THE VALUE OF VIRTUAL REALITY AS A COMPLEMENTARY TOOL FOR LEARNING SUCCESS

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ABSTRACT

A virtual reality learning unit for the functioning of a router is used to show how students at bachelor level can be provided with another teaching tool in the future, whereby the didactic approach of a change of perspective makes optimal use of the advantages of virtual reality and should enable a more profound understanding. Further studies are needed to determine a long-term learning effect as well as the efficiency of a combination of teaching methods. However, the high demand from students in the field study shows that students are open to virtual reality as a tool beyond traditional teaching methods.

KEYWORDS

Virtual Reality, Education, Change of Perspective, Field Study

1. INTRODUCTION

In this work, a virtual reality (VR) learning unit for explaining a router is created, optimized according to quality criteria and evaluated regarding the learning effect. Design criteria for the creation of the VR learning unit are derived from collected literature regarding potentials, learning effect, opportunities, challenges, and recommendations of the use of VR learning units at universities of applied sciences. Part of the literature review represents the conceptual design of the main functionalities of the selected network components. For each component, a use case is created based on the conceptual description as well as considering the design criteria, which is implemented using VR. Learning objectives are formulated during the creation of the use cases. The use cases cover only a part of the possible functions of the router. It is taken into account that the VR learning unit can be further developed with additional functions in the course of further work.

This paper is structured as follows. Chapters 2 to 4 state the relevance, objectives and applied methodology for the presented work. Chapter 5 gives a profound background on the state of the art. The VR learning unit with its design decisions are described in chapter 6. Chapter 7 contains the results of the field study which are discussed in chapter 8.

2. RESEARCH OBJECTIVE

Immersive VR applications offer numerous advantages when used in education, such as change of perspective, practical aspects and independent learning. As a result, an increase in learning success can take place. Nevertheless, VR applications are rarely used in education (Pirker et al., 2020). According to Martin-Gutierrez et al. (2017), a possible reason for this could be a lack of strategies and concepts regarding a media development and integration of the technology into the teaching process. Hellriegel and Čubela (2018) suggest that the rapid development of technologies is the reason for the low user numbers. Thus, there is only a limited amount of scientific publications dealing with virtual reality and its didactic use (Hellriegel and Čubela, 2018). Since little research has been done on how virtual reality can be integrated into the curriculum and how it can be part of a classroom experience, collaboration between educators and game designers is needed for future studies (Pirker et al., 2020; Hellriegel and Čubela, 2018).

The majority of studies reviewed by Pirker et al. (2020) evaluate the potential of virtual reality from the student's perspective. However, this is not sufficient for the development of learning environments. Future research should also consider the requirements, potential problems, and possible use cases from the instructor's perspective. Furthermore, according to Pirker et al. (2020), only a few studies have integrated game elements into their VR learning units. However, as this is seen as a valuable tool for learning information technology topics, this represents an elementary research gap (Pirker et al., 2020), which leads to the following research question for this work: "Does a change of perspective implemented by an immersive VR learning unit result in a measurable learning effect in action competence as well as technical competence? ".

3. METHODOLOGY

The approach follows the design science approach. This research paradigm is based on the creative and problem-solving application of the knowledge base for the creation of an artifact and for the evaluation of a new knowledge base. The design process includes determining design criteria, creating as well as evaluating the artifact (Hevner et al., 2004, p.76ff). SpringerLink, ACM Digital Library, IEEE Xplore Digital, and Web of Science were used as research databases. Didactical reduction, Learning Methods, Factors of a successful learning, Use of VR in education, VR chances and challenges in education, VR effects on learning, VR potential in education, recommendation use of VR-applications, and functionality of router are the used search terms.

During the development phase of the VR learning unit, several iterations of the design process are performed. After each iteration, compliance with the quality criteria is checked by conducting usability tests with different students as well as graduates. Iterations will be terminated once feedback reveals no new insights. Heterogeneous responses to the same topic are left open.

4. STATE OF THE ART

VR is well suited for explaining complex issues (Checa and Bustillo, 2020; Christ and Hirschi, 2021; Pirker et al., 2020). Like a workshop, students are encouraged to think actively and create their own experiences. With VR learning units, the acquisition of a wide variety of competencies, such as strategic problem-solving orientation, is possible. Learning in a shared virtual reality can reveal ways in which collaboration and problem solving work in practice (Reynard, 2017). Thus, according to Hellriegel and Čubela (2018), VR learning units show potential for increasing learning success as well as promoting constructivist learning. Scenarios can also be acted out using simulations (Reynard, 2017).

