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Inside the Router: An interactive VR learning application to practice routing and network address translation

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Abstract: This paper presents the evaluation of a VR learning application to practice routing and network address translation of a home router. The main didactical design feature of the application is the Inside the System approach, which lets the learners become part of the information system by performing the tasks themselves. Accordingly, process knowledge is to be built up and practiced and thus the competence level of Apply according to Krathwohl and Anderson is to be achieved by the learners. For comparability of evaluation results of VR learning apps, we introduced an evaluation design based on usability, VR specific design, and learning performance.

Keywords: VR, VR learning model, NAT, Router, Process Knowledge.

1 Introduction

One strength of a VR learning application (VRLA) is the ability to actively repeat sequences of actions by allowing the user to move freely and perform hand gestures such as pointing and grasping. By incorporating physical activities, interactions with objects within the application can be made more complex than is the case in desktop applications, for example. Since simulations also allow to visualize abstract learning content, we pursue the thesis that it is beneficial to practice procedural knowledge of abstract learning content through VRLAs.

The topic of networks and the Internet is an integral part of the school curricula for the subject of computer science (CS) in the German states as well as in the curricula of universities. A typical lesson in this field in vocational schools is the subject of Network Address Translation (NAT) in home networks. In exchanges with CS teachers seconded to our chair at the university, the problem was mentioned that tasks of the taxonomy level *Apply* are not always solved correctly in school and university and thus no competence is built up. Since desktop simulations like Filius[2] have already been used in teaching, the thesis is that a VRLA can be a successful digital support tool here. To test the thesis, we (1) reviewed VRLAs in the network domain, (2) analyzed study designs of VRLAs in the field of CS education, (3) designed and implemented our own VRLA, (4) created a

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[2] https://www.lernsoftware-filius.de/

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transferable model of a study design for VRLAs, and (5) evaluated the VRLA regarding the users' competence enhancement.

2 Related Work

The game Network Collapse is intended to help students learn concepts according to K-12 CS Standards from the CS Teachers Association [Pa19]. In the game, the player takes a central role within the router and must regulate network traffic. Unfortunately, the learning objectives are not listed and thus have not been traced back to the K-12 curriculum. An evaluation or scientific publication has not taken place. Meena Jah et al. developed a VR simulation that focuses on the computation to determine the target network. In the learning design, four steps are given for learners to perform as an activity: (1) reads the destination host address into memory from the incoming data packet, (2) performs a calculation on that address to determine its destination network, (3) determines whether the destination network is listed in its table and the associated exit, (4) Moves the data packet out of the appropriate exit [Jh20]. The paper presents a work in progress and does not contain any evaluation or further details on the learning design. Another approach is shown by the VR app BeTheRouter from Cisco Systems [Yu17]. Here, the aim is to interact directly with the network packets as 3D objects. The VR application has so far only been demonstrated at Cisco Live events.

In a systematic paper review of virtual reality applications related to CS education Pirker et. al. listed seven content areas in which a total of 13 applications could be assigned [Pi20]. To be included, the paper must be from a peer-reviewed conference or journal, be written in English, be published after 2013, focus on CS education topic and use VR technology. The identified papers were assigned to the categories of CS concepts, learning objectives, didactic design, and technology used. A comparison of the study design and methodology used was not made. However, this is a key aspect to make the research of VRLA in CS comparable and to comply with quality standards regarding technology and usability. Therefore, we analyzed and categorized the specific study design of all papers[3]. As part of the learning design the in-game performance (number of tasks solved, time to solve tasks) was measured by [Be19], [Ta19], [NSP18], [VIG15]. The self-assessment of the users regarding the achievement of the learning objectives was analyzed by [Ho19], [SS17], [VIG15], [Vi18], [Ta19]. Motivation was measured by [VIG15] and Joy of Use by [Ho19]. As VR specific factors in presence and immersion were analyzed in [Pa16]. Usability as part of the evaluation was surveyed by [SS17], [Pa16], [Vi18]. The paper [PVH17] analyzed the system performance. Only the paper [SS17] uses a standardized test for the evaluation. Otherwise, all other evaluations referred to self-formulated items or analysis of interviews. A broad approach to study design in terms of learning outcome, learning design, VR design, and usability is not found in any of the studies examined. None of the evaluations of VRLA addressed actual learning gains or competence gains.

