Assessment of Virtual Reality and Metaverse Applications in Higher Education

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Abstract— **This paper examines the use and effectiveness of consumer-grade Virtual Reality (VR) technology in traditional university courses. At the School of Economics, Universidad de la República in Uruguay, students were divided into four groups: in-person, standard video conferencing, VR with avatars in a metaverse classroom, and remote participation in the metaverse. The study assessed various Quality of Experience factors for students and professors, such as audiovisual quality, comfort, immersion, fatigue, and cognitive load. Findings reveal that VR promotes high student satisfaction, motivation, and interaction, reaching levels similar to in-person classes. However, issues like technical difficulties and discomfort with extended VR use were noted. The paper discusses the broader potential of VR for non-STEM higher education and offers recommendations for future implementation of immersive technologies.**

Link to graphical and video abstracts, and to code: https://latamt.ieeer9.org/index.php/transactions/article/view/10156

Index Terms—Virtual Reality (VR), Higher Education, Immersive Learning Environments, Quality of Experience (QoE), Metaverse Classroom

I. Introduction

THE adoption of remote classroom attendance through technology became widespread during the Covid-19 crisis. In the post-pandemic era, many universities continue to offer courses in virtual formats using classical on-line communication platforms such as Zoom, MS Teams, and Google Meet. Recent statistics indicate that online university courses serve over 30 million students globally, with projections suggesting this number will exceed 50 million by 2029 [1]. Virtual teaching in higher education is evolving rapidly, driven by advances in technology, changing pedagogical approaches, the pursuit of accessible and equitable education, and an increasing demand for flexible learning models [2].

Virtual reality (VR) is a technology that creates a completely digital world within which users can explore and interact [3]. With VR glasses or headsets, usually called head-mounted displays (HMD), the visual field of users is completely covered, and it is possible to be immersed in totally virtual "worlds". As VR technologies advance and consumer-grade HMDs become more affordable, classes can now occur in immersive virtual environments. Unlike traditional methods that rely on flat screens and two-dimensional content, VR enables learners to engage in three-dimensional environments, fostering a sense of presence and active participation. In technical courses, where visualizing and interacting with 3D objects is required, the use of remote access technologies with VR is clearly an advantage over traditional 2D visualizations. This includes courses in medicine, engineering and many other disciplines, generally identified with science, technology, engineering and mathematics (STEM). Nevertheless, most courses do not have the need to show interaction with 3D objects, thus the advantages of using VR technologies are not so evident. This is the case of many non-STEM higher education courses, in the areas of humanities, law, notary studies, and accounting, among others. The impact of using VR HMDs on both students and professors, in these types of courses, remains an area of research. Specifically, there is limited empirical evidence on whether consumer-grade VR metaverse classrooms provide measurable advantages over conventional videoconferencing in non-STEM university courses (where 3D visualization is not required), and on the associated trade-offs in usability, comfort, and interaction.

In a previous short article, we provided a partial overview of the results from a university course conducted in the metaverse using VR technology [4]. In the present paper, we describe the design, implementation and data analysis of the complete experience which involved delivering the same course in four different modalities for students' class attendance: in-person, classical video conferencing connected to the in-person classroom, VR using avatars in a metaverse classroom and remote assistance to the metaverse classroom. The goal of this study is to compare, across these four attendance modalities, (i) students' and instructors' Quality of Experience (QoE), (ii) satisfaction and perceived interaction, and (iii) learning outcomes, in a traditional non-STEM course delivered with consumer-grade VR technology. The course was conducted over two months at the School of Economics, Universidad de la República, Uruguay. The results include an analysis of various aspects of the QoE for both students and professors, as well as a comparison of student satisfaction levels and learnings outcomes across the different course modalities.

The remainder of this paper is organized as follows. Section II reviews related work. Section III describes the course design and the selected technologies. Section IV presents the students' demographics. Section V details the course development. Section VI describes the QoE evaluation design. Section VII reports the QoE results. Section VIII analyzes academic outcomes. Section IX concludes and discusses challenges.

The associate editor coordinating the review of this manuscript and approving it for publication was Ingrid Winkler (*Corresponding author: Jose Joskowicz*).

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II. Literature Review

Various studies on VR technology used in classrooms have been published. These works span over different aspects and academic levels, from primary schools to tertiary or higher education. This section reviews prior work on (i) VR in education (predominantly STEM), (ii) usability, QoE and discomfort in VR, and (iii) evidence comparing VR to traditional video-based learning, to position the specific gap addressed here: consumer-grade VR for non-STEM university courses and its value relative to videoconferencing.

In the work of Liu et al. [5], the authors analyzed emotions and learning in primary school science classes. They found students felt excited and happy during VR lessons and showed better understanding of science concepts.

