Evaluation of Proprietary Social VR Platforms for Use in Distance Learning

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Abstract. Distance learning in form of video chats or the streaming of recorded lectures are common ways for schools and universities to maintain teaching under the restrictions of the global SARS-CoV-2 pandemic. One possibility to improve distance learning can be the use of virtual reality (VR). To this day there are no common guidelines for educators for using VR, and therefore no recommendations to decide which platform to use and what specific requirements they entail. This paper presents an evaluation of currently available proprietary social VR platforms for the use in distance learning. Based on results of expert interviews ($n = 4$) with educators and an online survey ($n = 92$) of students, we identified ten relevant criteria for teaching in VR. We compiled a list of 155 currently available proprietary social VR platforms, which we filtered and evaluated. The results indicate that current social VR platforms can provide an easy and affordable way for educators to access the usage of VR in education, although we could not determine a single best social VR platform. Our recommendations rather provide different most suitable platforms for particular learning applications depending to respective educational requirements. Our research provides a guideline for interested educators in order to find an affordable entry into the usage of VR in education. Building on this, future research can shed light on questions of didactic effects, user-friendliness, or data protection.

Keywords: Virtual reality · Education · Distance learning · Social VR Platforms

1 Introduction

The global SARS-CoV-2 pandemic poses a major challenge for schools and universities to deliver adequate education to their students [12]. Learning in video chats and watching recorded lectures has become the daily routine for many students [5] when universities and schools had to stop their in-classroom teaching. Students and teachers have mixed opinions about this new form of learning, but this switch to digital learning can in turn open the doors for other technologies to improve learning outcomes. One of the technologies that has seen a

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strong increase in popularity in the past decade is VR: a 3D, multi-sensorial, immersive, real time, and interactive simulation of a space [19] that can provide students with exclusive first-person experiences that were previously impossible to obtain in formal education [45]. While the technology and early devices have already been known since the 1960s, more affordable VR devices have only recently started to appear. Today, users can experience immersive VR experiences with high-quality head-mounted displays (HMD) for under $ 300 [8,42]. There are also stand-alone HMDs, which do not require a powerful and expensive computer to operate. In addition to the availability of suitable hardware, teachers also need to have the proper software to execute their lessons and provide learning material. Custom made and specialised software is often expensive or requires a lot of time to be created. As part of the recent rise in popularity for VR, numerous social VR platforms, which provide virtual environments (VE) for people to meet and interact in VR, have been developed in the past years. These platforms are already available and likely to be more affordable than custom designed software. Building on the thesis and survey results of Fuchs [9], this work will therefore elaborate a methodology in order to evaluate the potential use of social VR platforms for distance learning. The focus is clearly on the technical consideration and evaluation, which is why pedagogical factors have been deliberately neglected.

2 Related Work

Since the creation of the first virtual reality device in the 1960s [39], a lot of research on VR and its applications has already been done. The following sections provide a short overview of topics related to VR and its benefits and challenges.

2.1 Presence and Immersion

Presence and immersion are two of the key aspects when talking about VR. But there is no consensus about the specific meaning among researchers yet. Both terms have at times been used synonymously, while being strictly separated in other cases. One explanation of their correlation was provided by Slater et al. [32]: "Presence is a human reaction to immersion". Following this explanation, presence describes how present the user feels inside VR, while immersion is how the user's senses are stimulated by external devices. Measuring the level of immersion is done by examining how the user's senses are targeted by the devices used. Presence on the other hand is much harder to evaluate from an objective point of view, as there are lots of different aspects that affect it. Pan et al. [27] found that errors in the visual representation, such as lagging graphics and flickering images, can have a negative impact on the user's perception of presence. In 2009, Jin [15] discovered that the individual representation of users inside the VE affects their perception of presence as well. Even the personal traits of users were found to have a major influence on how present the user feels in a study by Janssen et al. [14].

2.2 VR in Education

Over the past few decades, the potential of using VR in education has frequently been discussed. Winn [45] elaborated how immersive VR can enable students to have unique experiences that are otherwise impossible to achieve in formal education. Other studies showed more applications, in which using VR outperformed other teaching methods: Duff, Miller, and Bruce [6] compared virtual patients to actors playing patients in a medical study and found that users perceived the virtual patients as more realistic. Legault et al. [21] compared traditional learning methods for learning Mandarin to an immersive VR experience, which resulted in the VR experience showing better learning outcomes for participants. Various other studies [23,38,47] compared immersive VR simulations to other teaching methods and concluded that the usage of immersive VR simulations can lead to students showing greater motivation and interest as well as better results in tests. Kyaw et al. [18] analysed 31 studies dealing with education of medical health professions in order to compare VR learning methods to other forms of digital learning. They found out that the usage of VR lead to better learning results for the students. A different approach on how to enhance teaching methods by using VR was presented by Dyer et al. [7], who let nursing care personnel experience age-related conditions, which proved to be an effective teaching method to teach students to develop empathy. Merchant et al. [25] performed a meta-analysis of over 60 studies in a more general approach to evaluate whether a VR environment has a positive effect on teaching. They concluded that a VR environment is indeed effective for teaching in higher education and further found that, among different kinds of VR scenarios, game scenarios showed the best learning outcomes for students. In a study about teaching truss mechanics to engineering students, Banow and Maw [2] found that students using VR showed significantly better learning outcomes compared to the students using traditional teaching methods.

