HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

MASTER'S DEGREE THESIS

CollabVR: VR Testing for Increasing Social Interaction between College Students

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THESIS TOPIC

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Abstract

The COVID-19 pandemic has accelerated the shift towards synchronous and asynchronous online learning, significantly reducing students' social interactions. This study introduces CollabVR, a social virtual reality (SVR) platform designed to enhance social interaction among remote university students through extracurricular activities (ECAs). Using Unity3D for developing the SVR environment, Photon Unity Networking for real-time connections, Oculus Quest 2 for immersive experiences, and AWS for scalable performance, CollabVR aims to address the social interaction deficit in online education.

Motivated by the need to improve students' social engagement in virtual learning environments, the study employed the sociability scale of Kreijns et al. to evaluate CollabVR. A focus group in Lima, Peru, consisting of students participating in online ECAs, was used to compare CollabVR with traditional online platforms. Results indicated that CollabVR significantly enhanced perceived social interaction, with a mean score of 4.65 ± 0.49, compared to 2.35 ± 0.75 for traditional platforms.

The findings suggest that CollabVR fosters a sense of community and improves communication among students. This highlights the platform's potential as a powerful tool to address socialization challenges in virtual learning, offering a more immersive and engaging approach to distance education. The study underscores the importance of incorporating innovative technologies to enhance the social aspects of online education.

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CHƯƠNG 1. INTRODUCTION

The COVID-19 pandemic has precipitated a significant evolution in education by accelerating the adoption of online methods, ensuring continuity but also leading to reduced social interaction [1,2]. It is crucial to recognize that distance education has been integral to the educational landscape for more than three decades. Rather than initiating this digital transformation, the pandemic has expedited it, exacerbating existing challenges in online learning such as loneliness and decreased socialization [3,4].

The importance of social interaction in the learning and human development process is underscored by UNESCO [5]. Studies indicate that 71% of students have experienced negative impacts on their learning due to insufficient interaction, resulting in decreased motivation, academic performance decline, and reduced educational engagement [6,7,8].

Furthermore, there is a growing recognition of the significance of extracurricular activities (ECAs) in higher education, particularly in developing countries. Beyond academics, ECAs significantly contribute to students' personal, professional, and psychological development, fostering motivation, shared knowledge construction, and personal/social skill development, as well as community participation [9,10].

Virtual reality (VR) technology provides an immersive 3D experience that isolates users visually from the physical world [11]. This technology extends to social virtual reality (SVR), enabling real-time communication through full-body avatars that mimic face-to-face interactions, incorporating elements such as voice, gestures, proxemics, gaze, and facial expressions [12,13]. Despite existing VR solutions in education, there remains a gap in understanding the unique potential of SVR for enhancing remote learning experiences, necessitating further practical and empirical evaluations to establish best practices and integration guidelines [14].

This study aims to investigate whether SVR can enhance perceived social interactions among online students. The hypothesis posits that students engaging in ECAs through an SVR platform would perceive increased social interaction compared to traditional online platforms.

To achieve this, the study proposes the implementation of CollabVR 1.0.0, an SVR platform designed to augment social interaction in remote educational settings through various activities such as clubs, presentations, cultural events,

and workshops. This initiative aims to address the diminished social interaction among students and aligns with the growing recognition of ECAs for enhancing social engagement and mitigating the negative effects of remote education. CollabVR leverages technologies including microservices, Unity3D, Photon Unity Networking (PUN), Oculus Quest 2, and AWS. Microservices enable efficient management of platform functionalities, while Unity3D and PUN support the creation of an interactive multiplayer virtual environment that offers immersive experiences and is compatible with devices like the Oculus Quest 2 [15,16]. AWS ensures scalability and performance by hosting and managing the platform infrastructure.

To evaluate the perceived level of social interaction within CollabVR, this study will utilize the sociability scale developed by Kreijns et al., validated by Sjølie and van Petegem [17,18]. The experimental approach involves simulating a remote ECA in CollabVR and comparing the outcomes with those of traditional remote platforms

CHƯƠNG 2. SOLUTION AND DESIGN

2.1 CollabVR Solutions

CollabVR, a platform developed by the authors, consists of a VR application and a Web application that are connected using a RESTful API system. This system consists of six microservices, which communicate with each other through an event bus and expose their services through an API gateway. Microservices enable efficient modularity and deployment, facilitate the use of various technologies according to the specific needs of each component, and improve error management [29], key aspects for the effective integration of VR and web applications. Likewise, for real-time connection and collaboration in VR environments, Photon Unity Networking servers are used (Figure 1).

