for VR applications could be developed for each of these blocks. The vision created in this way was discussed with four teachers with regards to its didactic compatibility and the use cases were evaluated. The proposal "Environmental Problem Microplastics" selected for implementation not only fits well into curriculum 21, but has a high social relevance and is in line with the requirements for a VR learning environment defined in the literature.

ISBN: 978-989-8533-81-4

2. VIRTUAL REALITY IN THE EDUCATION DOMAIN

Using VR in schools is not a recent idea. The topic has been researched since the 1990s, especially in Anglo-Saxon countries. The field of research has its origin in the field of flight simulation.

Since the 1990s, various authors have been analysing the possibilities of VR and deriving potential benefits for training. In the following, a selection of relevant publications for Education is presented and briefly summarized.

Wickens (Wickens 1992) justifies the use of VR at school with four factors. At first he mentions the possibility that thanks to the interaction with the learning environment a higher intrinsic motivation can be achieved. Secondly, the presentation of real learning situations should allow an improvement in knowledge transfer. The third point is the property of taking on different perspectives and thus discovering certain scenarios in context. As a fourth factor, he mentions the chance to interact with the world in a natural way.

Winn (Winn 1993) argues in his work that the principles of constructivist learning theories and the characteristics of VR are compatible with each other. He sees the key to this compatibility in immersion, in particular in VR's ability to gain experience from the first person's perspective. Dede, Salzmann and others (Dede 2009), (Salzman et al. 1999) mention four factors of VR in addition to immersion which are highly compatible with constructivist learning methods. The three-dimensional presentation of content in different reference frameworks promotes in-depth learning, in which it enables different, complementary perspectives on a topic. VR controllers enable interaction that addresses the multisensory stimuli of users. This promotes in-depth learning and supports the safeguarding of knowledge. Furthermore, well-designed immersive worlds increase motivation, which leads to more time and concentration being allocated to the individual tasks in a VR environment. The last point is the possibility of telepresence, which allows shared experiences regardless of location.

Dede (Dede 2009) published a much-noticed work on the subject of immersion in 2009, in which he points out three ways how it can improve education. The study overlaps to a large extent with the findings of Wickens and Winn (Wickens 1992) described above. First, he mentions the opportunity to take both the egocentric and the exocentric perspective and thus better depict complex phenomena (enabling muliple perspectives). While he regards the exocentric view as suitable for abstract and symbolic insights, the egocentric perspective should increase the interaction and motivation of the learner. The second reason he cites is the possibility of putting the learner in a certain situation (situated learning). According to Dede, situational learning can improve commitment and academic performance. The third possibility is that the transfer of knowledge for learners is simplified by the representation of real situations (transfer).

Table 1 summarizes the findings regarding the benefits of VR for training in relation to the functions of VR in a simplified form. The authors' statements overlap at various points. In addition, the analysis reveals that functions and benefits are often mixed and that the distinction between immersion and the other possibilities of VR does not follow a clear pattern.

Table 1. Summarized benefits of VR for Education

	Benefits for Education					
VR Functions		Motivation / engagement	Knowledge transfer	Deep learning	Knowledge assurance	Location independent Learning
	Immersion	X	X	X	X	
	Interaction	X	X		X	
	Multiple Perspectives			X	X	
	3D-Visualization	X	X	X	X	
	Telepresence					X

Whether the benefits hoped for by VR can be achieved for training has been investigated since the beginnings of this research area. The results of various meta-studies are presented below.

Youngblut's meta-study (Youngblut 1998) includes the analysis of 20 VR learning units. The evaluation of the results was divided into the categories of effectiveness and user-friendliness. Despite positive results, the results are no longer relevant today for two reasons: Firstly, under the term VR, Youngblut also examined studies that were carried out with virtual desktop environments and secondly, fully immersive systems were not technologically mature at that time.