Pellas et al. [6] examine instructional design practices using VR in K-12 and higher education, emphasizing participant traits, methods, and STEM-oriented pedagogy. They review the integration of VR tools, equipment, and strategies, noting that over the last decade VR has been extensively defined, applied, and evaluated in STEM education. Similarly, the work of di Lanzo et al. [7] reports a growing use of VR in engineering education, where virtual classrooms increasingly complement traditional teaching and improve both cognitive and skill-based learning outcomes. The study performed by Muzata et al. [8] shows that VR deepens understanding of complex subjects through collaboration, exploration, and simulation. The work described by Kim et al. [9] found 360-degree videos increased student focus and immersion. Pellas et al. presented a review [10] that highlights consistent reports of improved outcomes and usability in STEM VR. More recently, Porcu et al. [11] compared VR with video-based online learning, with students rating VR higher in interactivity, naturalness, enjoyment, and immersion.

Although STEM studies show positive results, many educators remain unfamiliar with VR. A large-scale Russian survey [12] found teachers at an early stage of adoption, with limited experience but generally favorable views and recognition of barriers. A related study in Spain and Latin America [13] showed digital-native professors felt more proficient and highlighted VR's benefits, though non-STEM professors perceived more disadvantages than their STEM peers.

An essential aspect of VR is its usability, which significantly influences users' perceived QoE. While VR sessions are known to create a strong sense of presence and immersion [14], they can also induce various forms of discomfort [15], [16], [17] or even mental health issues [18]. A comprehensive review of key factors involved in perception-based QoE assessment for interactive VR applications can be read in the work performed by Vlahovic et al. [19].

The reviewed studies show improved STEM outcomes and usability, mainly in courses requiring 3D content or collaborative tasks [20]. Yet few works assess VR in non-STEM settings with consumer devices, leaving its value without specialized materials largely unknown. Evidence is lacking on whether VR surpasses videoconferencing for such courses, where 3D visualization is unnecessary and teachers rarely prepare VR-specific resources. Still, student–teacher interaction—often missing in conventional video conferencing platforms—remains crucial. This gap directly motivates our comparative study across four attendance modalities, evaluating QoE, satisfaction/interaction, and learning outcomes in a non-STEM course delivered without VR-specific materials.

III. Design of the Course and Technologies Selection for Remote Assistants

During the Covid-19 pandemic, the School of Economics at Universidad de la República adopted Zoom, providing licenses to all its students. Even after restrictions ended, some courses, including "Accounting in Integrated Management Systems" (seventh semester elective), continued in this format.

Normally, the course is taught in person, and the class is broadcast live via Zoom for students who prefer remote attendance. For research purposes, it was decided to carry out an experience with new VR technologies. The purpose was to evaluate the applicability of these technologies to classic academic courses, not related to STEM topics. Hence, it was decided to offer students four class attendance modalities as follows:

In-person: It is the classic form of the course, in which the teacher teaches the class in front of the students. A blackboard and the projection of pictures or texts on a screen are used.

Video Conference by Zoom: The in-person classroom is fully equipped with devices to broadcast the class by Zoom to which remote students connect to attend the class.

Avatars in a VR classroom: In this modality, each student and the professor have a personal avatar. Using HMD devices, the participants connect to the VR classroom in a Metaverse platform, and they can interact with each other in the virtual environment. Fig. 1 shows a classroom in a VR environment.

Remote assistance to the VR classroom: Remote students connect from their PCs or laptops to the VR classroom. In the VR classroom, a virtual monitor shows the remote assistants. Each remote assistant is presented in a box, with the real-time video of his face. An example is shown in Fig. 2. This view is similar to how Zoom shows the remote participants.

To compare attendance modalities fairly, the same teaching duo delivered identical content across groups, without preparing special VR materials. Activities included text analysis, case discussions, and problem-solving. In VR, only minor adjustments, such as enlarging fonts, were made. All students completed the same diagnostic and final knowledge tests to assess learning.

Fig. 1. A VR session emulating a classroom, general view.

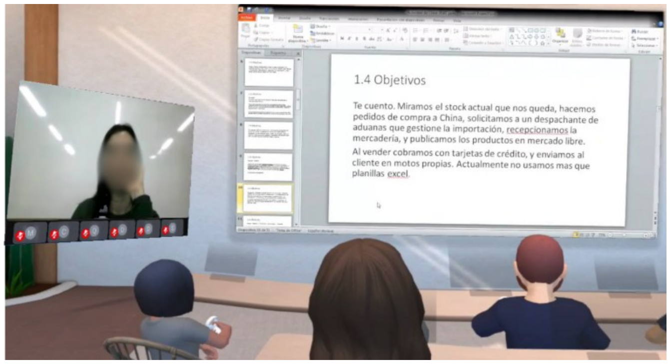

Fig.2. A monitor with remote assistants, inside a VR session classroom.