Focusing on the aspects of social interaction in VEs, Williamson et al. [44] demonstrated that the social behaviours in VR workshops mirror the social behaviours of real-life workshops. However, they highlighted the need for VR platforms to provide the users with diverse means of expressing themselves, as otherwise several social cues present in real life get lost. On the other hand, a survey by Yarmand et al. [46] found that many students are unwilling to share their videos, which hinders social interaction within class and poses a significant challenge to teachers. Educators who are met with static or even no images of their students have difficulties reading the engagement of their class. This impedes encouraging student participation, e.g. by addressing individuals directly. Hence, teaching in VR needs to account for the students' preference of not showing their real faces or surroundings while still communicating emotions, expressions or reactions to teachers and classmates. Additionally, studies by Petersen, Mottelson, and Makransky [28] as well as Gao et al. [11] found that the visual representation of the teacher and students influences the knowledge gained by learners in VR settings. This further reinforces the need for customisation options for classroom avatars.

2.3 Cybersickness

One drawback of using VR is the medical condition called cybersickness. Users of VR devices can experience symptoms similar to those of motion sickness. Those symptoms can range from mild symptoms like sweating, fullness of stomach, and dryness of mouth to more severe ones, like headache, vertigo, and vomiting [20].

LaViola [20] found that technical parameters, such as lag, position tracking errors, and flicker, are possible triggers for the occurrence of cybersickness. He further states that a refresh rate of at 30 Hz is generally enough to remove the issue of flicker. He also found individual factors, such as gender, preexisting illnesses, and age, to affect the occurrence and severity of cybersickness. Higher visual realism was found to cause more symptoms of cybersickness than lower visual realism in a study by Tiiro [41].

A qualitative study by Wang and Suh [43] about how users adapt to cybersickness in VR revealed that a change in body posture, adjusting the position of the HMD, resting the eyes, and slower movement can reduce the user's discomfort. They also had users reporting that the repeated use of the same VR application has decreased their feeling of cybersickness.

2.4 Internet Connection

According to Mangiante et al. [22], the internet requirement for what they call early stage VR with a resolution of 1K × 1K px, equivalent to 240p TV resolution, is 25 Mbit/s and a latency of 40 ms. A video resolution of 4K × 4K px, comparable to high definition (HD) TV, already requires 400 Mbit/s and a latency of 20 ms. This shows how important the aspect of sufficient internet connection is for a successful implementation of VR for education purposes. As an example, in 2019, about 5% of households in Germany had no internet access and the average connection speed was at just 24.64 Mbit/s. This vastly increased in 2020, when an average mobile internet connection of 57 Mbit/s with a latency of 33 ms and a fixed broad band connection of 118 Mbit/s with a latency of 21 ms were measured [26]. There has yet to be conclusive research done to evaluate whether the currently available internet infrastructure is enough to provide all students suitable circumstances for the use of VR in education.

3 Concept

Since, to the best of our knowledge and previous research, there are no uniform guidelines for the use of VR in teaching to date, there are neither recommendations for educators which platform would be best suited for this, nor which technical requirements are involved.

In the following, we present a methodology for the evaluation of currently available VR platforms for the potential use in distance learning. Our approach essentially consists of four main steps, which can be seen in Fig. 1. We begin the process with qualitative and quantitative studies to identify the individual

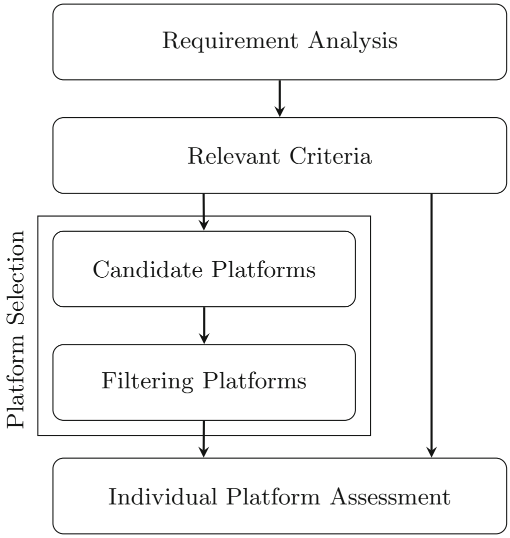

Fig. 1. This flowchart illustrates our concept to identify and evaluate the social VR platforms. First we conduct a requirement analysis, which allows us to formulate relevant criteria. We then use these criteria to select and filter the platforms. We finally analyse the remaining platforms individually.

requirements of educators and students (*Requirement Analysis*). Based on this data we define specific criteria which allow us to evaluate the suitability of the respective tested social VR platform (*Relevant Criteria*). In the next step (*Platform Selection Process*), currently available proprietary social VR platforms are firstly identified (*Candidate Platforms*) and subsequently reduced to a manageable selection (*Filtering Platforms*). Finally, the remaining platforms are individually subjected and compared to each other, regarding how well they meet the identified criteria, for final recommendations (*Individual Platform Assessment*).

4 Results and Discussion

To evaluate social VR platforms for the potential use in distance learning, we applied the methodology presented in Sect. 3. The observation period was between December 2020 and February 2021.

4.1 Requirement Analysis

For the identification or relevant criteria we chose a two-pronged approach: On the one hand we used expert interviews to gather qualitative data and thereby deeper insights from didactic experts. On the other hand we used an online survey to collect quantitative data on the needs of students.

Expert Interviews - Design. To carry out the qualitative analysis, we conducted four expert interviews and subsequently analysed them in detail. The use of expert interviews requires not only a general clarification of the definition of an expert itself, but also the examination of an appropriate interview format.