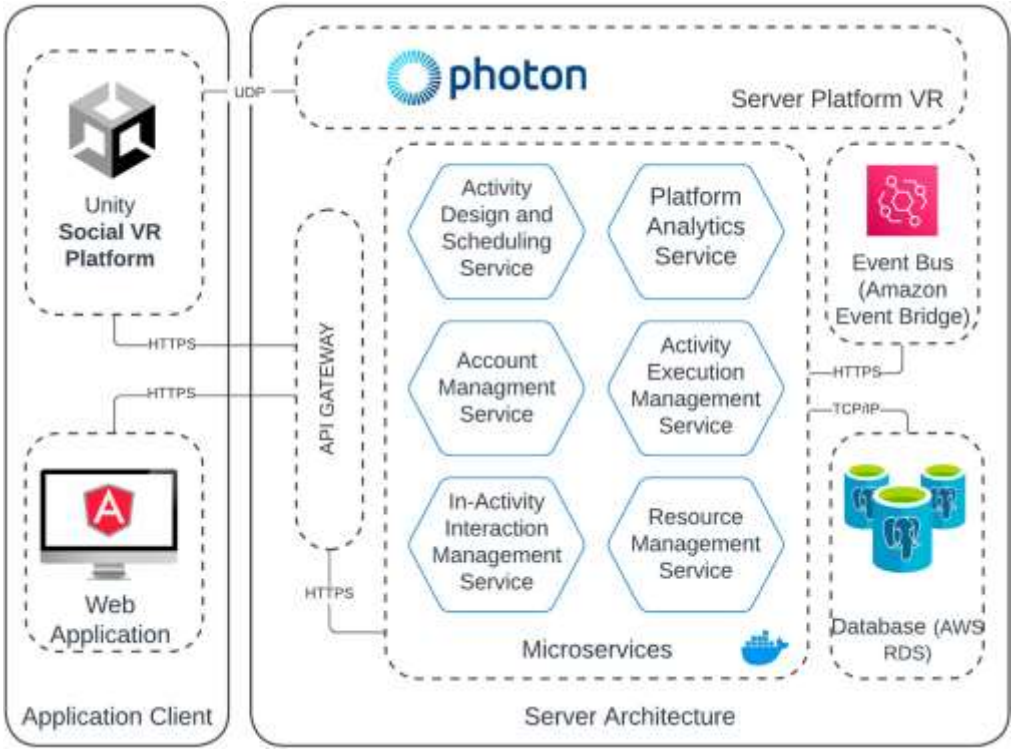
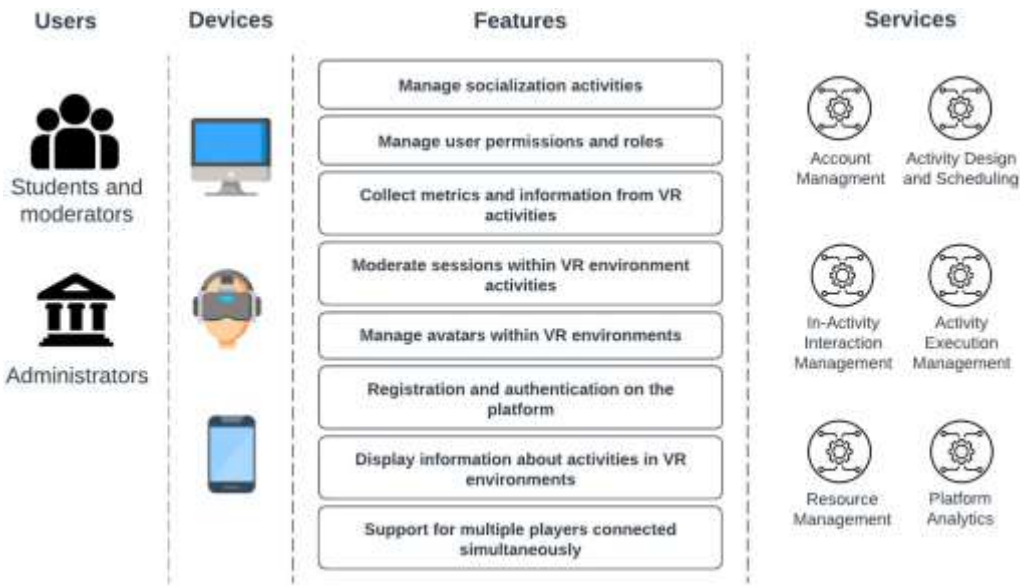


Figure 1. Context diagram CollabVR.