As part of the course design, selecting suitable VR tools was key. In the study of Hedrick et al. [21] Meta Horizon Workrooms was identified as a cost-effective option for engaging classrooms, while Zhang et al. [22] emphasized advances in realism. Based on this and our analysis, Workrooms was chosen for its natural interaction, presence, and Zoom-like remote access. The Meta Quest 2 HMD was selected for its high-resolution display, 6DoF tracking, ergonomic design, and affordability, ensuring clarity, comfort, and consistent VR experiences.

In preparation for the course, all students were given a 30-minute in-person training session. Teachers also received specific training sessions, focused on the use of the platform and its features.

Students connected to the sessions from their homes using their personal internet connections. This setup was critical in assessing the real-world applicability of VR in remote learning environments where network conditions vary. The importance of evaluating audio-visual quality, interaction responsiveness, and overall comfort was emphasized, given the uncontrolled network environments.

IV. Student's Demographics

In this work, 102 students registered for the course. To gather demographic information and to ask for their informed consent to participate in the experience a questionnaire was designed. 74 students answered this questionnaire – 46 women and 28 men. 40 students were between 20 and 30 years old, 29 were between 30 and 40, and 5 were 40 or more. Fifty-two students resided in Montevideo (Uruguay's capital city), while the rest lived in various locations across the country. Eighty-five percent of the students enrolled the course for the first time. Almost all (72 out of 74) had formal employment: 10 students worked between 20 and 30 hours per week, 32 worked between 30 and 40 hours per week, and 30 worked 40 or more hours per week. Notably, 88% of the registered students preferred to attend the course remotely.

To participate in the experience and gather objective information about the QoE and academic outcomes of the different class attendance modalities, students were asked to commit to attend at least 80% of the classes and to complete various questionnaires after and/or at the end of each session, besides the diagnostics and final knowledge tests.

Forty-three students agreed to participate. Among them, only one had previous experience using VR. 29 were women and 14 men. 22 students were between 20 and 30 years old, 17 were between 30 and 40, and 4 were over 40. Thirty students resided in Montevideo (Uruguay's capital city), while the rest lived in various locations across the country. Eighty-four percent of the students enrolled in the course for the first time. All had formal employment: 6 students worked between 20 and 30 hours per week, 19 worked between 30 and 40 hours per week, and 18 worked 40 or more hours per week. Notably, 81% of the students preferred to attend the course remotely.

To form the four groups for class attendance modalities, students were randomly assigned based on their availability to attend class at designated times, while also accounting for the limited number of HMDs (15 in total, with one reserved for the professor). Table 1 summarizes the number of students assigned to each modality and their compliance of participation requirements.

TABLE I
Students Assigned to each Modality, and Assistance to the Different Course Instances

Modality	Number of students	First knowledge diagnosis test	Attendance to class sessions	Filled the satisfaction surveys	Took final exam
In person	9	8	8 (89%)	8	9 (100%)
Video Conference	8	6	5 (63%)	5	7 (87.5%)
Avatars in a VR classroom	14	13	13 (93%)	14	13 (93%)
Remote assistance to the VR classroom	12	9	7 (58%)	9	10 (83%)
TOTAL	**43**	**36 (84%)**	**33 (77%)**	**36**	**39 (90.7%)**

V. Course Development

The course was divided into four groups, each with one weekly two-hour session, over seven weeks, linked to a specific modality. For "In person" and "Video Conference," the same teaching duo conducted hybrid classes in a room equipped with blackboard, projector, TV, camera, and lapel microphone. Zoom was used to connect remote students, displaying the classroom feed and shared materials.

The same duo of teachers taught classes for the groups assigned to "Avatars in a VR classroom" and "Remote assistance to the VR classroom" modalities. In the VR session, a group of 14 students and one professor attended in the modality "Avatars in VR classroom" (each represented by an avatar). The other teacher and 12 students joined the session from their browsers, in the “Remote assistance to the VR classroom” modality. Fig. 1 shows the general view of the VR room and Fig. 2 shows the interaction of a remote participant, in a virtual monitor, as seen by a student of the “Avatars in a VR classroom” modality. The student´s visual experience in the modality “Avatars in VR classroom” is shown in Fig. 3. Fig. 4 shows the experience for a remote participant, using his browser in remote assistance to the VR classroom modality.

Fig. 3. A VR session using Meta Horizon Workrooms as seen from one of the student’s avatar.