The expert status requires the completion of general training as well as training related to specialised knowledge. The corresponding qualification, in turn, is proven by the acquisition of a socially recognised and thus validated proof in form of a respective certificate [33].

Regarding the correct format of expert interviews, there is an ongoing discussion in the literature. Since it is neither clear how, nor whether it is possible at all to place expert interviews on a secure methodological basis, we recommend conducting the interviews in form of open questions without a rigid, restrictive, and thus possibly result-falsifying method until this debate has been clarified [3].

As our interviewees wished to remain anonymous, they will be referred to as I_1, I_2, I_3 and I_4.

- I_1 is a university professor for computer science at a German technical university.
- I_2 is a university professor of literature at a German non-technical university.
- I_3 is a teacher at a grammar school in Germany and is seconded part-time to a university.
- I_4 is a university professor at the department of computer science at a German technical university.

Furthermore, based on the given expert definition, the interviewed persons could doubtless be called experts from the fields of didactic and teaching.

In each of the four interviews, twelve questions were asked in the order presented in Table 1. The interviews were conducted in German, hence the questions were translated from German.

Expert Interviews - Results. All four experts showed a basic awareness for the use of VR in education. While I_1 plans to use VR for a project in the near future, I_2 and I_4 have already used VR in education. Due to their affiliation with a technical university, only I_1 and I_4 considered the technical requirements for the use of VR to be given. In addition to suitable hardware, for example in form of sufficiently powerful computers, slow internet connections at the workplaces were also identified as possible bottlenecks. With regard to a possible budget, the statements differed relatively widely. I_1 estimated the possible budget of their university for VR applications to be at least as high as for licences for other applications used in teaching, e.g. Zoom, and mentioned that up to 20 000 € should not be a problem. I_2 mentioned that a budget of up to 200 € is still an acceptable price for the use of a VR platform in a course. I_3 did not give an exact price, but stressed that with an annual budget of only 700 € for the school's IT department, costs should be kept as low as possible. Due to a complete lack of budget for courses, I_4 stated that the platforms would even have to be free of charge. Even if provided with funding, they mentioned that the budget would

Table 1. Structure of the expert interviews

ID	Question
E1	Have you tried using VR in education before?
E2	Do you have access to a computer powerful enough to run VR applications at your work place?
E3	Do you have access to a fast and stable enough internet connection at your work place?
E4	How much may a VR application cost for the use in your lectures?
E5	How do you evaluate the teaching setting of a classroom without media support and just a teacher presenting content in front of the class?
E6	How do you evaluate the teaching setting of a classroom with media support, e.g. sound, video, and text?
E7	How do you evaluate the teaching setting of an interactive and customisable environment?
E8	How important is easy usability for VR platforms?
E9	How detailed and realistic do you want a VR platform to be, to be suitable for teaching?
E10	Where do you see the biggest obstacles for using VR in education?
E11	What are essential qualities for a VR platform to be suitable for education?
E12	Would you like to see VR integrated into education?

probably be around 5 € per student. However, it must be mentioned that none of the interviewees have budget responsibility according to their own statements. In the context of the presentation of the different potential settings, all interviewees agreed that this mainly depends on the application case and the respective, associated requirements. Due to the assumed highest degree of immersion, all interviewees saw the greatest potential for teaching in an interactive and customisable environment (E7). However, they mentioned that the higher variety of possibilities and the possible distractions in such an environment do not necessarily lead to better teaching results. All four respondents agreed that the usability of a VR application should be as simple and natural as possible. The demand for level of detail and realism within the virtual world is again highly dependent on the use case. While the representation of certain objects, e.g. anatomically correct body parts in a medical course or the recreation of "real" social interaction, requires a high degree of detail and realism as possible, in some cases only simple representations or symbols are needed. However, I_4 noted that a higher level of detail and "cool look" could positively influence users' motivation and opinion of VR applications. Currently, the biggest obstacles are seen in technical limitations. I_1 mentioned that their university, even after a lot of work, were not able to organise proper online programming exams. Hence, they deem organising a VR course as too much of a challenge and expect it to ultimately fail due to hardware and software problems. In addition, the possible lack of acceptance and understanding of VR were also seen as potential limiting factors. However, the general consensus was that the technology offers many possibilities and should be used in education in the future.

We gather from the results of the interviews that the requirements for VR applications for the use in education depend strongly on the respective use case, which in turn affects the respective technical requirements. The interviewees saw the greatest advantages in the use of VR in education in the display and joint viewing of relevant objects. In addition to a high level of detail and possible interaction possibilities, the objects should also be easy to create or be able to be uploaded to the platform in common file formats. In addition, the realistic representation of social interaction between the participants was also considered as relevant. This is, for example, also reflected in the possibilities for self representation. Due to budget uncertainty, it appears that free VR applications have the greatest chance for acceptance and use in education.

Online Study - Design. For the quantitative research we applied a survey with prospective users, since the expectations of users of distance learning with VR are of great interest. The survey was mainly distributed in social media groups for students and lecturers. Over a six-week period, combined with active advertising, a total of 92 students participated in the survey. After a short introduction about how immersive VR can be used in education, the survey consists of five questions (see Table 2). Q1 through Q3 allow only single selection, Q4 allows the selection of multiple answers and Q5 asks participants to place a slider on a scale from 0 (low realism) to 100 (high realism). The online study was conducted in German, hence the questions were translated from German.