The solution is a system that allows universities to manage ECAs and



generate greater socialization opportunities for students enrolled remotely, for which CollabVR offers the following functionalities (Figure 2).

Figure 2. CollabVR features and supported devices.

2.2 VR Applications

In CollabVR software is compatible on desktop platforms and with all virtual reality headsets supported by Unity XR Toolkits, for example, the Oculus Quest series. This selec- tion is primarily to provide accessibility to those users who do not have an HMD device.

CollabVR includes four virtual reality environments that have been designed/selected to foster spaces for socialization (Figure 3).

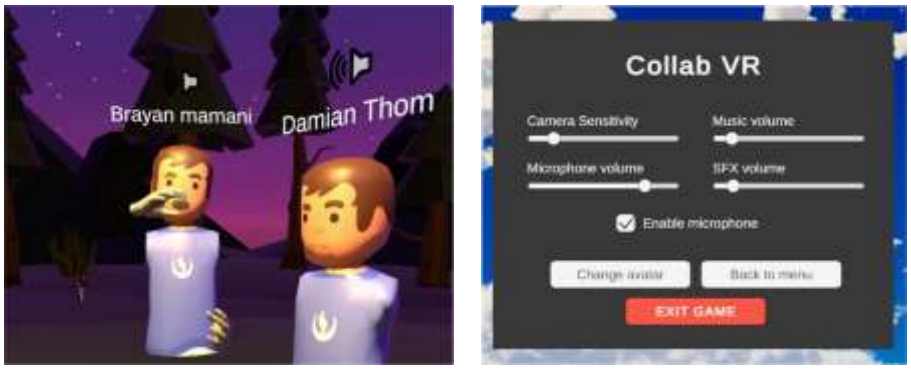
- Open Field: This environment gives users the feeling of being outdoors in nature, encouraging socialization in a natural and relaxed environment.
- Presentation Room: Designed for presentations and group talks, this room facilitates interaction between a presenter and several users, promoting learning and collaboration.
- Night Fire Pit: Provides a quiet and relaxing space for users to gather and socialize in a warm environment, promoting personal connections in an intimate setting.
- Futuristic Room: Offers diversified interaction options with corridors and different rooms, allowing users to have greater control and privacy, adapting to their preferences and needs.

To promote healthy socialization spaces, CollabVR has included moderation function- alities that allow users, in the role of moderator, to regulate the audio of participants and expel them in extreme situations. In addition to providing certain permissions to users within virtual reality rooms, such as the permission to interact with certain objects within the rooms.

Additionally, to facilitate universities in assessing activities, as well as enhancing the overall user experience, CollabVR implements the capability to send metrics of the conducted activities. This includes tracking the number of users connected to activities, identifying real-time activities with the highest user engagement, and monitoring interaction times within the rooms, among other metrics.

Furthermore, given that communication and user identification is essential in the environments, the possibility of customizing the avatar that best suits the user's preferences has been included (Figure 4). Likewise, within virtual reality environments the user who is speaking can be explicitly visualized. To enhance the overall experience, a microphone audio level modulator and proximity voice chat feature have been incorporated (Figure 5)

Figure 3. Environments intended for socialization included in CollabVR.



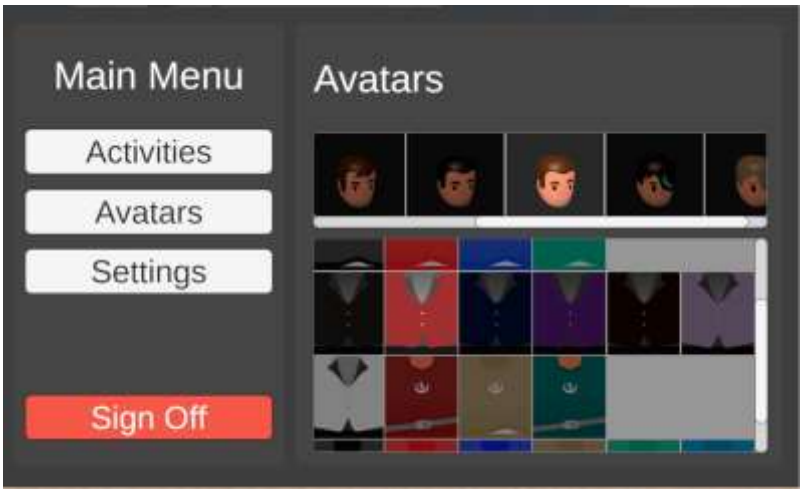


Figure 4. Avatar selection menu in CollabVR.