VI. Design of the Quality of Experience Evaluation

Evaluating the Quality of Experience (QoE) is essential to know if the students and professors have a satisfactory experience during the classes. QoE assessments in VR environments help identify issues related to visual clarity, audio quality, interaction responsiveness and overall comfort, which are critical for effective learning and students’ engagement. Conducting these tests allows us to measure how well the VR technology meets the students’ expectations and requirements of the professors, and it provides valuable feedback to make evaluations and improving the system for further courses.

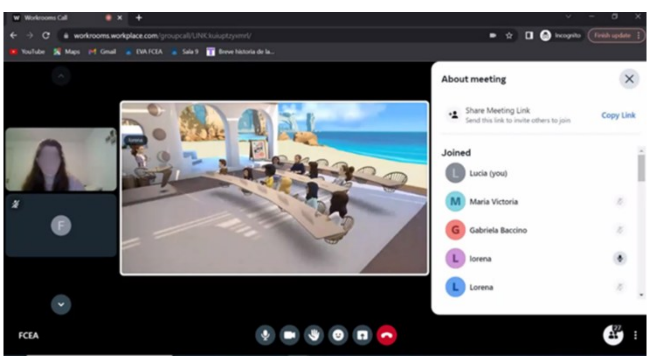

Fig. 4. The experience of remote students attending the VR session.

We performed two types of QoE evaluations. The first one was after each of the class sessions for the VR classroom modality, and the second at the end of all the sessions, for all modalities. In the following subsections we present the designed questionaries for each of these evaluations.

A. QoE Evaluation after each Session in VR Modality

The evaluation of QoE at the end of each VR session was performed using the general guidelines provided in Recommendation ITU-T P.1320 [23], including the assessment of audiovisual quality, comfort, sickness, immersion, presence, fatigue and cognitive load. After each session, the students and professors were asked to complete an on-line questionnaire. For each question, a standard scale was used, with points from 1 to 5, where 1 is “Bad” and 5 is “Excellent”, as recommended by [24]. The following subsections describe the evaluated aspects.

Audio and video quality perception significantly impacts the overall QoE in multimedia sessions [25]. Video resolution and spatial audio rendering had a significant effect on immersion and presence in virtual environments [26], [27]. Various types of degradation can occur in the multimedia stream, especially when accessed over the Internet through an uncontrolled network, where varying or low bitrates are common [28]. In this course, the HMDs connected to a local WiFi network, which in turn connected to the Internet via each student's home router.

To evaluate the perceived audio-visual quality, the following questions were asked after each session:

1. How would you rate the audiovisual quality of the video conference that just ended?
2. How would you rate the audio quality of the video conference?
3. How would you rate the video quality of the video conference?
4. How would you rate the synchronization between image and audio (the movement of the avatars in relation to their audio)?
5. How would you rate the perceived delay during the video conference (the time from when someone stops speaking to when you start hearing the remote participant's response)?
6. Did you experience any video freezing during the video conference?

Comfort issues may arise when wearing HMDs for extended periods, including both physical and visual discomfort [15]. HMDs can be heavy and may not fit comfortably on all head shapes and sizes, leading to pressure points. The weight and balance of the HMD can cause neck strain and the straps can cause pressure on the head [29]. The close proximity of the screen to the eyes can cause eyestrain [30]. Poor focus adjustment, lens quality, or a misaligned display can cause blurriness, making it hard to see clearly and leading to visual discomfort.

One question was included in the questionnaire, to know how the users judge the overall use of virtual reality devices:

7. How would you judge the overall use of virtual reality devices in this video conference?

Sickness in real motion environments has been studied for long time, based on the Motion Sickness Questionnaire (MSQ) proposed decades ago [31]. In the 1990s, the Simulator Sickness Questionnaire (SSQ) was introduced [32] to evaluate different aspects of sickness related to navy and flight simulators. These aspects include general discomfort, fatigue, headache, eyestrain, nausea, vertigo, blurred vision and stomachache, among others, which can be classified into three main categories: nausea, oculomotor issues, and disorientation. The SSQ concludes with an overall score, combining all factors with different weightings. To fulfil all the aspects, a long questionary is needed.

In a more recent study, a new scale specifically targeted at HMDs, called "Vertigo", was proposed [33]. This scale employs a five-level rating system, similar to those used for audio and video evaluations. It assesses a smaller set of aspects, making the questionnaire shorter. Inspired by this approach, the following questions were included:

8. Did you experience any effects such as nausea, dizziness, stomachache, or similar during the session?
9. Did you experience any effects such as nausea, dizziness, stomachache, or similar when removing the VR headset after the session?
10. If you had any symptoms or discomfort during or after the session, please briefly describe what you felt and at what time. (If you answered "5" to the previous two questions, answer "Not applicable")

Immersion is the extent to which a system can replace the user's natural sensory input with mediated input. To measure the propensity for immersion, different questionaries were proposed for virtual environments, games and augmented reality [34], [35], [36]. In our case, we choose to include only one question, representative for this aspect:

11. Rate the following statement: "I found everything so authentic that it made me think the virtual avatars and objects actually existed".