Online Study - Results. The majority of participants answered Q1 with agree or rather agree. While 18% were neutral, another quarter tended to disagree or completely disagreed with this statement. The results of Q2 show that the availability of fast internet is not given for all students. Almost a quarter of the participants have access to an internet connection of less than 50 Mbit/s and only about 14% have access to more than 100 Mbit/s. Nevertheless, more than 33% of the participants could not answer this question at all due to lack of knowledge, which could change the results again in case of a corresponding future works. The results of Q3 show a clear tendency towards a relatively low willingness to pay, with 50% of participants saying they would only use VR in education as part of free offerings. 32 % would accept up to 25 € per semester, 14% up to 50 €, and only about 3% would be willing to pay up to 100 € or more. The results of Q4 show that with 89%, high costs were seen as the biggest obstacle. This was followed by the considerable hardware requirements and a stable and fast internet connection. Complicated handling and lack of interest

Table 2. Online survey of students ($n = 92$): Prompts Q1–Q5, response options and results

Q1: I would like to use VR in education.				
Agree	Rather agree	Neutral	Rather disagree	Disagree
17	35	17	20	3

Q2: What internet connection do you currently have at home?					
No internet	<20 Mbit/s	21–50 Mbit/s	51–100 Mbit/s	>100 Mbit/s	I don't know
0	6	16	26	13	31

Q3: How much money would you be willing to spend on the use of VR in education per semester?			
Free of charge	Up to 25 €	Up to 50 €	More than 50 €
46	30	13	3

Q4: What are the biggest obstacles to the use of VR in education?				
High costs	Complicated handling	Internet connection	Technical equipment	Motivation and interest
82	43	53	57	39

Q5: On a scale of 0 to 100, how realistic do you want the virtual environment to be?				
0–19	20–39	40–59	60–79	80–100
3	16	26	35	12

were named as the fourth and fifth biggest obstacles. In addition to the obstacles already mentioned, in descending order, privacy, copyright, feasibility and the inconvenience of having to wear an HMD and, e.g. take it off in order to take notes, were mentioned in the free field. The results of Q5 basically show a wide range of user ratings, with the lowest user rating 6 and the highest 100. The average user rating was 58 and the median was 61.

4.2 Relevant Criteria

In total, we identified ten relevant criteria from the *Requirement Analysis*. The platforms considered are tested for suitability with regard to these identified criteria.

Preliminary Filtering. We assigned the five readily verifiable selection criteria to this category. Platforms that fail to fulfil at least one of these selection criteria are eliminated. We regard platforms that fulfil all these selection criteria as social VR platforms which are generally suitable for distance learning.

– *Availability*: The social VR platform must be available and accessible during the respective test period in order to be able to test it.
– *HMD Support*: HMDs are used in a majority of studies in the context of higher education and could be seen as a potential prerequisite for immersive learning experiences [30]. Therefore the social VR platform must support the usage of an HMD.

- *Costs*: Only cost-free platforms are considered against the background of uncertain budgets and low willingness to pay.
- *No Age Restrictions*: Adult content is avoided in view of the fact that potential users might include minors. Therefore only social VR platforms without age restrictions are considered.
- *Content Creation*: One decisive advantage of using VR in education is the possibility to present educational content in a creative, unique and interactive way in 3D. Since there is no complete 'out of the box' solution, only social VR platforms were considered that offer options to upload or directly create content in the VE. Simple VR experiences without customisable content are therefore not considered.

Popularity Check. The second category includes only one criterion. Here, popularity refers to the number of users. We use this metric as a simplified measure for the probability of continued support by developers. However, it must be emphasised that user numbers are not directly related to suitability in terms of distance learning. The potential risk here is rather seen in a possibly unsustainable recommendation. We obtained the number of users on the basis of publicly available information or through direct communication with the developers and operators of the respective platform.

- *Popularity*: The number of average daily users.

Aspects to Analyse. The third category includes all criteria that are considered relevant for conducting a comparative analysis of the remaining platforms. The platforms selected in this step all have the basic prerequisites for the use in distance learning. The comparison on the basis of the respective identified criteria of this category should provide a solid foundation for possible recommendations. For this purpose, the individual platforms are examined more closely. The criterion *Content Creation* already appeared as a criterion in the context of the knockout category. However, the criterion is applied slightly different in the respective category. In the knockout category it was only tested for basic feasibility on the basis of publicly available information. In this category, the criterion is applied in form of a detailed usage and functionality test for each platform individually.

- *Content Creation*: As described above.
- *Social Interaction*: Individual character representation and communication with other users within the VE.
- *Hardware and Software Requirements*: Requirements of the respective social VR platforms in terms of computation power.
- *Internet Connection*: Requirements regarding the internet connection.
- *Cross-Platform Support*: Ability of users to access the same VE from different devices.

4.3 Platform Selection Process

Within the platform selection process, we compiled a list of currently available social VR platforms. We then reduced the list by applying the identified *Relevant Criteria*. The identification of the currently available platforms as well as the filtering process are subsequently described.

Candidate Platforms. There is a large number of available social VR applications online. A detailed and potentially comprehensive compilation of currently available social VR platforms and virtual worlds is provided by the work of academic librarian Ryan Schultz [31]. This list was cross-checked with several other lists of currently available social VR platforms to verify completeness [10,13,16,17,29]. This, however, did not reveal any additional platforms.

Table 3. Average daily users of social VR platforms as of February 2021. The number for FRAME was provided via E-Mail by the developer in February 2021. The user number for Tivoli Cloud VR is an estimation based on the observed number of concurrent users in February 2021.