The work of Mikropoulos et al (Mikropoulos and Natsis 2011) examines 53 scientific papers on VR in education published between 1999-2009. Of the 53 studies, 16 used a fully immersive solution with head mounted displays (HMD). For the rest, a desktop-based solution was used. One finding of this work is that the combination of technological characteristics of VR and the individual prerequisites and needs of the learning person must be put in relation to learning success. It was also found that the students and teachers accepted the new technology with a positive attitude. No statement could be made as to whether learners with VR would retain their knowledge for longer. An important conclusion of the work is that every virtual learning environment must be oriented to the didactic goals of the application area.

The meta-study by Merchant et al (Merchant et al. 2014) examines the effectiveness of desktop-based VR applications in the areas of games, simulations and virtual worlds for primary and secondary school education. The authors analysed a total of 67 papers. Since the studies are based on desktop-based VR applications, a statement is only possible to a limited extent as to what degree the results also apply to fully immersive VR applications. The work has shown that the transfer of knowledge with playful components is much more effective than the other two types of knowledge transfer. The results of knowledge testing of the students shortly after the application of a VR game and at a later time, were at the same level. According to the authors, this is an indication that knowledge is retained for a long time through the use of this technology. Whether this knowledge can be better transferred to other situations by the students was not examined in the study. Another finding is that students learn less well in collaborative learning environments than in non-collaborative ones. The authors were able to prove that the novelty of the technology has a positive effect and that the performance of the students decreases when used several times.

Liu et al. (Dix 2009) summarize the challenges that should be solved for a successful use of VR in the training sector (Table 2).

Table 2. Challenges of VR for education ((Dix 2009), S. 123)

Category	Challenges
Technology	The costs of VR hardware need to decrease and the portability must improve.
	The simulation of the environment must improve thereby improving the degree of immersion.
	The human – machine interaction must become more natural and intuitive.
VR Learning Unit	Adequate learning units, tested by pedagogues, must be created.
	Cognitive overload of students needs be avoided.
	The monitoring and evaluation of learning effects must be researched in depth.
Experience of Students	The technology must be user friendly and easy to use.
	A VR identity (avatar), which can be used in the environments, is to be established.
	Privacy protection and security must be ensured.
Integration	VR learning environments must be easily integrated into existing learning environments.

Despite the interesting characteristics of VR in the context of education, the areas of application should be specifically selected. For a complete list of the conditions under which the use of VR makes sense, please refer to the publication "Reasons to Use Virtual Reality in Education and Training Courses and a Model to Determine When to Use Virtual Reality" by Pantelidis (Pantelidis 2009). It can be emphasized that VR can always be used when a situation is difficult to represent in the real world and a simulation serves the better understanding.

Merchant (Merchant et al. 2014) examined 25 papers on VR for primary and secondary education (K-12) as part of her meta-study. More than 50% of the surveys are in the field of natural sciences and mathematics. Winn (Winn 1993) provides an explanation for this focus: This highlights the possibility that any size comparisons are possible in the virtual world. For example, learners can move within an atom and replace electrons in orbitals or take intergalactic excursions into space. According to Salzman et al. (Salzman et al. 1999), VR has the potential to complement model-based science teaching.

ISBN: 978-989-8533-81-4 © 2018

3. VR ENHANCED LEARNING UNIT

As part of the project a VR enhanced learning unit has been designed, implemented as a prototype and evaluated by students.

As a project partner the secondary school in Meilen was selected. Based on curriculum 21 and the features of VR the potential areas of highest impact have been identified and discussed with experienced teachers from the circle of acquaintances. Following Table 3 summarizes the relevant features of the chosen learning unit. In a next step the prototype for the learning unit has been designed. As a platform for the VR application the Unity engine with HTC Vive as the HMD has been selected. The prototype was then tried out with students on 19. April 2018 at the Meilen secondary school. Of the 16 participants, 10 were female and 6 male. The majority of the students were 14 years old at the time of the study. Around 60% had already gained experience with VR. Of these, 80 % tried out VR systems at one event. 100% of male participants and 20% of female participants said they played video games. During 120 minutes, the students were able to test the VR learning environment on two systems in succession. Directly after each student had experienced the learning unit the student had to fill out a survey. The survey asked questions about usability, learning experience and comprehensibility. The evaluation of the learning success was not the aim of the study.