Figure 5. Voice display and modification: (**a**) voice indicator of the participant who is speaking; (**b**) voice/microphone volume control.

2.3 Web Application

To allow universities to manage activities more easily, a web application has been developed, enabling users to effortlessly view, create, and assess activity metrics.

Within the activity creation section, a user-friendly form has been designed with three straightforward steps: creation of general details of an activity, schedule and participants of the activity, and selection of the virtual reality environment most in line with the theme of the activity (Figure 6).

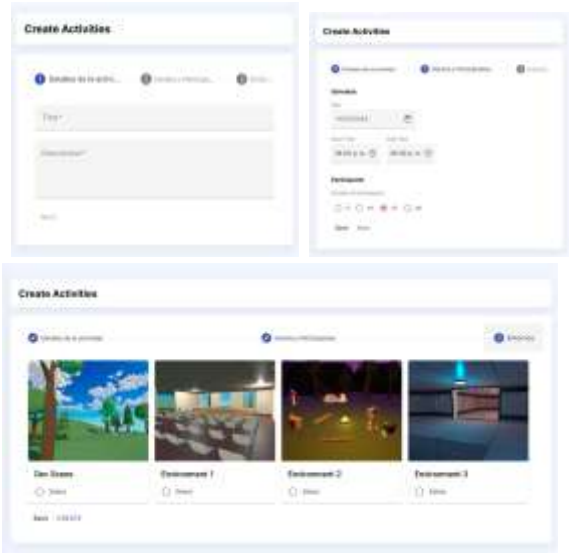


Figure 6. Creating activities in the web application. (a) Activity detail form; (b) schedule and participants form for an activity; (c) selection of environments for the VR activity. * means the field is required.

Regarding the registration of users for activities, they can access a list of activities and view the details of a specific activity (refer to Figure 7). In the latter, users can also see the participants registered for the selected activity. In both scenarios, users interested in registering for an activity can do so by utilizing the “Register” button.

Finally, through a dashboard, administrators will be able to view the metrics of the previously conducted activities (Figure 8).

The application is responsible for collecting metrics within the development of ECAs. This includes data such as the time during which a user is participating, the connection time of the users and the number of users within the activities. With these data, information can be extracted, such as the average time of student participation, the level of retention of the activities, and the like. These metrics are essential to provide universities with information about activities development and student engagement. This aims to enable universities to make informed decisions, enhancing their services and adapt to the needs of students in the development of ECAs. While the current set of available metrics is limited, future versions

of the application will incorporate additional metrics, expanding analytical capabilities, and offering a more comprehensive perspective on activities development.

2.4 Study Design

At the end of the development, we aimed to validate the hypothesis: "Implementing CollabVR for ECAs could increase students' perceived social interaction compared to traditional online platforms". For the planning and development of this experiment, an experiment-driven product development methodology was adopted [30].

To this end, a focus group was organized in the city of Lima, Peru, in October 2023, involving students from the Peruvian University of Applied Sciences (UPC) who had participated in some online ECAs during the 2023-1 and 2023-2 semester. The study included young students aged 18–23 of both genders, engaged in university ECAs, divided into two groups (AS-IS and TO-BE), each consisting of 12 participants. It is worth noting that all participants had prior experience with traditional online platforms and some with virtual reality tools. During the session a questionnaire was administered to each group to evaluate the perception of traditional platforms in contrast to CollabVR.

The questionnaire design is based on the sociability scale by Kreijns et al., which mea- sures the social and emotional aspects of perceived sociability in computer-assisted collabo- rative learning environments [17]. This scale was chosen for its comprehensive approach to assessing the quality of social space and group dynamics in virtual learning contexts. Its development, grounded in computer-supported cooperative work and human–computer interaction studies, focuses on key elements like group awareness, communication, and community facilitation. Consisting of 10 items, the scale invites participants to express their perceptions on a 5-point Likert-type scale [31]. In addition, open questions were included in the questionnaire with the purpose of collecting feedback on the environment used for online ECAs.