Hellriegel and Čubela (2018) evaluate the learning effect and potential of VR based on four surveyed principles for successful learning. The evaluations are confirmed by Zender et al. (2018), among others, who used brainstorming sessions with subject matter experts to determine the impact of VR for teaching and learning settings (Zender et al., 2018).

When developing a VR learning unit, cognitive overload must be avoided. According to Liu et al. (2017), this must be taken into account both in the design of the scenes and in the organization of the learning materials. The challenge is to align with the learners' cognitive process. For example, the number and arrangement of objects in the environment as well as the learners' level of knowledge must be taken into account. The organization and presence of pluralistic media, such as sound or animation, must also be considered. In addition, reducing repetitive delivery of information can help conserve cognitive resources (Liu et al., 2017).

Health side effects such as nausea, dizziness, or eye fatigue pose another challenge when using VR glasses (Zender et al., 2018). VR use can also have a detrimental effect in cases of severe anxiety. Due to this, an alternative solution must always be available when using VR learning sessions (Baniasadi, Ayyoubzadeh, and Mohammadzadeh, 2020).

Niedermeier and Müller-Kreiner (2019) conducted surveys in 2018 and 2019 with 124 students from Bavarian universities regarding their assessment of VR and AR technologies. The study was based on the question of how the students intend to use the technologies in their everyday studies in the future. At the time, the students surveyed were studying to become teachers, mainly in the fields of education, psychology and economics. The surveys revealed that the students knew what VR was. However, they showed little knowledge regarding learning scenarios that used VR or AR. The application of the technologies was rated as low by the students. It was striking that they stated that they had already used VR glasses more often than the far more accessible AR apps. Niedermeier and Müller-Kreiner (2019) concluded that students are not yet aware of the already widely established integration of AR even on mobile devices. According to the survey, the students surveyed consider it useful to use the two technologies as a supplement in didactic learning. The basis for these assessments was not investigated. Finally, the respondents were asked about their assessment of future learning. It became clear that digital media play a central role. However, the respondents were rather pessimistic about the regular use of VR and AR in everyday study in the next 10 years. Nevertheless, the survey showed that topics such as VR and AR would become more future-oriented in the next 50 years and would increase in terms of assessed importance. Students were also asked about their aspirations. The use of VR and AR technologies as supplementary learning methods was hardly mentioned. Interactive and individual learning was desired by the majority. Since VR and AR are said to have great potential to increase the learning success of students, Niedermeier and Müller-Kreiner (2019) recommend a didactically sensible variety of media with integration of VR and AR. An increased dialog with students can capture the needs for the optimal use of the media (Niedermeier and Müller-Kreiner, 2019).

A further assessment of the use of VR in everyday study was made by the ZHAW, the International Association of Lake Constance Universities (IBH) and the Lake Constance Graduate School (HTWG). By means of teaching projects, several teaching sequences were designed and implemented using VR systems. The aim of the projects was to develop evaluation criteria of possible uses of VR systems based on different teaching scenarios at the undergraduate level. The projects showed that the identification of suitable teaching scenarios proved to be difficult and the development laborious. Knaack et al (2019) estimates that the use of VR in teaching is not yet sufficiently efficient, given the high costs, the time required for programming, and the still unclear benefits. This is also confirmed by (Keller and Brucker-Kley, 2021; Keller, Brucker-Kley, and Ebert, 2020). Knaack et al (2019) recommend increasing the number of usefully applicable scenarios and making these scenarios available on a cross-university platform for continuous further development.

In a systematic literature review, Pirker et al. (2020) investigated the potential and application of VR for computer science education. For this purpose, they identified learning objectives, interaction properties, and challenges and advantages of using immersive VR learning units for computer science education and extracted recommendations for action. For example, for an improved learning effect, it is recommended to incorporate interaction, immersion, visualization, game-like design, use of metaphors and analogies, and social experiences within the virtual environments (Pirker et al., 2020). In a systematic review of the literature, Hellriegel et al. (2018) adopt the constructivist view to evaluate the potential of VR in the classroom. According to Liu et al. (2017), constructivism places learners at the center of learning and teaching. In this view, students are actively involved in processing information and constructing objects under the guidance of teachers. Hellriegel et al. (2018) recommend that teachers not only design the content selection of VR learning units due to the different scenarios and possibilities for action, but also consciously control didactic potentials with regard to students' possibilities for action and participation. To this end, teachers must be adequately trained (Hellriegel and Čubela, 2018).