[3] Of the 13 papers, two were discarded because their content did not address a CS topic (Project skills, Document Organization), one because no evaluation was done and one because the evaluated follow-up paper was also present in the analysis.

For this reason, our study presents an evaluation design that focusses on learning gain with the user interface design and the VR design as control variables.

3 Learning Application Design of Inside the Router

The VRLA is designed to support and not replace a teaching unit on the topic of NAT. Thus, teaching of factual and contextual knowledge below the learning taxonomy level *Apply* is not a learning objective of the application. In the scenario of a home router there are three main cases for routing IP packages, which all can be associated with everyday use cases: *Internal Packages*, *Outgoing Packages*, and *Incoming External Packages*. In the application all three occur and need to be handled by the user. Expected learned competencies are: One can (1) forward a network package from a local source to a local destination address, (2) assign an outgoing local network packet to the WAN port and forward them, and (3) map incoming external packets to a local destination address based on the destination port using the NAT table.

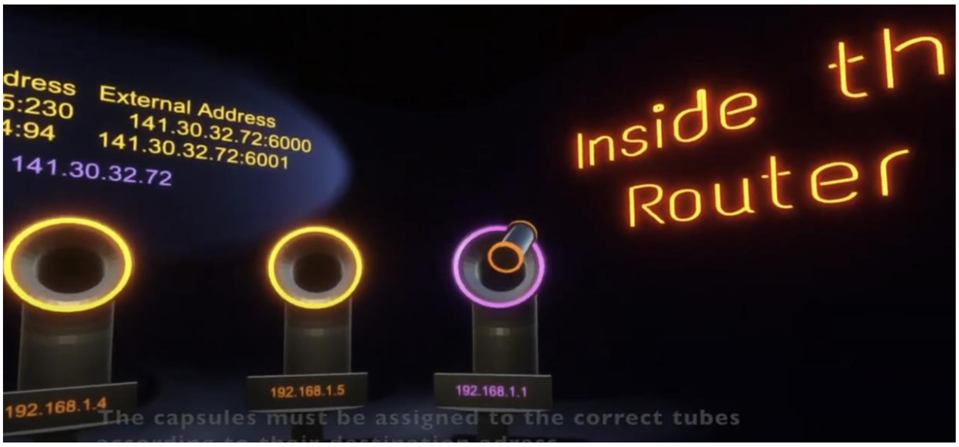


Fig. 1 – VR Design of Inside the Router

The didactic reduction in reference to the German educational standards of CS for *Inside the Router* is described in detail in [Ba22]. To exercise an abstract task like routing a concept for a metaphor to access the task haptically is needed. For Inside the Router this metaphor is a pipe post system in which the routes to the different network components are the pipes (fig. 1). The IP packages are symbolized by capsules that are transported by the pipes. Information like the NAT table must be visible but not interactive, which is realized by displaying it in the background. The main interaction as part of the game mechanics are the three steps: *Catch*, *Decide*, *Throw*. First a package must be caught, then the player must analyze the information on the package, chose a target, and then throw the package. Game mechanics and gamification elements of Inside the Router are discussed in [Ba22]. In short (fig. 2), whenever a package comes in, a sound alerts the user to get ready for the catch. The package follows a fixed trajectory, that makes it possible for the user to catch the package mid-flight. If the user misses the catch, the package lands on a desk and can be picked up. On the package the source and destination IP addresses can be found. If a package lands in a tube, the tube gives visual and audio feedback whether the assignment was correct. If the assignment was correct there will be a green flash and the catch - decide - throw cycle will start with the next package. If a given number of packages was assigned correctly the application ends and presents the player a score.