Table 3. Tabular representation of the learning unit

Learning unit	**Environmental problems and challenges**
Reference to Curriculum 21	NT.3.3 c / BNE / MI
Learning outcomes according taxonomy levels of Bloom	K1: Students can describe environmental problems caused by the use of plastic. K4: The students analyse how microplastic enters the food cycle.
Learning contents	What impact does the use of plastic have on the environment? • How and where do environmental problems arise? • What impact does plastic have on the environment? • What is microplastics? • Toxicity of plastics and influence on the hormonal balance of living organisms.
Knowledge assurance	Poster - Showing the plastic cycle and the impact on the environment and me personally. Learning documentation - analysis of the products at my home, where could microplastics occur.
VR use cases	• Students are in a place contaminated with plastic waste. • Problem of microplastic: What is microplastic? Size comparison based on living organisms in waters.

The VR prototype consists of the following three scenes: «below the water”, «microworld”, and “enjoy your meal”. The prototype is available for download at http://neuelehrkonzepte.ch/.

3.1 Scene 1 – Below the Water

At the start of the learning environment, the student is underwater. The underwater landscape is decorated with plants, rocks, fish, a car wreck and a boat. The student receives an order to search for illegally disposed waste via an audio output. Orders can be displayed in all scenes at any time at the push of a button. As the student approaches the rubbish heap, the task becomes more specific. He should look for the bottle with the sauce he normally eats with french fries. The ketchup bottle is hidden in the middle of a bush of blades of seaweed and emits microplastic. This is represented by pink dots which radiate from the bottle body. An audio output explains to the student that the particles are absorbed by the carp eating in the sea grass. Next, the student has to pick up the bottle and bring it to the laboratory. He walks past the car wreck and the boat to the surface. The scenery on land resembles the shore of a mountain lake. Birds circle in the sky, a hare and a deer are feeding and in the middle of the square there is a wooden hut, which is prominently labeled "Laboratory". The acoustics have changed in the meantime. While the student has heard underwater diving noises, the birds now chirp ashore. With the ketchup bottle stretched out, the student enters the laboratory and the "Microworld" scene is loaded.

Figure 1. Impressions of scene 1

3.2 Scene 2 – Microworld

The student is inside the hut and stands in front of a blackboard. In front of it are a pike, a perch and the ketchup bottle. A robot voice tells him that within the laboratory the fish and the ketchup bottle are displayed in their original size. The sizes are displayed on the blackboard. After the student has looked at the objects, he should go outside into the micro world. He goes through the door for it. Outside he sees a perch enlarged 1000 times and an equally large ketchup bottle. Four microplastic particles lie on a base. Now the student should compare the particles with the fish and the ketchup bottle to get a feeling of how small microplastic is. Next, the student should dispose of a microplastic particle in the trash can. As soon as the particle touches the bottom of the trash can, a screen and a button appear. The student is asked to press it. Now a three-minute film starts about plastic and its consequences for the environment. After the film, the student is asked to look for the exit. As soon as he walks through the door, the scene "Enjoy your meal" starts.