2.5 Group AS-IS

This group represented the current situation, in which the students completed the questionnaire based on their previous experiences with traditional online platforms used for online ECAs, with the Blackboard Collaborate tool as the platform for the development of this activities. Students who had previously had experience in developing virtual ECAs taught by the university were recruited through university forums and email.

2.6 Transfer Learning and Ensemble Learning

Students in this group, before taking the questionnaire, participated in a one-hour ECA conducted in CollabVR. In this way, their responses reflected their perception of sociability after experiencing the immersive interaction in VR.

For the activity in which they participated, we sought to simulate the “Virtual Public Speaking” workshop offered by the UPC. To achieve this, the “Night Fireplace” envi- ronment was chosen to provide a calm and relaxing atmosphere for the 12 students and 2 moderators/instructors involved. The activity was structured in the following stages: We began with an “Introduction and Adaptation to the VR Environment” (10 min) to familiarize students with the application. Moderators offered instructions on navigation and tool use. Next, in “Fundamentals of Public Speaking” (10 min), basic concepts about the structure of speech were taught. The “Practical Activity—Lightning Speeches” (20 min) allowed students to practice short speeches. Students, in their groups, prepared speeches on assigned topics. Each group had 8 min to prepare and 12 min for presentations. During presentations, groupmates provided constructive feedback, reinforcing collaboration and mutual support. To manage anxiety, a section on “Stress and Anxiety Management” (5 min) was included. Facilitators guided students through breathing techniques. This activity was carried out in groups, allowing students to support and reassure each other. Then, “Improvisation and Reaction Exercises” (8 min) were carried out to encourage adaptability. Groups faced improvisation challenges, encouraging adaptability and teamwork when responding to unexpected topics. The activity culminated with a “Question and Answer Session” and “Conclusion and Closing” (both in total 7 min). Students had the opportunity to ask questions and share reflections, both individually and in groups. Finally, the instruc tors summarized the learnings and emphasized the importance of continuous practice in public speaking and teamwork.

The objective of this activity was to evaluate how CollabVR is able to improve social in- teraction and communication skills in a virtual educational context, focusing on teamwork, socialization, and the development of public speaking skills. The activity environment together with the participants are shown in (Figure 9).

Figure 9. Screenshots of the development of the virtual public speaking activity provided through CollabVR: (**a**) capture of the interaction of the groups in the development of the activity; (**b**) capture of the formation of groups for the development of the activity carried out in CollabVR.

CHƯƠNG 3. RESULT

3.1 Experimental Results of Benchmark Models

the questionnaires administered after the activity to the "AS-IS" and "TO-BE" groups revealed valuable information about how CollabVR improves perceived social interaction in distance collaborative learning environments compared to traditional platforms such as "Blackboard Collaborate".

Descriptive statistics for each item on the sociability scale are presented in Table 1, and additional detailed information can be found in Appendix A. The mean score on the sociability scale was 2.55 ± 1.37 for the AS-IS group and 4.65 ± 0.49 for the TO-BE group. Within the AS-IS group, the mean scores ranged between 1.92 in the item "This platform allows spontaneous informal conversations" and 3.17 in "I felt comfortable with this platform", the latter value being probably high due to the familiarity of students with the platform. Meanwhile, the mean scores for the TO-BE group varied between 4.50 and

4.92. In this group, all standard deviations were less than 1, indicating consistency in the perception of sociability with CollabVR. In contrast, in the AS-IS group, 90% of the items had a standard deviation greater than 1, reflecting significant variability in the perception of sociability on traditional platforms.

Table 1. Sociability scale items and means for ECAs using traditional online platforms and CollabVR.

Code	Item	M	S.D.	M
Q03	CollabVR allowed me to easily contact my teammates	2.67	1.23	4.83
Q04	I did not feel alone on this platform	3.17	0.94	4.83
Q05	CollabVR allowed me to get a good impression of my teammates	2.92	1.44	4.67
Q06	CollabVR allowed for spontaneous informal conversations	1.92	1.31	4.92
Q07	This platform allowed us to develop as a well-performing team	2.50	1.31	4.50
Q08	This platform allowed me to develop good working relationships with my teammates	2.33	1.56	4.50
Q09	This platform allowed me to identify with the team	2.33	1.56	4.58
Q10	I felt comfortable with this platform	3.17	1.47	4.67
Q11	This platform allowed for conversations unrelated to the workshop task	2.25	1.48	4.83
Q12	This platform allowed me to establish close friendships with my teammates	2.25	1.42	4.67
Total		**2.55**	**1.37**	**4.65**

Note: 1 = not applicable at all; 2 = rarely applicable; 3 = moderately applicable; 4 = largely applicable; 5 = totally applicable.