Presence refers to the user's interpretation of immersion, and can be defined has a psychological state in which the individual perceives himself or herself as existing within an environment [37]. ***Plausibility*** can be considered a component of presence, and it may be thought to refer to the illusion that perceived events in the virtual environment are really happening [38]. The following questions were used to assess these two perceptions:

12. How natural were the interactions with the environment? (looking around, using your hands, interacting with other participants, etc.)
13. How would you judge the effort required to interrupt another participant?

The ***fatigue and cognitive load*** experienced when interacting with various human-machine interface systems can be assessed using the NASA Task Load Index (TLX) [39]. This tool employs a multidimensional approach to calculate an overall workload score. This score is derived from a weighted average of ratings across six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration. Based on it, we included the following questions:

14. Rate the cognitive load the activity required from you.
15. Rate your level of fatigue at the end of the session.

Usefulness of the technology has been shown in training and 3D object inspection, but our goal was to evaluate its role in traditional courses without dedicated VR materials. To this end, we included the following question in the assessment:

16. How useful was the virtual reality technology in improving your understanding of the educational material in this class?

Technical issues can strongly affect the VR experience, and given the technology's novelty, some were expected. We included the following questions in the assessment:

17. Did you encounter any difficulties during the video conference?
18. If you answered "Yes" to the previous question, briefly describe what difficulties you encountered.

Other comments were gathered through the following open-ended question:

19. If you have any other comments, you can enter them here.

B. QoE Evaluation from all Students at the end of the Course

At the end of the course, all students completed a final questionnaire to evaluate each modality, the technologies used, and their contribution to learning. The questions are detailed below.

Satisfaction with the Class Attendance Modality and its Components

The overall satisfaction with the course was asked to be declared directly in a 1-10 scale, with 1 being "very unsatisfied" and 10 "very satisfied" as follows:

1. Considering all the classes you attended, how satisfied are you with the class attendance modality?

To evaluate the dimensions contributing to students' satisfaction with the class attendance modality, they rated six statements on a 1–10 scale, where 1 meant "totally disagree" and 10 "totally agree." The statements were:

2. The class attendance modality positively contributed to my learning process.
3. The class attendance modality kept me motivated to participate in the classes.
4. The class attendance modality encouraged active participation during the classes.
5. The class attendance modality facilitated interaction with my classmates.
6. The class attendance modality facilitated interaction with the instructors.

7. The class attendance modality met my expectations regarding the course.

Two open questions asked students to identify the main advantages and disadvantages of each attendance modality:

8. Name the main positive aspect of participating in classes in a metaverse/zoom/remote/in-person (as appropriate) classroom. (open text)
9. Name the main negative aspect of participating in the classes in a metaverse/zoom/remote/in-person (as appropriate) classroom. (open text)

Further Questions about the use of the VR Technology

The final perception of VR use in the "remote assistance" and "avatars in VR classroom" modalities was assessed on a 1–5 scale with the following questions:

For "avatars in VR classroom":

10. At the end of the experience, how would you rate the ease of use of the virtual reality technology? (use of controls, way of interacting with the virtual world, etc.)

For "remote assistance to the VR classroom":

10a. Compared to Zoom, how would you rate the ease of use of the platform used to participate remotely in the VR classroom?

10b. Compared to Zoom, how would you rate the features of the platform used to participate remotely in the VR classroom? (audio quality, display quality of the shared screen, among others)

For both:

11. Overall, my perception of using virtual reality technology for a course of this type is:

Preferences for Future Courses

To explore preferences for future courses, students ranked VR, videoconferencing, and in-person classes as their first, second, and third choices:

12. If you could choose the class participation modality in a course in the future, with content similar to the recently ended course, in what order would you prioritize the following modalities?
    Metaverse Zoom In-person

Net Promoter Score

Net Promoter Score (NPS) measures the likelihood of recommending a product or service [40]. In this case, we assessed the NPS of the overall experience:

13. Based on your experience, how likely are you to recommend a friend taking a course in virtual reality?

Final Suggestions

The final open questions were included:

14. What suggestions would you make to the instructors for future courses using this modality? (open text)

For "remote assistance to the VR classroom" and "avatars in VR classroom" modalities, this last question was added:

15. What features would you add to the virtual classroom? (open text)

VII. Quality of Experience Evaluation

QoE of Participants with Avatars after each VR Session

Table II summarizes responses from 14 students and one teacher (all VR novices) using avatars in the VR classroom. Columns show averages (A), standard deviation (D), maxima (M), minima (m), and session numbers (S). Question 9 was added after session 1.