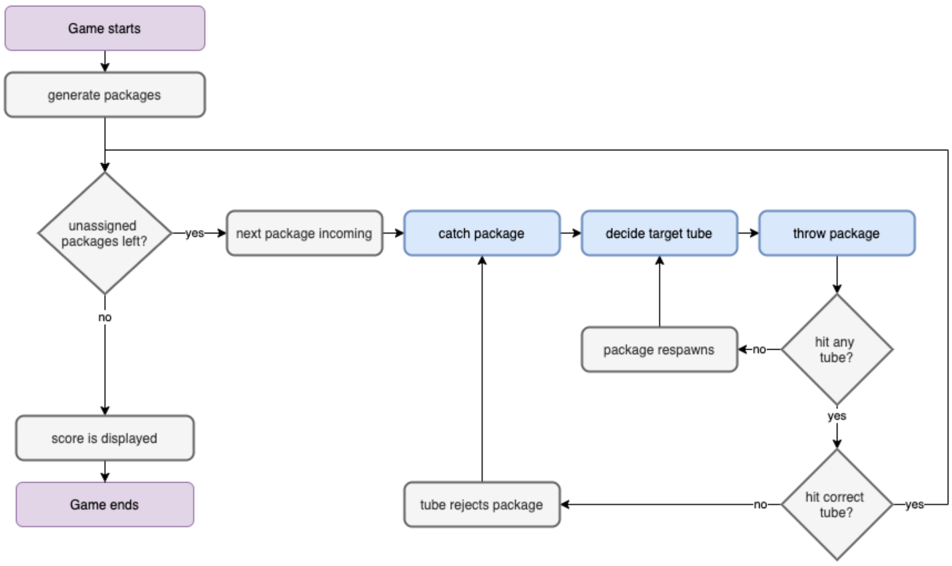


Fig. 2 – Game schedule of Inside the Router

4 Evaluation Design

To determine the quality of the VRLA Inside the Router, it needs to be examined from usability perspectives, VR specific learning design decisions, and learning growth or competency gain as the main feature. Since none of the studies examined in the related work included an appropriate study design, an evaluation design was developed in accordance with a general study design for measuring virtual reality shopping experience [SCK17]. The evaluation design is based on the three evaluation components: *3D User Interface*, *Virtual Reality* and *Learning Performance* (fig. 3).

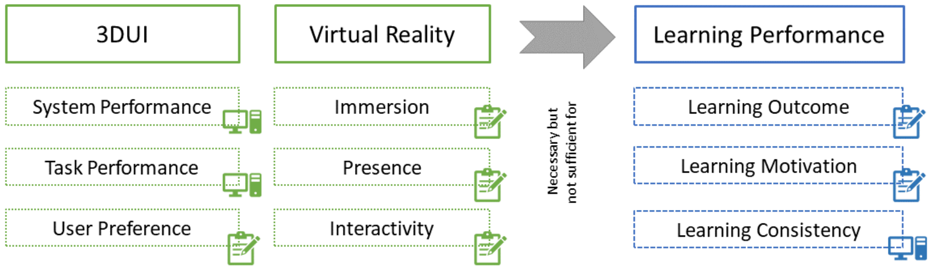


Fig. 3 - Structure of the evaluation design

To measure the quality of the user interface for VR applications, [SCK17] recommends the 3DUI Evaluation Metrics. This is based on the evaluation metrics: *system performance*, *task performance*, and *user preference*. System performance here refers to all system characteristics that can count towards negatively impacting the application experience (average frame rate, average system latency). Task performance includes quantitative measurements such as time, error rate, and accuracy of interactions. For example, in the study, this could be grabbing a package. Delays due to cognitive hurdles regarding a learning step is explicitly not meant here. One way of measuring user experience is the User Experience Questionnaire[4] (UEQ). With this standardized questionnaire (26 items), comparisons can be achieved even to non-VR applications. User preference can be surveyed according to [SCK17] about user experience, usability and as VR specific motion sickness. To evaluate usability, the System Usability Scale (SUS) is suggested as this is a reliable and valid measure of perceived usability. To measure motion sickness the Motion Sickness Assessment Questionnaire (MSAQ) is proposed as a valid instrument to assess motion sickness.