According to Pirker et al. (2020), educational media with a high degree of technological immersion positively influence the engagement, presence, and motivation of students. Stimulating student motivation can additionally be done by means of interesting and age-appropriate stories on the topic. In order for the VR experience to be seen by students as more than just a playful element, the immersive experience must be embedded in the instructional sequence. This can be achieved by aligning the virtual environment with learning objectives. A side effect of using VR technologies is cybersickness. Pirker et al. (2020) recommend using teleportation as a method of locomotion, which can prevent nausea and dizziness when using immersive VR learning sessions. In addition, lecturers need to be present when using the VR applications to support students and possibly offer other tasks if cybersickness cannot be overcome. This is also confirmed by Hellriegel and Čubela (2018) in their study. From Pirker et al.'s (2020) study, it appears that integrating an introductory phase with a simple example program can eliminate possible uncertainties among users. In doing so, students can familiarize themselves with the controls. According to Pirker et al. (2020), the design of VR scenarios is thus not limited to complex issues, but can be applied to a wide variety of topics (Pirker et al., 2020). According to Baniasadi et al. (2020), learning scenarios should be developed that can be repeated as often as desired. It should also be considered that regular and immediate feedback is given when scenarios are completed to encourage the user (Baniasadi, Ayyoubzadeh, and Mohammadzadeh, 2020).

5. VR LEARNING UNIT

According to the objectives of this project, the use of virtual reality for explaining complex issues at university level will be tested. The change of perspective by means of VR is to be used as a supplement to traditional teaching methods. The choice of a router as the use case is justified by the fact that network components represent complex issues in computer science education. Routers represent central roles in networks and contribute an important part to information security. Due to the increasing relevance of data security, there is also a growing focus on networks and their components in education. The router has a multitude of functionalities, which can be illustrated and presented by means of VR. In the sense of a didactic reduction according to Lehner (2020), the content of the teaching material is reduced to two main functionalities of the router. These are limited to the assignment of IP addresses and the forwarding of communication requests to the next gateway. Since an understanding of a network is required for the assignment of IP addresses, this is also taught. The construction of two networks is therefore also part of the project. For the selection of the learning method, the needs of the students have to be taken into account. For example, according to Niedermeier and Müller-Kreiner (2019), students want interactive and individual learning. Students are encouraged to think actively and create their own experiences by means of VR. The change of perspective plays a central role in this. Students no longer have the entire context in front of them, but experience the router performing its tasks.

VR learning units promote the activation of students through self-directed action by means of interactions. As Hellriegel and Čubela (2018) also state, interaction and self-design of the learning process contributes to sustainable learning success. Curiosity as well as motivation of students must be encouraged (Hellriegel and Čubela, 2018). With the use of VR, students' interests can be addressed, which can lead to a promotion of intrinsic motivation. Another motivating component in learning units according to Hellriegel and Čubela (2018) is sample solutions. Students are made aware of correct interactions in the VR learning unit of this project, thus teaching pattern solutions. Also, correct answers cannot be revoked. Incorrect answers are not accepted. According to Baniasadi et al. (2020), learning units should also be able to be repeated as many times as needed. Most learning units in the VR learning unit can be repeated as many times as needed. Immediate feedback when completing learning units helps to motivate students.

The pilot study by Christ and Hirschi (2021) shows that test groups with repetitive process steps showed more motivation and higher learning progress than those who were randomly assigned a process step. When designing the learning unit, care is taken to ensure that students have to work their way through levels. Some of the exercises are repeated, but they become more challenging as the level increases. For example, there is some time pressure in Level 2 compared to Level 1 implemented in this VR learning unit. Repetition allows students to reinforce what they have learned. Students from Christ and Hirschi's (2021) pilot study wanted variety such as competition. At the different levels, trophies can be won depending on the speed of the user. This creates a competitive atmosphere.

Cognitive overload must be avoided when developing a VR learning unit (Liu et al., 2017). In the project, students have to master different tasks. For reducing the complexity, a scaffolding principle is applied (Singh, 2017). Help and components for the next tasks are shown only when the previous task is finished successfully. The procedure helps students to identify the relevant aspects of the task. To support the students' cognitive process, objects are deliberately placed in the project. Colors for the networks, the Internet, and the associated cubes serve as another aid. The same colors are used throughout all scenarios. The colors have a high contrast so that people with a visual impairment can also perceive the different colors.