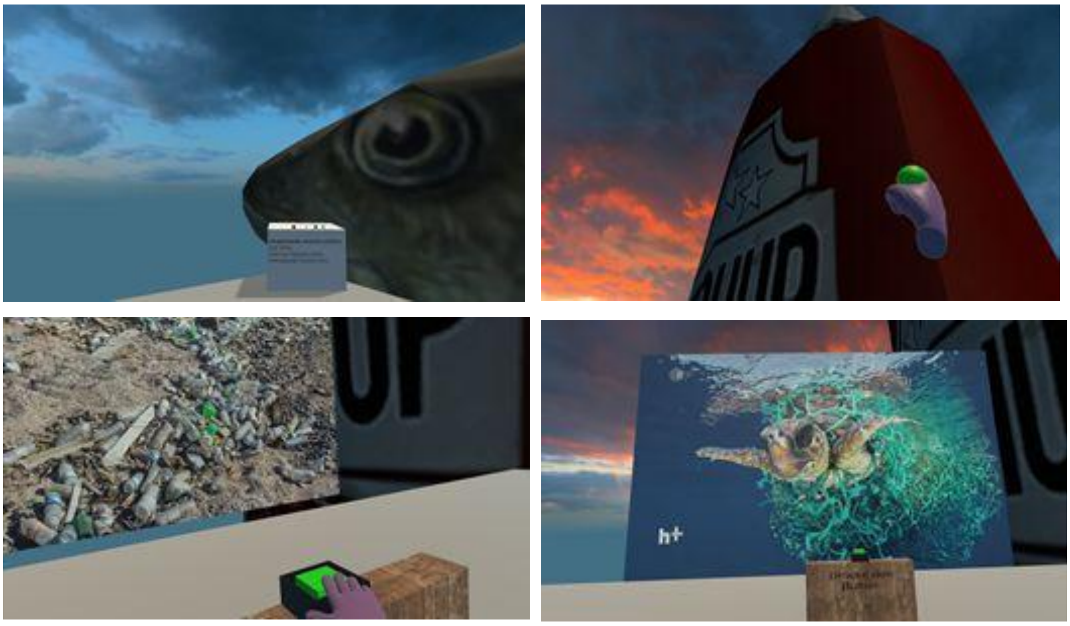

Figure 2. Impressions of scene 2

3.3 Scene 3 – "Enjoy your Meal"

The student sits at a camping table, which has been set up in the initial scene in the meantime. The table is set. On the student's plate lie two fish. The student's family is also present. The father sits on the chair, the mother is by the fire and the brother dances to the music that sounds from the loudspeaker. The student is given the task of eating the "right" fish via an audio output. One of the fish is marked with the pink dots representing the microplastic particles. The other fish looks normal. After the student has brought the fish to his mouth without microplastic, he is congratulated on the successful conclusion. He is asked to turn around. The instruction to take off the VR-glasses is now written on a blackboard.

Figure 3. Impressions of scene 3

4. RESULTS

In the following, the results of the survey are presented according to the VR functions in Table 1.

4.1 Immersion

Nearly 70% of the participants stated that the world depicted looks realistic. The remaining 30% assessed the question as neutral or negative. This result is not surprising and can probably be traced back to various reasons. The resolution of the used HTC Vive is 1080*1200 pixels per eye. Raja Koduri was CEO of chip manufacturer AMD until 2017. He said in an interview in 2016 that for a VR experience that looks real, a resolution of 15360*8640 (16k) per eye is required (AMD's Graphics Boss Says VR Needs 16K at 240Hz for "True Immersion" 2016). On the hardware side, VR is therefore still far from the optimum properties. A second aspect is the 3D models used. Various compromises had to be made in the work. For example, objects with a low number of polygons were sometimes used due to a lack of alternatives.

Nevertheless, the experience felt realistic for 95% of the participants. The detailed decoration of the landscape, the audio effects and the possibility of interacting with the world could have played a role in this. It is advisable to collect the exact reasons for this in a further survey.

Furthermore, 95% of the students stated that they were more concentrated than in normal class. This is certainly due to the fact that this was their first experience with VR in the school context and the pilot experiment was a special, unusual event for the test persons. In addition, the students were under observation of the two system supervisors. Reliable data should be collected by means of long-term studies. An interesting approach could be the measurement of body functions, such as heart rate. Such an experiment was carried out by the Universita` della Svizzera italiana in Lugano with a VR application in the tourism sector (Marchiori, Niforatos, and Preto 2018). It was found that the presentation of content from special perspectives and the interaction with animated objects have the potential to be remembered in the long term.

Three participants felt uncomfortable during their stay in the VR environment, one person had to abort early. This result is not surprising, as many users complain about a weak stomach during the first experience in a VR environment. Cobb et al. (Cobb et al. 1999) describe as a possible cause the user's urge to discover everything the first time and thus execute very fast movements. In fact, there are also users who are uncomfortable with multiple use of a VR environment.