Immersion, presence, and interactivity are important characteristics of VR [SCK17]. The distinction and definition of immersion and presence is still part of the scientific discourse [BA19]. We follow Slater here in defining immersion as an objective property of a system [Sl18]. Lower or higher immersion therefore is to be specified as aspects such as display resolution, field of view, sound, and similar relevant system components. Definitions of immersion via user engagement or a flow state [Pl21] should be rejected due to the strong interrelationship with psychological constructs and learning design. Creating detailed virtual environments or, conversely, using poor quality 3D models certainly influences the quality of the VRLA and the factors being studied, but desktop 3D learning environments are subject to similar influence. Mayer's Immersion Principle [Ma21] should therefore be investigated as a principle of the depth of detail of the representation. Therefore, we do not consider the design of the VR environment as part of the definition of immersion. Plotzky et. al. found no scientific consensus regarding the influence of presence on learning effects [Pl21], mainly because of the low number of studies. As argued by learning theories a positive relationship between feeling presence and learning motivation

[4] https://www.ueq-online.org/

and learning effect are suspected. Presence is defined as the impression of being part of the virtual environment. According to Slater, the illusion is perceptible, but is only slowly identified by the cognitive system as the perceptual system recognizes events and objects as well as the brain-body system automatically reacts to changes in the environment [Sl18]. Schwind et. al. provide an overview of 15 presence questionnaires published between 1995 and 2009 [Sc19]. As a result, the IPQ was recommended as the questionnaire that best reflects the construct of presence. Interactivity indicates the extent to which a VR application design allows users to participate in the actions of tasks in real time. For a general consideration, the perspective of the interactions in the learning situations of the application (number, type) on the one hand and the assessment of the interactivity by the user on the other hand must be considered. To build competencies related to procedural knowledge, learners must be placed in situations where they can repeatedly apply the actions and sequences. To measure the user's impression of the application's interactivity, [Mü18] theoretically derived and evaluated a 3-item scale (IS) with very good internal reliability.

To circumscribe learning performance as a concept and make it measurable, motivation in the learning process, consistency of learning steps, and gain in competence as learning outcome are defined. A direct influence on performance is the learner's motivation to actively participate in the learning process. A related psychological construct is the flow state. This, in conjunction with the Flow Short Scale (FSS), predicts performance [ER08]. The flow state describes a balance between the perception of one's own abilities and the perception of the difficulty of the activity (task demand). This is characterized by coherence of the activity, concentration on a limited stimulus field, change in time experience, and merging of self and activity [ER08]. In addition to the definition of flow as the balance between skills and challenge, the perceived importance of the activity and the individual achievement motive are also important components. According to [ER08] other influencing factors are likely, and flow should be measured in its multidimensionality in the future. Situational interest should be measured as one way of supplementing. Situational interest is defined as a multidimensional construct in the interaction between person and activity. Chen et. al. developed a 24-item scale (SIT) to measure Situational Interest in the 5 dimensions Novelty, Challenge, Exploration Intention, Instant Enjoyment, and Attention Demand [CDP99]. We propose the term learning consistency as another component for determining learning performance. Particularly Especially VR applications offer a new perspective to explore the learning process with reference to the research field of learning analytics due to technical possibilities of data recording (direction of gaze, sequences of actions). The Framework EduXR.xAPI offers extensive support here [HGS22]. Thereby, contradictory requirements, the logical structure, and instructions for action within the application can be measured. Learning outcome refers to the gain in competence about the intended learning goal of the VRLA. For this purpose, sub-objectives must be defined and operationalized in corresponding tasks. This step is difficult to generalize because learning content and learning objectives are tailored to specific curricula and learning settings. Collections of standardized competency tasks on specialized topics exist only to a limited extent in the school context. Thus, the development of specific test items to measure competency gains is necessary for each study.

5 Study Design

To conduct the study, a seminar room at the university was provided with a fixed experimental setup. This consisted of a 4 by 4-meter area as a free VR surface and an HTC Vive Pro Eye with wireless connector and two HTC Vive controllers as devices. A period of 60 minutes was reserved for each participant. The experimental procedure consisted mainly of the phase’s pre-questionnaire, tutorial, implementation of the application and post questionnaire [TDN22]. A guided tutorial is part of the VRLA and introduces the user to the game elements and interactions as part of the game mechanics [TDN22]. The observed run consists of 21 packets, 7 each local, incoming, and outgoing in mixed order.