Part of the teaching concept of a VR learning unit is the definition of learning objectives in terms of competencies (Reynard, 2017). Learning objectives are therefore defined for each learning unit of the project, as well as associated questions that can be queried after using the application. By answering the questions, the learning objectives become verifiable. The learning objectives as well as the associated questions also represent a summary for the students and contribute to the orientation of the learning content. Defining learning objectives also ensures that VR experiences are not only perceived by students as a playful element (Pirker et al., 2020).

A VR learning unit with 5 different scenes is developed to achieve the goal. In the first scene, two networks can be created and devices can be assigned an IP address. For the transition to the second scene, the change of perspective to the router, an Internet search is started. In the router, there are different levels for forwarding data packets from the perspective of a router. Each level is represented by its own scene. Since words are limited in explaining a VR learning unit, the executable Unity project for Windows can be found at (Curcio, 2022).

6. FIELD STUDY

The learning effect of using a VR application to introduce and explain a router is evaluated using a quantitative randomized field experiment according to Döring and Bortz (2016). Subjects are randomly divided into test and control groups for later comparison (control group design). In this field experiment, the test group trains with the VR learning unit and the control group trains with the conventional conceptual description of the network components with text and images. The training is conducted under guidance and observation.

The VR learning unit for explaining a network as well as a router was evaluated by 26 ZHAW students in the bachelor's degree program in business informatics. The majority (80%) of the respondents have no computer science background. Before and after testing, the subjects filled out a semi-structured questionnaire with semi structured questions (Curcio, 2022). Thus, the learning effect could be determined retrospectively. The detailed survey results are provided at (Curcio, 2022).

For testing, half of the subjects were presented with the VR learning unit, the other half with the theoretical preparation. In order to accompany the subjects during the execution, the students were assigned in groups of four. While two students were able to carry out the study with the theory on their own, the other two subjects were mainly accompanied in getting to know the VR learning unit and the corresponding interaction concept with the controllers. Students of the test group, who acquired the knowledge about routers purely theoretically, were offered to play through the VR learning unit as well after completing the questionnaires. All accepted this offer, which shows the curiosity and acceptance towards VR learning units.

Table 1 shows an evaluation of all tests before the knowledge transfer by means of the VR learning unit and the theory. To determine possible learning effects, the questionnaires of both groups were evaluated both before and after the knowledge transfer by means of the VR learning unit or the theory. A normal distribution of the sample is assumed. Thus, despite the rather small number of subjects of 26, trends can be described as to whether the VR learning unit leads to a learning effect. This will then be put in relation to the control group.

Table 1. Aggregated pre and post test results and comparison of the test group with the control group regarding the learning impact

	Correct answers concerning network functions	Correct answers concerning router functions	Combined learning impact for network and router functions
Test group (VR) pretest	60%	30%	n/a
Test group (VR) posttest	75%	55%	45%
Control group pretest	45%	30%	n/a
Control group posttest	90%	80%	125%

7. CONCLUSION

A measurable learning effect could be ascertained with the use of the VR learning unit based on the field study. The evaluated survey results show a learning effect of 45% after using the VR learning unit. The learning effect after the use of the theoretical preparation was also evaluated. The learning effect of 125% is much more than the learning effect with the use of the VR learning unit. From this it can be deduced that the sole use of a VR learning unit is not advantageous. It will probably be more beneficial to include a VR learning unit as an additional offering in the curriculum.

It is assumed that the highest learning effect is achieved with the use of the theoretical preparation followed by the use of the VR application. Thereby, it is important to define learning objectives, as well as corresponding questions for each task within the VR learning unit that can be asked after using the application. By answering the questions, the learning objectives can be verified. The learning objectives and the associated questions provide a summary for the students and contribute to the orientation of the learning content. The results from the study and the high demand show that the router use case is a suitable choice for a VR learning unit in higher education.

Another deduction from this field study result is that as long as VR must be considered new and challenging for the subjects the learning effect is negatively affected. Even if help is provided within the VR learning unit the subjects were reliant on help from the instructor. Which means that instructors with a profound knowledge of the learning units need to be available on site. Apart from that instructors need to have also a technical understanding of the VR infrastructure to solve technical problems which are ever present as long as the maturity of the technology is in its current state.

During the field study it was further observed that subjects of the VR learning unit showed signs of fatigue after 30 minutes. A longer learning unit is not recommended for students at bachelor level.