On the other hand, in relation to the comments and feedback obtained from the participants in this study, the key findings of the study regarding the CollabVR virtual reality platform are summarized. These findings highlight both the positive features perceived by users and the distinctive differences of CollabVR compared to traditional online learning platforms. These tables present an analysis of the results from the responses obtained from participants based on the questionnaire about the perception of using CollabVR, highlighting the most beneficial and distinctive aspects they identified.

Table 2 illustrates the positive aspects of CollabVR, highlighting features that partici- pants found particularly attractive and useful. These aspects include

the ease of access and quality of personal interactions, the motivating environment provided by proximity chat, and the immersive experience that facilitates a deeper connection.

3.2 Discussion

In this study, CollabVR has been evaluated as a means to improve perceived social interaction in a remote educational environment, where this SVR platform was compared with Blackboard Collaborate, a traditional web platform. The total mean score of the socia- bility scale for the first group (Blackboard Collaborate) was 2.55 ± 1.37. This result aligns with the findings of Savci et al., where they reported a mean score of 2.35 ± 0.75 using Zoom as a collaborative web platform [32]. This suggests that, despite the socialization functionalities offered by traditional web platforms, levels of socialization remain moder- ately low. Furthermore, the consistency in these results suggests a possible trend toward limited socialization in online collaborative web environments, at least within the settings examined in the research. These parallels underscore the relevance of inquiry in CollabVR, aiming to address and potentially improve socialization in distance learning. These find- ings regarding the low level of socialization on web platforms should inspire more work in developing better features for them or the search for new technologies that do not re- place, but rather complement, the current state of distance learning. Adopting existing VR applications, such as Mozilla Hubs, for the development of ECAs in education, is a good starting point. Although these applications are not specifically designed or optimized for management by universities, beginning with them is strategic. However, it is important to recognize that any process of technological adoption in education is inherently slow, requiring ongoing adaptations and technological advancements [33].

In contrast, the perceived level of socialization of the second group, which participated in ECAs in CollabVR, was significantly higher, with a total mean on the sociability scale of 4.65 ± 0.49. The results have shown that VR not only favors greater opportunities for socialization but also allows for more organic and spontaneous socialization opportunities during the development of activities. This represents a fundamental catalyst to strengthen personal relationships, allowing simultaneous socialization spaces and generating a greater sense of belonging, critical elements in building a sense of community among students.

On the other hand, one of the limitations was the representativeness of the users; although the study included a segment of the student population, it may not reflect the complete diversity of the global university population. This aspect is crucial since students' experiences and needs can vary widely in different cultural and educational contexts. Furthermore, the fact that the study was conducted in a specific context of students en- rolled remotely, who lack in-person social interactions, raises questions about whether the results would be replicable in a group of students with regular access to physical and social interactions.

Likewise, the availability of users' HMD peripherals is one of the main accessibility concerns. To address this issue, support has been implemented for "Desktop VR", which is a less immersive type of virtual reality; 3D virtual worlds like Second Life are examples of this [34]. Although the immersive experience is not the same, it is much cheaper and more accessible than the most immersive forms of virtual reality. However, it is important to highlight that technological advances in the field of artificial intelligence (AI) and trends in the technological advancement of virtual reality technologies are increasingly reducing this gap. For example, the integration of AI technologies that simulate hand and head movements through a Webcam allows users without HMD to access more functionality without the need for additional hardware. Additionally, advancement in VR technology is decreasing the costs and sizes of peripherals, making them more accessible to a wide range of users.