Platform name	Average daily users	Time of data
AltspaceVR	15 (on Steam) [34]	January 2021
Anyland	3 [35]	January 2021
FRAME	500	January 2021
Mozilla Hubs	No information found	n/a
Neos VR	110 [36]	January 2021
Roblox	31 000 000 [4]	January 2021
Sansar	14 [37]	January 2021
Sinespace	1700 [40]	March 2019
Tivoli Cloud VR	less than 10	February 2021

Filtering Platforms. In a first step, the formerly identified 155 available social VR platforms were selected by applying the identified *Preliminary Filtering* criteria. On the basis of publicly available information, only nine social VR platforms were able to meet the respective requirements for *Availability*, *HMD Support*, *Costs*, *No Age Restrictions* and *Content Creation* (see Table 3). If there was no information publicly available, the respective platform was also excluded. The nine remaining social VR platforms all meet the requirements for the potential use in distance learning.

In order to ensure a potential higher degree of long-term developer support, the *Popularity* criteria was applied for the remaining nine social VR platforms. Therefore, the average daily users per month were compared. In cases where no public information was available, the operators or developers of the respective platform were contacted directly.

Table 3 shows the average daily users of each selected social VR platform. We chose 100 average daily users as the lower population threshold. This leaves Roblox, Sinespace, FRAME and Neos VR are therefore part of the individual assessment in the next step. With regard to Mozilla Hubs, consistent and reliable user figures were not available and direct contact attempts were not answered or could barely provide any further information.

4.4 Individual Platform Assessment

Assessment Design. We used the HMD Oculus Quest for our tests. The Oculus Quest is a stand-alone HMD that can run VR applications independently. However, since the stand-alone configuration does not support all VR applications due to higher computing requirements, the Oculus Quest was connected to a computer via a USB 3.0 cable. This allows the computer to supplement the computing power of the Oculus Quest. The computer used for the test is equipped with an AMD Ryzen 5 3600 6-core processor, an NVIDIA RTX 2070 Super graphics card and 16 GB of DDR4 RAM. The recommended system requirements for the tested VR platforms were met or exceeded in all cases. All quality settings were set to the highest available options for the tests. Regarding the internet connection, the computer was connected via LAN to a DSL internet connection with 63.67 Mbit/s downstream and 12.73 Mbit/s upstream on average.

We then used this setup in the following step in the individual assessment to evaluate and analyse the respective platform.

As far as available, the *Hardware- and Software Requirements* are taken from the publisher. In the case of missing information, the respective developers were contacted and thus missing information was supplemented as best as possible. As a measure of visual fidelity, the frame rate during the internet connection test described below was documented. The display quality was set to the highest available setting for each of the evaluated platforms.

For the examination of *Social Interaction*, the possibilities for customising avatars as well as available functionalities for communicating with other users through text, speech, gestures and emotes were considered.

To evaluate *Content Creation*, we examined the options for uploading or creating content, as well as the respective possibilities for interacting with content in more detail.

Cross-Platform Support, as part of this analysis, describes the ability of users to access the same software from different devices, such as computers, mobile devices and HMDs. Many VR platforms offer such forms of cross-platform support. The different access options, required accounts and software needed were taken from the respective websites and listed for each platform.

Internet Connection refers to the performance of each VR platform in terms of latency and average bandwidth usage. We measured these attributes over a time windows of five minutes, during which we cycled through the provided functionalities of the different platforms. In order to monitor the internet traffic for each computer process individually, we recorded the used upstream and downstream bandwidth with NetBalancer. Information on latency was taken directly from the platform-own monitoring where possible and, in cases where it was not possible, from the resource manager of the operating system.

Assessment Results. After using the earlier mentioned assessment methodology, we found the following results:

For internet use and performance, the results of the 5-minute test are presented in Table 4.

For *Hardware- and Software Requirements*, FRAME, Neos VR and Sincespace state almost identical requirements, with a medium level CPU and graphics card from 2014 and 4 GB RAM. Because Roblox does not state specific requirements for the use of their platform in VR mode, the system requirements are for the desktop use and therefore much lower compared to the other platforms.

For *Social Interaction*, information about communication methods and body tracking is shown in Table 4. FRAME offers only basic avatar models with limited customisation options and no emotes or gestures. Roblox also also simple character designs, but additionally also a large shop for customisation options and more than 50 emotes and gestures is available. Sinespace uses realistic avatar designs with over 100 sliders to adjust certain details together with 13 available emotes and gestures. It also features a shop where users can publish their own assets to customise avatars. Neos VR supports 49 file formats for uploading 3D avatars. With various options to integrate and adjust features of avatar models, as well as the possibility of full body tracking, a realistic model of the user can be created. There are no default emotes or gestures available, but the support of full body tracking, including lip and eye tracking, enables users to use natural gestures and emotes in the VE.

For *Content Creation*, each platform has its own approach on how to create and present content. FRAME only offers the option to add elements to a variety of predesigned spaces. All customisation is done within the platform, either in desktop or in VR mode. Roblox and Sincespace have their own separate creation tools, where users can freely design VEs, assets and functionalities. In Neos VR, users perform all content creation in VR. Adding, modifying and creating assets can all be done with the tools available in VR. The number of supported data formats for images, 3D models, audio files and video files can be seen in Table 4.

For *Cross-Platform Support*, all platforms are accessible via desktop and VR. Mobile access is supported for FRAME, Roblox and Sinespace.

4.5 Discussion

The expert interviews and the online survey showed that an added value is to be expected through the use of VR in distance education. In addition to advantages in the area of social interaction, we see the possibilities of presenting interactive 3D content in VR as decisive advantages of VR in general.