Audiovisual quality was consistently high, with MOS averages of 4.2 for audio and video, 4.6 for synchronization, and 4.7 for delay, though 25% reported occasional freezing. Comfort improved from 3.1 in the first session to 3.7 in the last, indicating habituation, though some noted neck strain. Sickness ratings rose from 3.7 to 4.8, with early complaints of eyestrain and headaches disappearing later. Immersion averaged 3.5, peaking at 3.7. Presence questions scored 3.8 for interaction and 4.7 for ease of interruption. Fatigue declined over time, while cognitive load averaged 3.6. Perceived usefulness was modest at 3.4. Technical issues, affecting 60% in the first session, fell to 20% by the fifth, mainly involving WiFi, freezing, or battery problems.

Final Perceptions of all Students after the end of the Course

Tables III to VI summarize the information gathered from the questionnaire applied after the end of all sessions to all students who agreed to participate in the experience evaluation and met the 80% class attendance requirement. In the four tables, for the "S" column, row "A" represents the average for all answers, row "M" the maximum values, and row "m" the minimum values. Each of the remaining columns corresponds to a specific question number, as detailed in previous section.

Final Perceptions for Avatars in the VR Classroom Modality

Students attending as avatars in the VR classroom reported high satisfaction (Table III), averaging 8.5/10, and rated ease of use very positively (4.8/5). The technology's suitability for this type of course was slightly lower (4.2/5), with an NPS of 62%. Preferences for future courses were split between metaverse and Zoom, with only one student choosing in-person.

Positive feedback emphasized increased interaction, presence, and motivation, comparable to or exceeding in-person classes. Teachers noted similar engagement. The experience was described as dynamic and fun, fostering natural exchanges.

Negative comments cited headaches, technical delays, difficulty reading materials, and the inability to take personal notes. Connection drops and feelings of exposure were also mentioned. Suggestions included using VR for group tasks and adding personal note-taking tools, the most requested feature.

Final Perceptions for Remote Assistance to the VR Classroom Modality

Students attending remotely to the VR classroom (Table IV) reported high satisfaction, though lower than those using avatars. Interaction with classmates and teachers scored 1.4 points lower (on a 1–5 scale), and participation was rated weakest. Still, comparisons with Zoom were favorable, showing VR offered advantages even without HMDs.

Positive feedback highlighted novelty, organization, and an engaging atmosphere. However, remote students often felt like passive spectators compared to avatar users. Negative points included lack of name visibility, long setup times, technical delays, and unequal headset access, which limited inclusiveness. Suggested improvements included visible hand-raising, displaying speaker names, adding chat, offering a first-person view for remote users, and recording sessions.

Final Perceptions for Remote Assistance to the Classical Videoconference Modality

Table V shows that students attending via Zoom rated satisfaction lower than both VR modalities, with averages of 6.4–7.4/10. Although engagement was limited, 80% still preferred videoconferencing for future courses, likely due to its convenience and familiarity. NPS was only 20%, underscoring its weaker appeal compared to VR.

Positive comments highlighted flexibility to join from home or work. Negative feedback noted poor audio when in-person students spoke, unstable connections, and weak integration with the classroom setup. Several participants felt disengaged, describing the experience as detached and passive.

Final Perceptions for in-person Modality

Table VI shows that in-person classes received the highest satisfaction, averaging 9.3–9.8/10. Seventy-five percent preferred this modality for future courses, and NPS reached 100%. Although these students did not experience VR directly, some (13%) still expressed interest in it.

Positive feedback emphasized direct interaction and socialization, with small groups fostering meaningful exchanges and collaboration. Negative comments focused on scheduling conflicts, commuting time, and limited interaction with Zoom participants.

VIII. Academic Results Evaluation

As described in section IV, all students completed the same diagnostic knowledge test at the beginning and at the end of the course and the same final exam. Tables VII and VIII provide descriptive statistics for the incremental score between final and initial knowledge tests and for the scores in the final exams overall students opened by group of class attendance modality.

To explore the possible influence of the class attendance modality on student´s learnings we adjusted two regression models considering the modality as explicative factor, one model with the incremental score obtained in the final and initial diagnostic knowledge tests as dependent variable and, the other model was built to explain the score in the final exam. We adjusted each model considering the data collected from students who completed the final diagnostic test and the final exam, first based on data of students who met the class attendance requirement (at least 80% of the classes) and then based on data of all students who agreed to participate in the experience regardless their compliance to the class attendance requirement.

Error normality and homoscedasticity hypotheses for the adjusted models are not rejected at a 1% significance level, being the smallest p-value for normal errors equal to 0.029 and 0.1982 for equal variances.