4.2 Interaction

Nearly 90% of the participants said they would welcome learning together with a classmate in the virtual world. Liu describes this possibility as Social Learning (Liu et al. 2017).

For most of the participants it was clear how they should operate the controllers. This is certainly due to the high technological affinity of this generation. Over 85% of the students understood the instructions. Only half stated that the number of instructions was sufficient. The nervousness of the students could have played a role in this assessment. The first time in the immersive world, many users are focused on environmental impressions and control. In doing so, they cannot follow the orders conveyed via the soundtrack. Few people have used the option of displaying instructions at the touch of a button. The interaction with the objects was considered simple and logical by most of the students.

4.3 Learning

The majority of the students stated that the VR learning environment was helpful in understanding the topic of microplastics. In analyzing this question, it is noticeable that 8 subjects said it was true, but did not select the maximum evaluation. This may be an indication of how far the students have understood the content. The same applies to the result of the question whether size comparison in the micro-world was helpful for understanding. More than 95% of the students realized that microplastic enters our food chain.

Both the possibility to move and research freely, as well as the audio comments and the video were rated by the students as conducive to understanding. The video received the highest number of ratings with the maximum number of points.

4.4 Motivation

A good 95% of students say that VR could increase their interest and motivation to learn. Only one person has marked this as inapplicable. One reason for this assessment could be the participant's comment that the VR glasses were too heavy. All students would like to learn again in a virtual learning environment.

5. CONCLUSION

Although the results of previous research and this work partly point to a positive effect of VR on training, they should be treated with caution due to various limitations. Most previous studies are not based on fully immersive systems as they have been available since technological development in recent years. Another problem is the lack of long-term studies. This means that the effect of novelty comes into play with every evaluation, which can lead to improved results. As a result, there are only assumptions and indications of potential added value. However, no scientifically founded statement can be made in this respect. Dede and Richards (Liu et al. 2017) underline that it requires strategic planning and research collaboration to obtain reliable data on the effects of VR on the school development of students. Specifically, joint research laboratories, design heuristics, terminologies and process models are required. The statements of the two researchers coincide with our own findings from this work.

Furthermore, the effects of social learning, i.e. joint learning in the virtual world, should be investigated. Most of the students surveyed would welcome to study together with a classmate in the VR. The possibility of telepresence could play an important role here in the future. For example, it would be possible for a student from a class in Geneva to work together with a student from a class in Zurich in the VR learning environment.

An important point for practical use is the manageability of a fully immersive VR system. The installation takes up a considerable physical area. It is unlikely to be available in many schools today. Here we would like to introduce the idea of making the systems mobile and setting them up, for example, in rooms that are not used very often. The auditorium was used for this purpose in the pilot experiment. On the hardware side, the investment has meanwhile fallen to an affordable level for end consumers, which certainly lowers the entry hurdle. Since the fully immersive systems have only been on the market for a few years, the software range is still small.

The way VR is integrated into the classroom and the role of the teacher are important factors for the success of the technology in the classroom. Integration should be viewed from an organisational and didactic perspective. During the pilot test it became clear that system support takes a lot of time. In addition, no complete class can currently study together in the VR environment These limitations must be taken into account when using the technology in everyday school life. From a didactic perspective, VR should be optimally integrated into the classroom. During the pilot test, not the entire learning unit was carried out. The students were given a reading assignment as preparation. The learning assignment after the test attempt, which should have ensured the transfer of knowledge according to the model of De Freitas and Neumann (de Freitas and Neumann 2009), could not be carried out for time reasons. Simplicity in operation is important for the success of VR learning units. If the systems are designed too complicated and can only be operated with extended IT knowledge, the technology will hardly be able to establish itself.

In this work, the added value of VR for the Swiss secondary school could not be conclusively evaluated. There are various signs that indicate positive effects. Fully immersive VR systems are still little known to the general public. The prototype created can make an important contribution to presenting VR's possibilities for training in a practical way. It will be the starting point for conducting medium to long-term studies on the assurance of learning.

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