Table 4. Individual analysis and test results of each platform

Criteria	FRAME	Neos VR	Roblox	Sinespace
Frame rate (fps)	101–140	26–48	54–60	36–60
Latency (ms)	110–116	127–180	52–78	109–144
Average bandwidth used (Mbit/s)	0.06	9.27	9.44	5.74
Full body tracking	✗	Up to 11 tracking points	✗	✗
Text/Voice chat	✓/✓	✓/✓	✓/✗	✓/✓
Supported image data formats	2	33	4	11
Supported 3D model data formats	4	49	2	4
Supported audio data formats	1	No data	2	4
Supported video data formats	4	No data	12	1

Since the requirements for VR applications are very diverse, e.g. due to different subjects in education, it is difficult to recommend a single best social VR platform for digital distance learning.

Rather, the most suitable platform for a particular application depends on a number of factors, such as the technical equipment, the content available for presentation, the number of students and lecturers, the nature of the training itself and certainly a degree of personal preference.

The system requirements for using social VR platforms are significant, which are reflected in the results. The system requirements for the Sinespace and Neos VR platforms and the requirements for the Oculus Link and SteamVR software are at a similarly high level. The Roblox and FRAME platforms do not specify explicit requirements for use in VR mode, but due to the significantly lower level of detail compared to the other platforms, it can be assumed that their requirements are also lower.

Framerate test results can be used to evaluate the visual performance of each platform. This is, however, highly dependent on the complexity of the currently displayed scene in the VE.

In terms of social interaction, the platforms studied differ greatly from each other. The Neos VR platform offers by far the most sophisticated and extensive features for communication and interaction possibilities. With the help of the multitude of supported input devices for full body tracking, lip tracking and eye tracking, interactions between users in VR become almost lifelike. The platforms Roblox and FRAME, offer only basic communication options, which, combined with the low level of realism of the avatars, does not help to improve social interaction possibilities. Sinespace offers a higher degree of visual realism, but the provided communication and interaction options are poor.

In terms of content creation and uploading, there were also significant differences. Neos VR offers by far the most comprehensive range of content creation options within VR. With advanced creation tools and scripts, as well as dozens of supported data formats, Neos VR wass able to replicate any of the trials and experiments we ran possible on the other platforms. However, the multitude of possibilities is very much at the expense of usability given the state of the user interface in VR. we question to what extent this can be seen as an advantage or even a disadvantage for the planned use in education.

FRAME, on the other hand, offers the simplest framework of all the platforms compared for creating a VE quickly and easily, sharing content with the available tools and communicating with other users. This may already be sufficient in the education sector for some applications of VR, thus enabling a quick and easy entry into the use of VR in education.

It should be noted that by limiting the results to free social VR platforms, platforms that might be more suitable in terms of functions were possibly excluded. Furthermore it must be mentioned that the qualitative and quantitative data were collected in a highly developed country, which is why the results are only of limited significance when viewed globally and may differ in a less developed country.

5 Conclusion

The aim of this work was to compile criteria relevant to the deployment of proprietary social VR platforms in distance learning. We then applied these criteria to a list of currently available social VR platforms to identify promising candidates for use in education. In order to gather and group individual requirements, we conducted fours interviews with experts from didactic fields and an online study among students with 92 participants.

In total, ten criteria could be classified as relevant with regard to distance learning in VR. *Availability* describes that the social VR platforms must be available during the test period. *HMD Support* is a potential prerequisite for immersive learning experiences. *Costs* ensures, that only free platforms are considered. *No Age Restrictions* describe that adult content is avoided, since we expect at least some of the users to be minors. *Content Creation* relates to the options for uploading or directly creating content in the VE, as well as the respective possibilities for interacting with this content. *Popularity* refers to the popularity in order to maintain the support of developers. *Social Interaction* refers to possibilities of individual character representation and communicating with other user within the VE. *Hardware and Software Requirements* considers the requirements of the respective social VR platforms in terms of computation power. *Internet Connection* considers the requirements regarding the internet connection. *Cross-Platform Support* relates to a cross-platform support in order to enable user a to access the same VE from different access devices.

We compiled a list of 155 currently available social VR platforms. By applying We were able to reduce this to a manageable selection of four platforms which in turn were subjected to a more detailed examination and furthermore compared with each other in an individual assessment.

Although the results of this analysis indicate that social VR platforms are certainly an option for expanding the existing possibilities of distance learning through the use of VR, no single best social VR platform for digital distance learning could be recommended. The recommendation of a certain platform is strongly linked to the respective requirements of the different potential applications of VR for education. Therefore recommendations head into the direction of a most suitable platform for a particular application.

Nevertheless, since there have been no uniform guidelines for the use of VR in teaching so far, the presented and directly applied methodology of this work provides value in many respects.

In light of the recent SARS-CoV-2 pandemic and associated, often time-critical decision-making concerning teaching in schools and universities, our criteria can support rapid and valid solutions.

6 Future Work

There are numerous research questions that should be examined more closely in future work and, if possible, also explored in less developed countries. Some suggestions, which in some cases might possibly build on the results presented here, will be made in the following.

To be able to shed more light on the general didactic effects of the use of social VR platforms in education, the evaluation of concrete use cases would be beneficial. Particularly, use cases in the context of simulating and analysing 3D content can further highlight the advantages of VR for educational purposes.

Another interesting research question with regard to user-friendliness might be, to what extent the platforms are considered as simple and comprehensible enough for educators to use them widely in their courses. For the evaluation, teaching objectives could be defined which are taught in the context of the use of selected social VR platforms and the creation of a VE. Based on a survey conducted on how easy or difficult it is to create the VE in the social VR platform, a further selection criterion might be developed for the respective social VR platform for an even finer selection of potentially suitable platforms to be used in education.