The analyses of variance results showed no significant effect of class modality at 5% significant level (smallest p-value = 0.11), indicating that academic performance was similar across in-person, videoconference, and VR groups. Thus, VR does not provide measurable advantages in these types of courses but also does not negatively affect learning outcomes.

Student preferences for future course modalities appear influenced by novelty bias and technical challenges. For example, VR participants who experienced discomfort or technical issues were less inclined to prefer VR again.

IX. Conclusions and Challenges

This study evaluated four attendance modalities—in-person, videoconferencing, VR with avatars, and remote access to the metaverse classroom. Our objective was to assess, in a traditional non-STEM course delivered without VR-specific materials, whether consumer-grade VR can improve the learning experience (QoE, interaction, student’s satisfaction) relative to conventional videoconferencing, and whether it affects learning outcomes. Results show that consumer-grade HMDs can greatly enhance engagement, motivation, and interaction, offering a learning experience closer to in-person classes than traditional remote tools. This objective was addressed by the comparative evaluation across modalities.

In-person sessions achieved the highest scores across all QoE measures, but the VR modality also performed strongly, providing a sense of presence valued by students and professors. Technical issues and discomfort from prolonged headset use remain challenges, pointing to the need for lighter devices, better text legibility, and integrated note-taking.

Our findings are consistent with prior literature reporting high immersion and perceived interactivity in VR learning, while confirming that usability and discomfort remain key barriers; importantly, we extend this evidence to a non-STEM course without VR-specific materials, where the main benefits are experiential/interactional rather than reflected in final exam performance.

Overall, the Metaverse platforms, with VR HMDs show strong potential for higher education, even when no special 3D materials are needed. Nevertheless, further research and technical improvements are needed for broader adoption. From a practical/pedagogical standpoint, VR appears most suitable for discussion-based classes where social presence and student–teacher interaction are central; implementation should include brief onboarding, planned breaks, shorter exposures times, and an alternative modality for students who experience discomfort.

Our study provides a reproducible and comparative protocol—using the same content, the same instructors, multiple delivery modalities, and a multidimensional QoE assessment—that can be generalized and extended in future work. The findings can motivate the development of explanatory or predictive models centered on acceptance, preference, and engagement, with perceived presence, interaction quality, comfort, and technical friction acting as key predictors. In this sense, the study offers empirical grounding and well-defined operational constructs upon which formal models and theoretical frameworks can be systematically developed in subsequent research.

Future studies should replicate these results with larger samples across multiple non-STEM courses, evaluate longer deployments to separate novelty effects, and incorporate objective interaction and engagement measures (e.g., platform logs regarding *what participants actually did* during each session) alongside questionnaires; additionally, controlled comparisons using newer HMD generations could quantify how hardware advances mitigate comfort and usability barriers.

TABLE II

RESULTS OF THE QOE EVALUATION AT THE END OF EACH SESSION FOR THE AVATARS IN A VR CLASSROOM

		Audio visual quality						**Comfort**	**Sickness**			**Immersion**	**Presence and plausibility**		**Fatigue and cognitive load**		**Technology**	**Tech issues**
S	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	15	4.1	4.3	4.2	4.7	4.7	4.2	3.1	3.7	-	-	3.3	3.7	4.4	3.1	3.0	3.4	60%
2	15	4.2	4.4	4.3	4.6	4.7	3.9	3.6	4.3	4.2	-	3.2	3.7	4.6	3.5	3.8	2.9	53%
3	11	4.5	4.7	4.5	4.6	4.9	4.8	3.6	4.4	4.6	-	3.3	4.0	4.8	3.5	4.1	3.5	27%
4	13	4.2	4.3	4.2	4.6	4.6	4.5	3.6	4.8	4.8	-	3.5	3.7	4.7	3.6	4.1	3.5	31%
5	10	4.2	4.4	4.2	4.4	4.7	4.2	3.6	5.0	4.9	-	3.6	3.8	4.9	3.9	4.6	3.7	20%
6	11	4.1	3.4	4.4	4.5	4.6	4.5	3.4	4.7	5.0	-	3.7	3.7	4.8	3.8	4.5	3.2	36%
7	13	4.3	4.4	4.2	4.7	4.8	4.8	3.7	4.8	4.9	-	3.7	3.9	4.6	3.3	4.2	3.8	46%
A	**13**	**4.2**	**4.3**	**4.3**	**4.6**	**4.7**	**4.4**	**3.5**	**4.5**	**4.1**	**-**	**3.5**	**3.8**	**4.7**	**3.5**	**4.0**	**3.4**	**39%**
D	13	0,1	0,4	0,1	0,1	0,1	0,3	0,2	0,4	0,3	-	0,2	0,1	0,2	0,3	0,5	0,3	15%
M	15	4.5	4.7	4.5	4.7	4.9	4.8	3.7	5.0	5.0	-	3.7	4.0	4.9	3.9	4.6	3.8	60%
m	10	4.1	3.4	4.2	4.4	4.6	3.9	3.1	3.7	4.2	-	3.2	3.7	4.4	3.1	3.0	2.9	20%