However, VR learning units show great potential for consolidating acquired knowledge. Above all, the change of perspective from the viewer to the performer makes it easy to deepen what has been learned. VR learning units should not be seen as an alternative, but as a supplement to classic teaching methods. If VR learning units are used in this way, they can find great use in teaching.

REFERENCES

Baniasadi, T., S.M. Ayyoubzadeh, and N. Mohammadzadeh, 'Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment', *Oman Medical Journal*, Vol. 35, No. 3, 2020, p. e125.

Checa, D., and A. Bustillo, 'A Review of Immersive Virtual Reality Serious Games to Enhance Learning and Training', *Multimedia Tools and Applications*, Vol. 79, No. 9, 2020, pp. 5501–5527.

Christ, O., and M. Hirschi, 'Virtual Reality in der Berufsbildung. Pilotstudie der login Berufsbildung AG und der Hochschule für Angewandten Psychologie (FHNW)', January 2021.

Curcio, R., 'Router Learning Unit', June 7, 2022.

Döring, N., and J. Bortz, *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften*, 5. vollständig überarbeitete, Aktualisierte und erweiterte Auflage., *Springer-Lehrbuch*, Springer, Berlin Heidelberg, 2016.

Hellriegel, J., and D. Čubela, 'Das Potenzial von Virtual Reality Für Den Schulischen Unterricht-Eine Konstruktivistische Sicht', *MedienPädagogik: Zeitschrift Für Theorie Und Praxis Der Medienbildung*, 2018, pp. 58–80.

Hevner, A., S.T. March, J. Park, and S. Ram, 'Design Science in Information Systems Research', Vol. MIS Quarterly, 28 (1), 2004, pp. 75–105.

Keller, T., and E. Brucker-Kley, 'Experiences with Virtual Reality at Secondary Schools: Is There an Impact on Learning Success?', in D. Ifenthaler, D.G. Sampson, and P. Isaías (eds.), *Balancing the Tension between Digital Technologies and Learning Sciences*, *Cognition and Exploratory Learning in the Digital Age*, Springer International Publishing, Cham, 2021, pp. 77–94.

Keller, T., E. Brucker-Kley, and N. Ebert, 'The Use of Virtual Reality at Lower Secondary Schools', in P. Isaias, D.G. Sampson, and D. Ifenthaler (eds.), *Technology Supported Innovations in School Education*, *Cognition and Exploratory Learning in the Digital Age*, Springer International Publishing, Cham, 2020, pp. 15–32.

Knaack, R., J. Wickert, D. Volz, N. Münchbach, W. Eich, P. Hug, and T. Hocker, 'Einsatz von" Virtual Reality" in Der Ausbildung von Ingenieurinnen Und Ingenieuren', *4. Symposium Zur Hochschullehre in Den MINT-Fächern, Nürnberg, 26.-27. September 2019*, Technische Hochschule Nürnberg, 2019, pp. 176–183.

Liu, D., C. Dede, R. Huang, and J. Richards, *Virtual, Augmented, and Mixed Realities in Education*, Springer Berlin Heidelberg, New York, NY, 2017.

Martín-Gutiérrez, J., C.E. Mora, B. Añorbe-Díaz, and A. González-Marrero, 'Virtual Technologies Trends in Education', *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 13, No. 2, 2017, pp. 469–486.

Niedermeier, S., and C. Müller-Kreiner, 'VR/AR in Der Lehre!? Eine Übersichtsstudie Zu Zukunftsvisionen Des Digitalen Lernens Aus Der Sicht von Studierenden', 2019.

Pirker, J., A. Dengel, M. Holly, and S. Safikhani, 'Virtual Reality in Computer Science Education: A Systematic Review', *26th ACM Symposium on Virtual Reality Software and Technology*, 2020, pp. 1–8.

Reynard, B.R., and 04/26/17, 'The Impact of Virtual Reality on Learning -', *Campus Technology*, n.d. https://campustechnology.com/articles/2017/04/26/the-impact-of-virtual-reality-on-learning.aspx.

Singh, G., 'Using Virtual Reality for Scaffolding Computer Programming Learning', *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology, VRST '17*, Association for Computing Machinery, New York, NY, USA, 2017, pp. 1–2.

Velev, D., and P. Zlateva, 'Virtual Reality Challenges in Education and Training', *International Journal of Learning and Teaching*, Vol. 3, No. 1, 2017, pp. 33–37.