Another important topic is data protection. As users can use additional devices to increase the level of immersion, a lot of data could potentially be obtained on the respective used social VR platform. This raises questions such as what user data is stored, how it is processed and what it is or could be used for.

Finally, the options for representing oneself as well as expressing emotions or social cues during VR distance learning warrant closer inspection. Especially 'unconventional' avatars can offer advantages and, to date, little explored potential [24]. This research can likewise be expanded to cover education of adults and senior citizens [1].

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References

1. Baker, S., et al.: Avatar-mediated communication in social VR: an in-depth exploration of older adult interaction in an emerging communication platform. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. CHI 2021, Association for Computing Machinery, New York, NY, USA (2021). https://doi.org/10.1145/3411764.3445752
2. Banow, R., Maw, S.: First results from a study on the efficacy of using virtual reality (VR) to teach truss mechanics. In: Proceedings of the Canadian Engineering Education Association (CEEA) (2019). https://doi.org/10.24908/pceea.vi0.13763
3. Bogner, A., Littig, B., Menz, W.: Interviewing Experts. Springer (2009). https://doi.org/10.1057/9780230244276
4. Craft.co: Roblox company profile (2021). https://craft.co/roblox. Accessed 31 May 2021
5. Dhawan, S.: Online learning: a panacea in the time of COVID-19 crisis. J. Educ. Technol. Syst. **49**(1), 5–22 (2020). https://doi.org/10.1177/0047239520934018
6. Duff, E., Miller, L., Bruce, J.: Online virtual simulation and diagnostic reasoning: a scoping review. Clin. Simul. Nurs. **12**(9), 377–384 (2016). https://doi.org/10.1016/j.ecns.2016.04.001
7. Dyer, E., Swartzlander, B.J., Gugliucci, M.R.: Using virtual reality in medical education to teach empathy. J. Med. Libr. Assoc. JMLA **106**(4), 498–500 (2018). https://doi.org/10.5195/jmla.2018.518
8. Facebook Technologies, LLC: Oculus quest 2: Our most advanced new all-in-one VR headset (2020). https://www.oculus.com/quest-2/. Accessed 31 May 2021
9. Fuchs, N.: Comparison of Virtual Reality Social Platforms under the Aspect of Digital Distance Teaching. Bachelor thesis, Ludwig-Maximilians-Universität München (2021)
10. G2.com Inc: Best VR collaboration in 2021 (2021). https://www.g2.com/categories/vr-collaboration. Accessed 31 May 2021
11. Gao, H., Bozkir, E., Hasenbein, L., Hahn, J.U., Göllner, R., Kasneci, E.: Digital transformations of classrooms in virtual reality. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. CHI 202121, Association for Computing Machinery, New York, NY, USA (2021). https://doi.org/10.1145/3411764.3445596
12. Goetz, M.: Distance Learning in der COVID-19 Krise: Ein Praxischeck. Medienimpulse 58(2) (2020). https://doi.org/10.21243/mi-02-20-19
13. Hayden, S.: 10 free apps to hang out with friends in VR (2020). https://www.roadtovr.com/10-apps-hang-friends-vr/. Accessed 31 May 2021
14. Janßen, D., Tummel, C., Richert, A., Isenhardt, I.: Towards measuring user experience, activation and task performance in immersive virtual learning environments for students. In: International Conference on Immersive Learning, vol. 621, pp. 45–58. Springer International Publishing (2016). https://doi.org/10.1007/978-3-319-41769-1_4
15. Jin, S.A.A.: Avatars mirroring the actual self versus projecting the ideal self: The effects of self-priming on interactivity and immersion in an exergame, wii fit. Cyberpsychol. Behavior **12**(6), 761–765 (2009). https://doi.org/10.1089/cpb.2009.0130
16. Johansson, N.: Best apps for VR meetings 2021 (2021). https://immersive.ly/best-vr-apps-productive-remote-meetings/. Accessed 31 May 2021