The participants should already have basic knowledge about the structure of IP addresses and network components before using the VRLA, but they should not already have expert knowledge about the topic of networks. The participants were mainly recruited from the first semester of the teacher training program in CS. The experiment was conducted after a unit on networks, in which the school basics of the topic of networks (layer models, client-server architecture, transport protocols, IPV4, IPV6) were presented and worked on in a 90-minute lecture and two 90-minute exercises. The topics of routing and NAT were not covered. Participation in the experiment was voluntary for the students. Of the 38 students in the course, 18 participated in the experiment. 6 participants of the experiment were students of the teaching CS of higher semesters and 4 were employees of the University, but who had not completed any further specialized course regarding the topic. In total, the study has 28 participants.

To evaluate the VRLA Inside the Router, the user interface was analyzed with the 3DUI Evaluation Metrics. System Performance and Task Performance were determined by system data. User Preference was mapped by the SUS and MSAQ scales. The Virtual Reality component was captured by Immersion (via system data), Presence (IPQ), and Interactivity (IS). The Learning Performance component was divided into Learning Motivation (FSS, SIT), Learning Consistency (xAPI-compliant Learning Analytics data from the system), and Learning Outcome (pre-post design of competency tasks). Regarding learning consistency, the xAPI-compliant data included which object was viewed and when, the user's interactions with the packets, and the assignment of packets to tubes. The pre-post-design referring to the learning outcome consist of 3 tasks. The 3 tasks were identical in each of the pre-version and the post-version. In the first task, the destination must be specified for 4 packages (1 internal-internal, 2 internal-external, 1 external-internal). The structure of the network with IP addresses, a NAT table and the packet with source address and destination address including port are given. In the second task, the structure of a network was sketched and then a sequence of packets arriving at the router was given. Based on this, the resulting NAT table was to be specified. Only outgoing packets should be included in the NAT table and addresses and ports had to be assigned correctly. In task 3, a network structure was specified, and an existing NAT table was given for this purpose. The task is to identify the three errors internal-external address, internal IP as external address of the router and double allocation of an outgoing port of the router.

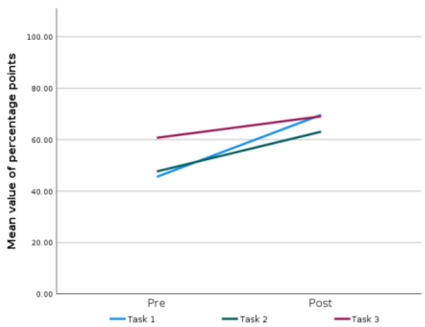
6 Results

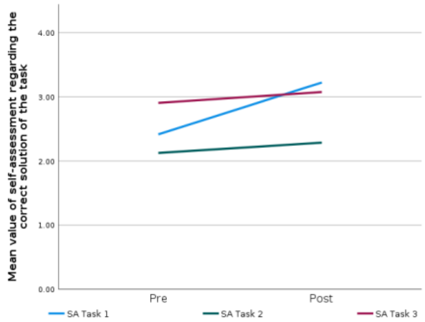
System performance was consistently adequate (average delay 8ms, jitter below 11ms, no frame drop). There was no controller or wireless kit connection failure. As task performance gripping and throwing were observed. Gripping the packages was not a handicap for any of the users. However, the participation of 3 left-handers showed a display error, since the snap zones optimized for right-handers displayed the writing upside down for left-handers. A total of 1190 packages were thrown of which 968 hit the tubes in 42 runs (time M=2:55min SD=1:23min). The initial error rate in throwing the packages decreased sharply during the game. The sound was disabled for 3 users due to configuration errors.