TABLE III

RESULTS OF THE QOE EVALUATION AT THE END OF ALL SESSIONS FOR THE AVATARS IN A VR CLASSROOM

		Satisfaction with the class attendance modality and its building components (scale 1-10)							**Use of the technology and preferences for future courses (scale 1-5)**			**NPS**
S	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**10**	**11**	**12**	**13**
A	**13**	8.6	8.5	8.8	7.8	8.5	8.8	8.5	4.8	4.2	**Metaverse: 46%**	**62%**
D	13	1,4	1,6	2,0	2,9	2,6	2,5	2,4	0,4	0,9	Teams/Zoom: 46%	
M	13	10	10	10	10	10	10	10	5	5	In-person: 8%	10
m	13	5	4	4	1	1	1	1	4	2		3

TABLE IV

RESULTS OF THE QOE EVALUATION AT THE END OF ALL SESSIONS FOR THE REMOTE ASSISTANCE TO THE VR CLASSROOM

		Satisfaction with the class attendance modality and its building components (scale 1-10)							**Use of the technology and preferences for future courses (scale 1-5)**				**NPS**
S	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**10a**	**10b**	**11**	**12**	**13**
A	**9**	8.1	8.1	8.0	6.9	7.1	7.4	7.6	4.0	4.0	4.3	**Metaverse: 33%**	**55%**
D	9	1.1	1.7	1.1	2.5	1.8	1.6	1.9	1.0	0.9	1.0	Teams/Zoom: 56%	
M	9	10	10	10	10	10	10	10	5	5	5	In-person: 11%	10
m	9	7	5	7	3	5	5	4	2	3	2		6

TABLE V
RESULTS OF THE QOE EVALUATION AT THE END OF ALL SESSIONS FOR THE VIDEO CONFERENCE

		Satisfaction with the class attendance modality and its building components (scale 1-10)							Use of the technology and preferences for future courses (scale 1-5)	NPS
S	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**12**	**13**
A	**5**	7.4	6.6	6.4	6.4	5.4	7.2	6.8	**Metaverse: 20%**	**20%**
D	5	3.6	4.2	4.9	3.8	3.8	3.7	4.4	Teams/Zoom: 80%	
M	5	10	10	10	10	10	10	10	In-person: 0%	10
m	5	3	2	1	2	1	1	1		2

TABLE VI
RESULTS OF THE QOE EVALUATION AT THE END OF ALL SESSIONS FOR THE IN PERSON

		Satisfaction with the class attendance modality and its building components (scale 1-10)							Use of the technology and preferences for future courses (scale 1-5)	NPS
S	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**12**	**13**
A	**8**	9.6	9.6	9.5	9.3	9.8	9.8	9.6	**Metaverse: 13%**	**100%**
D	8	0.5	0.5	0.8	1.2	0.5	0.5	0.7	Teams/Zoom: 12%	
M	8	10	10	10	10	10	10	10	In-person: 75%	10
m	8	9	9	8	7	9	9	8		9

TABLE VII
DESCRIPTIVES FOR THE INCREMENTAL SCORE BETWEEN FINAL AND INITIAL KNOWLEDGE TESTS (BOTH OVER 10 POINTS)

	All participants	In Person	Video Conference	Avatar in VR Classroom	Remote Assistance to the VR Classroom
N	36	8	6	13	9
A	1.75	2.50	0.75	1.77	1.72
D	1.64	1	1.32	1.94	1.67
M	5.25	4.25	3	5.25	4.50
m	-1	1.50	-1	-1	-0.50

TABLE VIII
DESCRIPTIVES FOR SCORES IN THE FINAL EXAM (OVER 10 POINTS)

	All participants	In Person	Video Conference	Avatar in VR Classroom	Remote Assistance to the VR Classroom
N	39	9	7	13	10
A	6.64	5.92	6.61	6.60	7.38
D	2.24	1.98	3.11	2.02	2.18
M	10	8.25	10	9	10
m	1	3.5	1	2.5	3.75

X. ACKNOWLEDGMENTS

This work was possible thanks to professors Fabián López and Gabriel Budiño, and teaching assistants Mariana Álvarez, Marianela Da Silva, Lorena Pérez, and Lucía Pintos from the School of Economics, Universidad de la República, who enthusiastically conducted the classes. We also acknowledge the financial support of the Education Sector Commission (CSE) and the Statistics Institute (IESTA) of the School of Economics.

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