17. Kim, S.J.: List of the most popular social VR platforms (2018), https://www.vrandfun.com/popular-social-vr-platform-list/. Accessed 31 May 2021
18. Kyaw, B.M., et al.: Virtual reality for health professions education: systematic review and meta-analysis by the digital health education collaboration. J. Med. Internet Res. **21**(1) (2019). https://doi.org/10.2196/12959
19. Latta, J.N., Oberg, D.J.: A conceptual virtual reality model. IEEE Comput. Graphics Appl. **14**(1), 23–29 (1994). https://doi.org/10.1109/38.250915
20. LaViola, J.J.: A discussion of cybersickness in virtual environments. ACM SIGCHI Bull. **32**(1), 47–56 (2000). https://doi.org/10.1145/333329.333344
21. Legault, J., Zhao, J., Chi, Y.A., Chen, W., Klippel, A., Li, P.: Immersive virtual reality as an effective tool for second language vocabulary learning. Languages **4**(1) (2019). https://doi.org/10.3390/languages4010013
22. Mangiante, S., Klas, G., Navon, A., Zhuang, G., Ran, J., Silva, M.: VR is on the edge: How to deliver 360° videos in mobile networks. In: Proceedings of the Workshop on Virtual Reality and Augmented Reality Network, pp. 30–35. Association for Computing Machinery, New York, NY, USA (2017). https://doi.org/10.1145/3097895.3097901
23. Maresky, H.S., Oikonomou, A., Ali, I., Ditkofsky, N., Pakkal, M., Ballyk, B.: Virtual reality and cardiac anatomy: exploring immersive three-dimensional cardiac imaging, a pilot study in undergraduate medical anatomy education. Clin. Anat. **32**(2), 238–243 (2019). https://doi.org/10.1002/ca.23292
24. McVeigh-Schultz, J., Isbister, K.: The case for "weird social" in VR/XR: a vision of social superpowers beyond meatspace. In: Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems. CHI EA 2021. Association for Computing Machinery, New York, NY, USA (2021). https://doi.org/10.1145/3411763.3450377
25. Merchant, Z., Goetz, E.T., Cifuentes, L., Keeney-Kennicutt, W., Davis, T.J.: Effectiveness of virtual reality-based instruction on students' learning outcomes in k-12 and higher education: a meta-analysis. Comput. Educ. **70**, 29–40 (2014). https://doi.org/10.1016/j.compedu.2013.07.033
26. Ookla, LLC.: Germany's mobile and broadband internet speeds (2020). https://www.speedtest.net/global-index/germany. Accessed 31 May 2021
27. Pan, X., et al.: The responses of medical general practitioners to unreasonable patient demand for antibiotics - a study of medical ethics using immersive virtual reality. PloS one **11**(2) (2016). https://doi.org/10.1371/journal.pone.0146837
28. Petersen, G.B., Mottelson, A., Makransky, G.: Pedagogical agents in educational VR: an in the wild study. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. CHI 2021. Association for Computing Machinery, New York, NY, USA (2021). https://doi.org/10.1145/3411764.3445760
29. Pita, P.: List of social VR apps and projects (2017). https://virtualrealitytimes.com/2017/04/16/social-vr/. Accessed 31 Mar 2021
30. Radianti, J., Majchrzak, T.A., Fromm, J., Wohlgenannt, I.: A systematic review of immersive virtual reality applications for higher education: design elements, lessons learned, and research agenda. Comput. Educ. **147** (2020). https://doi.org/10.1016/j.compedu.2019.103778
31. Schultz, R.: Comprehensive list of social VR platforms and virtual worlds (2020). https://ryanschultz.com/list-of-social-vr-virtual-worlds/. Accessed 31 May 2021
32. Slater, M., Lotto, R., Arnold, M., Sanchez-Vives, M.: How we experience immersive virtual environments: the concept of presence and its measurement. Anuario de psicología **40**(2), 193–210 (2009)

33. Sprondel, W.M., Grathoff, R.: Alfred Schütz und die Idee des Alltags in den Sozialwissenschaften. Ferdinand Enke Verlag (1979)
34. Steamcharts: Altspacevr (2021). https://steamcharts.com/app/407060. Accessed 31 May 2021
35. Steamcharts: Anyland (2021). https://steamcharts.com/app/505700. Accessed 31 May 2021
36. Steamcharts: Neos VR (2021). https://steamcharts.com/app/740250. Accessed 31 May 2021
37. Steamcharts: Sansar (2021). https://steamcharts.com/app/586110. Accessed 31 May 2021
38. Stepan, K., et al.: Immersive virtual reality as a teaching tool for neuroanatomy. Int. Forum Allergy Rhinol. **7**(10), 1006–1013 (2017). https://doi.org/10.1002/alr.21986
39. Sutherland, I.E.: A head-mounted three dimensional display. In: Proceedings of the 9–11 December 1968, Fall Joint Computer Conference, Part I, pp. 757–764. Association for Computing Machinery, New York, NY, USA (1968). https://doi.org/10.1145/1476589.1476686
40. Takahashi, D.: Sinespace teams up with unity to sell do-it-yourself virtual world SDK (2019). https://venturebeat.com/2019/03/19/sinespace-teams-up-with-unity-to-sell-do-it-yourself-vr-items-in-asset-store/. Accessed 31 May 2021
41. Tiiro, A.: Effect of Visual Realism on Cybersickness in Virtual Reality. Master's thesis, University of Oulu (2018)
42. Ung, G.M.: Razer's open-source headset aims to disrupt virtual reality (2015). https://www.pcworld.com/article/2865515/razers-open-source-headset-aims-to-disrupt-virtual-reality.html. Accessed 31 May 2021
43. Wang, G., Suh, A.: User adaptation to cybersickness in virtual reality: a qualitative study. In: 27th European Conference on Information Systems (ECIS 2019): Information Systems for a Sharing Society (2019)
44. Williamson, J., Li, J., Vinayagamoorthy, V., Shamma, D.A., Cesar, P.: Proxemics and social interactions in an instrumented virtual reality workshop. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. CHI 2021. Association for Computing Machinery, New York, NY, USA (2021). https://doi.org/10.1145/3411764.3445729
45. Winn, W.: A Conceptual Basis for Educational Applications of Virtual Reality. Technical publication r-93-9, Washington Technology Center (1993). http://www.hitl.washington.edu/research/education/winn/winn-paper.html
46. Yarmand, M., Solyst, J., Klemmer, S., Weibel, N.: "it feels like i am talking into a void": Understanding interaction gaps in synchronous online classrooms. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. CHI 2021. Association for Computing Machinery, New York, NY, USA (2021). https://doi.org/10.1145/3411764.3445240
47. Zhao, J., Xu, X., Jiang, H., Ding, Y.: The effectiveness of virtual reality-based technology on anatomy teaching: a meta-analysis of randomized controlled studies. BMC Med. Educ. **20**, 1–10 (2020)