User preference can be surveyed about user experience (UEQ), usability (SUS) and as VR specific motion sickness (MSAQ) [SCK17]. Since the UEQ was conducted as part of the usability test, the abbreviated UEQ-S was applied. The UEQ-S provides less detailed information regarding the possible improvements of the application, but it offers a good basis for ranking the user experience by a benchmark [SHT17]. Overall, the user experience was rated at 2.058 (SD=0.612) on average on a scale between −3 to 3 (Subscales: Pragmatic Quality M=2.036 SD=0.863, Hedonic Quality M=2.080 SD=0.736). The UEQ benchmark contains the data from 21175 persons from 468 studies. The benchmark classifies Inside the Router into category excellent (range of 10% best results). Please note that the UEQ comparison is based on data from business software, web pages, web shops and social networks. A direct comparison is therefore difficult to classify here. According to the usability the overall SUS score was M=84.732 SD=11.083. SUS scores can be converted into percentile ranks based on dataset of SUS scores. The SUS score of 84.723 is at the 96th percentile, this scoring better than 96% of the scores in the database. The results on the MSAQ for measuring motion sickness gave a total score M=16.0218 SD=5.402 on a scale between 11.11 (no motion sickness) to 100 (severely motion sickness). In the subscales, there is a slight upward deviation in the peripheral scale M=18.386 SD =12.116. This may be due to the movement of the user, as the application requires continuous movement, which can result in heat sensation and sweating. Overall, no to little motion sickness can be detected among the users.

Characteristics regarding VR of the application are considered in factors immersion, presence, and interactivity. As values for immersion, the HTC Vive Pro Eye offers a resolution of 1440x1600 per eye, a field of view of 110 degrees and a wireless kit for wireless use of the VR goggles. The IPQ to measure presence consists of 13 items on a scale between 1 to 6. 12 of the items are divided into 3 subscales (Spatial Presence 5 items, Involvement 4 items, and Experienced Realism 3 items). The last item (G1) loads on all three factors and simultaneously represents the General Presence factor. The IPQ evaluation resulted in a General Presence of M=5.21 SD=.791, on the Spatial Presence subscale M=5.357 SD=.791, on the Involvement subscale M=4.473 SD=1.163, and on the Experienced Realism subscale M= 3.179 SD=1.128. The Interactivity Scale (IS) by [Mü18] consists of 3 Items on a scale between 1 and 7. The results show an interactivity score of the application of M=1.571 SD=.753. Thus, users perceive the application as highly interactive.

Learning performance is investigated by considering motivation in the learning process, consistency of learning steps, and gain in competence as learning outcome. FSS consists of 13 items on a scale between 1 and 7. The items are divided into 3 subscales (Fluency of Performance, Absorption by activity, Concern). The first two subscales together form the general flow factor. The FKS evaluation shows a general Flow factor of M=5.714 SD=.753, a Fluency of Performance of M=5.768 SD=.809, an Absorption by activity M=5.634 SD=.883, and on the Concern subscale M=2.202 SD=1.090. Compared to the midpoint of the scale, users indicate a high level of flow. The SIT shows on the subscales Novelty (M=4.048 SD=.768), Attention quality (M=4.392 SD=.621), Instant Enjoyment (M=4.50 SD=.461), and Exploration intention (M=4.089 SD=.720) high scores (scale between 1 to 5). The subscale Challenge (M=2.080 SD=.589) describes the classification of the perceived complexity of the activity and should be located around the midpoint of the scale.





The analysis of the learning outcomes was carried out by assigning points to the 3 tasks as well as the respective assessment of the participants as to how confident they considered their own solution to be correct. According to the results of the dependent t-test the participants score significantly higher on task 1 (Pre: M=1.821 SE=.206, Post: M=2.786 SE=.220, t(27)=-4.484, p<.05,r=1.138)[5] and on task 2 (Pre: M=1.43 SE=.158, Post: M=1.89 SE=.157, t(27)=-2.931, p<.05,r=.838)[6] on average. There was no significant change in task 3[7]. In the self-assessment on the correct solution of the tasks, the participants indicated significantly higher confidence in task 1 (Pre: M=2.415 SE=.157,

[5] 1 reduction of points, 11 times unchanged, 16 times improvement of points.
[6] 3 reduction of points, 12 times unchanged, 13 times improvement of points.
[7] 5 reduction of points, 14 times unchanged, 9 times improvement of points.