Initial research highlighted that SVR environments could offer a more suitable means of addressing these challenges compared to traditional virtual interaction methods. With this precedent, CollabVR was designed incorporating essential features that facilitate a rich and immersive socialization experience. Looking forward, it is vital to investigate the long- term impact of SRV use on students' social interaction and academic performance. It would be interesting to see how the continued integration of SVR platforms into the educational curriculum influences learning and the development of social skills. Finally, conducting comparative studies between different extended reality technologies could provide valuable insights to optimize social interaction in virtual environments, significantly contributing to the development of a more inclusive and effective pedagogy for the future of distance education. Nowadays, there is little use for VR technologies to promote socialization spaces related to university life. By providing support technologies that can complement the services provided by universities, these technologies can help many; the road is long but not impossible.

[1,2].

References

1. Morgan, C.; Tsai, M.C.; Hsu, C.E.; Chow, H.W.; Guo, H.R.; Lee, M.H. Qualitative impact assessment of COVID-19 on the pedagogical, technological and social experiences of higher education students in Taiwan. *Educ. Inf. Technol.* **2022**, *27*, 10471–10495. [CrossRef]
2. Aristovnik, A.; Keržicˇ, D.; Ravšelj, D.; Tomaževicˇ, N.; Umek, L. Impacts of the COVID-19 Pandemic on Life of Higher Education Students: A Global Perspective. *Sustainability* **2020**, *12*, 8438. [CrossRef]
3. Nurjanah, W.; Musadad, A.A.; Purwanta, H. Implementation of distance history learning during the Pandemic COVID-19. *Int. J. Educ. Vocat. Stud.* **2021**, *3*, 243–247. [CrossRef]
4. Rotnitsky, I.; Yavich, R.; Davidovich, N. The Impact of the Pandemic on Teachers' Attitudes toward Online Teaching. *Int. J. High. Educ.* **2022**, *11*, 18–38. [CrossRef]
5. UNESCO IIEP Learning Portal. Available online: https://learningportal.iiep.unesco.org/es/fichas-praticas/mejorar-el- aprendizaje/el-entorno-psicosocial-de-la-escuela (accessed on 10 November 2023).
6. Mushtaha, E.; Abu Dabous, S.; Alsyouf, I.; Ahmed, A.; Raafat Abdraboh, N. The challenges and opportunities of online learning and teaching at engineering and theoretical colleges during the pandemic. *Ain Shams Eng. J.* **2022**, *13*, 101770. [CrossRef]
7. Çoban, M.; Goksu, I˙. Using virtual reality learning environments to motivate and socialize undergraduates in distance learning.
8. *Particip. Educ. Res.* **2022**, *9*, 199–218. [CrossRef] Canela-Ruano, A.J.; Orange Grove, V.R.; Pessina Itriago, M.M.; Salazar Coba, C.G. Effects and perspectives of education in a pandemic and on social interaction in teaching and learning relationships. Case of the UTE University. *Tsafiqui—Sci. J. Soc. Sci.* **2022**, *12*, 18. [CrossRef]
9. Díaz-Iso, A.; Eizaguirre, A.; García-Olalla, A. Understanding the Role of Social Interactions in the Development of an Extracurricular University Volunteer Activity in a Developing Country. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4422. [CrossRef]
10. Cortellazzo, L.; Bossesso, S.; Gerli, F.; Pizzi, C. Experiences That Matter: Unraveling the Link Between Extracurricular Activities and Emotional and Social Competencies. *Front. Psychol.* **2021**, *12*, 659526. [CrossRef]
11. Rauschnabel, P.A.; Felix, R.; Hinsch, C.; Shahab, H.; Alt, F. What is XR? Towards a Framework for Augmented and Virtual Reality. *Comput. Hum. Behav.* **2022**, *133*, 107289. [CrossRef]
12. Freeman, G.; Maloney, D. Body, Avatar, and Me: The Presentation and Perception of Self in Social Virtual Reality. *Proc. ACM Hum.-Comput. Interact.* **2021**, *4*, 1–27. [CrossRef]
13. Burova, A.; Palma, P.B.; Truong, P.; Mäkelä, J.; Heinonen, H.; Hakulinen, J.; Ronkainen, K.; Raisamo, R.; Turunen, M.; Siltanen, S. Distributed Asymmetric Virtual Reality in Industrial Context: Enhancing the Collaboration of Geographically Dispersed Teams in the Pipeline of Maintenance Method Development and Technical Documentation Creation. *Appl. Sci.* **2022**, *12*, 3728. [CrossRef]
14. Young, G.W.; O'Dwyer, N.C.; Smolic, A. A Case Study on Student Experiences of Social VR in a Remote STEM Classroom. In Proceedings of the Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems, Hamburg, Germany, 23–28 April 2023. [CrossRef]
15. Dave, C.V.; Patel, A.; Keshri, U. Microservices Software Architecture: A Review. *Int. J. Res. Appl. Sci. Eng. Technol.* **2021**, *9*, 1494–1496. [CrossRef]
16. Coronado, E.; Itadera, S.; Ramirez-Alpizar, I.G. Integrating Virtual, Mixed, and Augmented Reality to Human–Robot Interaction Applications Using Game Engines: A Brief Review of Accessible Software Tools and Frameworks. *Appl. Sci.* **2023**, *13*, 1292. [CrossRef]
17. Kreijns, K.; Kirschner, P.A.; Jochems, W.; van Buuren, H. Measuring Perceived Sociability of Computer-Supported Collaborative Learning Environments. *Comput. Educ.* **2007**, *49*, 176–192. [CrossRef]
18. Sjølie, E.; van Petegem, P. Measuring the sociability of virtual learning environments for interdisciplinary student teams—A validation study. *Scand. J. Educ. Res.* **2022**, *66*, 1–12. [CrossRef]
19. Xu, X. To social with social distance: A case study on a VR-enabled graduation celebration amidst the pandemic. *Virtual Real.* **2022**, *27*, 3319–3331. [CrossRef]
20. Chen, Z.; Cao, H.; Deng, Y.; Gao, X.; Piao, J.; Xu, F.; Zhang, Y.; Li, Y. Learning from Home: A Mixed-Methods Analysis of Live Streaming Based Remote Education Experience in Chinese Colleges during the COVID-19 Pandemic. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, Yokohama, Japan, 8–13 May 2021. Art. No. 348. [CrossRef]
21. 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, Yokohama, Japan, 8–13 May 2021. Art. No. 351. [CrossRef]
22. Barreda-Ángeles, M.; Hartmann, T. Psychological benefits of using social virtual reality platforms during the COVID-19 pandemic: The role of social and spatial presence. *Comput. Hum. Behav.* **2022**, *127*, 107047. [CrossRef]
23. Siani, A.; Marley, S.A. Impact of the recreational use of virtual reality on physical and mental well-being during the COVID-19 lockdown. *Health Technol.* **2021**, *11*, 425–435. [CrossRef]
24. Baccon, L.A.; Chiarovano, E.; MacDougall, H.G. Virtual Reality for Teletherapy: Avatars May Combine the