Post: M=3.223 SE=.119, t(27)=-5.421, p<.05,r=.789). There was no significant change in the confidence on task 2 and task 3.

7 Discussion

Inside the Router as a VR application shows an excellent usability with the participants (high UEQ, high SUS, low MSAQ, adequate system performance, increasing task performance over the application duration). The VR-specific observation showed a strong sense of presence of the participants (high IPQ) as well as a high sense of interactivity (high IS). Immersion was supported using the HTC Vive Pro Eye with wireless kit as a current high-end system. Both components (3DUI, VR) of the evaluation design are necessary but not sufficient conditions for creating VRLA, as negative experienced or distracting factors interfere with the learning process. Keeping this influence on a minimum through the didactic and learning design seems to have succeeded with the participants.

The most important contribution of a VRLA is the learning performance of the participants. Participants gave very good scores for the app in the Learning Motivation categories Flow Experience and Situational Interest (high FSS, high SIT especially on the crucial Instant Enjoyment and Exploration Intention subscales). In task 1, which directly deals with the intended competence of assigning the 3 types of packages to the correct targets, a significant improvement in the subtasks as well as in confidence could be observed. Task 2 dealt with the creation of a NAT table and was only observed by the participants during the execution and not executed by them. Here, the participants achieved a significantly higher average score, but the confidence of the correct solution did not increase significantly. The thesis is that the execution of the tasks has a direct influence on the confidence of the participants. In task 3, a NAT table had to be analyzed for errors. There were no significant changes in the participants. This could be due to the task construction, since 2 errors were schematically recognizable and only the third error required a knowledge transfer.

The evaluation design aims to achieve comparability of VRLA to enable meta-analysis in learning design and learner skill growth. This requires the use of standardized learning psychological constructs and related test instruments, as well as a general exchange of research data. Especially the provision of measurement instruments for subject-specific competencies is one of the most important prerequisites to support joint research. In support of this, Inside the Router is released under MIT License and all project data and test instruments in this study are accessible in the Open Science Framework [TDN22][8].

[8] The project data are released under the CC-By Attribution 4.0 license International.

Bibliography

[BA19] Berkman, M. I.; Akan, E.: Presence and Immersion in Virtual Reality. In (Lee, N. Ed.): Encyclopedia of Computer Graphics and Games. Springer International Publishing, Cham, pp. 1–10, 2019.

[Ba22] Baberowski, D. et al.: Inside the Router. eleed 2/14, 2022.

[Be19] Bebis, G. et al. Eds.: Advances in Visual Computing. Springer International Publishing, Cham, 2019.

[CDP99] Chen, A.; Darst, P. W.; Pangrazi, R. P.: What Constitutes Situational Interest? Validating a Construct in Physical Education. Measurement in Physical Education and Exercise Science 3/3, 157-XXX, 1999.

[ER08] Engeser, S.; Rheinberg, F.: Flow, performance and moderators of challenge-skill balance. Motivation and Emotion 3/32, pp. 158–172, 2008.

[HGS22] Heinemann, B.; Görzen, S.; Schroeder, U.: Systematic Design of Effective Learning Scenarios for Virtual Reality: 2022 International Conference on Advanced Learning Technologies (ICALT), Bucharest, Romania, 2022.

[Ho19] Horst, R. et al.: FunPlogs – A Serious Puzzle Mini-game for Learning Fundamental Programming Principles Using Visual Scripting. In (Bebis, G. et al. Eds.): Advances in Visual Computing. Springer International Publishing, Cham, pp. 494–504, 2019.

[Jh20] Jha, M. et al.: Work-in-Progress—Designing a Virtual Reality Simulation to Teach Elements of Network Routing: 2020 6th International Conference of the Immersive Learning Research Network (iLRN). IEEE, pp. 279–282, 2020.

[Ma21] Mayer, R. E.: Multimedia learning. Cambridge University Press, Cambridge, 2021.

[Mü18] Mütterlein, J.: The Three Pillars of Virtual Reality? Investigating the Roles of Immersion, Presence, and Interactivity. In (Bui, T. Ed.): Proceedings of the 51st Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences, 2018.

[NSP18] Nicola, S.; Stoicu-Tivadar, L.; Patrascoiu, A.: VR for Education in Information and Tehnology: application for Bubble Sort: 2018 International Symposium on Electronics and Telecommunications (ISETC). IEEE, pp. 1–4, 2018.

[Pa16] Parmar, D. et al.: Programming moves: Design and evaluation of applying embodied interaction in virtual environments to enhance computational thinking in middle school students: 2016 IEEE Virtual Reality (VR). IEEE, pp. 131–140, 2016.

[Pa19] Pacific Northwest National Laboratory: Network Collapse - Teachers guide. https://www.pnnl.gov/sites/default/files/media/file/Network_Collapse_Teachers_GuideIR_05-21-2019.pdf, accessed 11 Apr 2022.

[Pi20] Pirker, J. et al.: Virtual Reality in Computer Science Education: A Systematic Review. In (Teather, R. J. et al. Eds.): 26th ACM Symposium on Virtual Reality Software and Technology. ACM, New York, NY, USA, pp. 1–8, 2020.

[Pl21] Plotzky, C. et al.: Virtual Reality in Healthcare Skills Training: The Effects of Presence on Acceptance and Increase of Knowledge. i-com 1/20, pp. 73–83, 2021.

[PVH17] Puttawong, N.; Visoottiviseth, V.; Haga, J.: VRFiWall virtual reality edutainment for firewall security concepts: 2017 2nd International Conference on Information Technology (INCIT). IEEE, pp. 1–6, 2017.

[Sc19] Schwind, V. et al.: Using Presence Questionnaires in Virtual Reality. In (Brewster, S. et al. Eds.): Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. ACM, New York, NY, USA, pp. 1–12, 2019.

[SCK17] Speicher, M.; Cucerca, S.; Krüger, A.: VRShop. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 3/1, pp. 1–31, 2017.

[SHT17] Schrepp, M.; Hinderks, A.; Thomaschewski, J.: Design and Evaluation of a Short Version of the User Experience Questionnaire (UEQ-S). International Journal of Interactive Multimedia and Artificial Intelligence 6/4, p. 103, 2017.

[Sl18] Slater, M.: Immersion and the illusion of presence in virtual reality. British journal of psychology (London, England 1953) 3/109, pp. 431–433, 2018.

[SS17] Stigall, J.; Sharma, S.: Virtual reality instructional modules for introductory programming courses: 2017 IEEE Integrated STEM Education Conference (ISEC). IEEE, pp. 34–42, 2017.

[Ta19] Tanielu, T. et al.: Combining Analogies and Virtual Reality for Active and Visual Object-Oriented Programming. In (Zhang, M. et al. Eds.): Proceedings of the ACM Conference on Global Computing Education. ACM, New York, NY, USA, pp. 92–98, 2019.

[TDN22] Thiemo Leonhardt; David Baberowski; Nadine Bergner: Evaluationinstruments and data of Inside the Router: An interactive VR learning application to practice routing and network address translation. Open Science Framework, 2022.

[Vi18] Visoottiviseth, V. et al.: Lord of Secure: the Virtual Reality Game for Educating Network Security: 2018 Seventh ICT International Student Project Conference (ICT-ISPC). IEEE, pp. 1–6, 2018.

[VIG15] Vallance, M.; Ibayashi, K.; Goto, Y.: Engineering Active Learning in 3D Virtual Worlds. In (Uden, L.; Liberona, D.; Welzer, T. Eds.): Learning Technology for Education in Cloud. Springer International Publishing, Cham, pp. 268–282, 2015.

[Yu17] Yusuf Bhaiji: CCIE Virtual Reality (VR) Experience. https://www.linkedin.com/pulse/ccie-virtual-reality-vr-experience-yusuf-bhaiji, accessed 11 Apr 2022.