Benefits of Face-to-Face Communication with the Anonymity of Online Text-Based Communication. *Cyberpsychol. Behav. Soc. Netw.* **2019**, *22*, 158–165. [CrossRef]
25. Yan, Z.; Lv, Z. The Influence of Immersive Virtual Reality Systems on Online Social Application. *Appl. Sci.* **2020**, *10*, 5058. [CrossRef]
26. Jin, Q.; Liu, Y.; Yarosh, S.; Han, B.; Qian, F. How Will VR Enter University Classrooms? Multi-Stakeholders Investigation of VR in Higher Education. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems, New Orleans, LA, USA, 30 April–5 May 2022. Art. No. 563. [CrossRef]
27. Qi, J.; Tang, H.; Zhu, Z. Exploring an Affective and Responsive Virtual Environment to Improve Remote Learning. *Virtual Worlds* **2023**, *2*, 53–74. [CrossRef]
28. Yoshimura, A.; Borst, C.W. Evaluation and Comparison of Desktop Viewing and Headset Viewing of Remote Lectures in VR with Mozilla Hubs. In Proceedings of the ICAT-EGVE 2020—International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments, Virtual, 2–4 December 2020. [CrossRef]
29. Gan, Y.; Delimitrou, C. The Architectural Implications of Cloud Microservices. *IEEE Comput. Archit. Lett.* **2018**, *17*, 155–158. [CrossRef]
30. Rissen, P. *Experiment-Driven Product Development: How to Use a Data-Informed Approach to Learn, Iterate, and Succeed Faster*, 1st ed.; Apress: Berkeley, CA, USA, 2019. [CrossRef]
31. Likert, R. A technique for the measurement of attitudes. *Arch. Psychol.* **1932**, *140*, 5–53.
32. Savci, C.; Akinci, A.Ç.; Keles, F. The association of perceived sociability and social intelligence with loneliness in online learning among nursing students. *Nurse Educ. Today* **2022**, *109*, 105226. [CrossRef]