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Desktop-based virtual reality social platforms versus video conferencing platforms for online synchronous learning in higher education: An experimental study to evaluate students' learning gains and user experience

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Abstract

Background: Online synchronous learning in higher education frequently struggles to overcome the social presence gap, resulting in dissatisfaction and poor learning outcomes.

Objectives: This study examined the effectiveness of desktop-based virtual reality (VR) social platforms compared to video conferencing (VC) platforms in enhancing students' learning gains and experiences in online synchronous learning.

Methods: The study used a within-subject design, involving 34 college students in two online lecture modules, one via a VR social platform and another through a VC platform. Knowledge assessments occurred pre- and post-modules and after 1 week. Students also completed post-module questionnaires to evaluate their learning experience, in terms of social presence, easiness of use and perceived emotions. In-depth interviews provided further insights into their experiences with both platforms.

Results: The study showed that using VR social platforms for online synchronous learning enhanced immediate knowledge, especially in students less interested in the content, yet it did not notably impact long-term knowledge retention. Despite no significant findings in social presence from questionnaires, interviews indicated that the VR's heightened interactivity might be offset by the effect of not seeing others' real appearances in promoting social presence. Furthermore, the VC platform was found to be easier to use, attributed to its familiarity and user-friendliness. Finally, students experienced increased fun, awe and interest, along with reduced boredom, when using the VR social platform.

Conclusion: The findings highlight the potential of VR to enrich online learning while underscoring the need for effective strategies facilitating a smooth integration into educational settings.

KEYWORDS

emotions, online learning, social presence, usability, virtual reality

1 | INTRODUCTION

The unprecedented challenges brought by the COVID-19 pandemic have reshaped the landscape of higher education. Universities and academic institutions worldwide had to innovate rapidly, ensuring continuity in learning by migrating to online learning platforms (Al-Ansi, 2022). In this context, traditional video conferencing (VC) platforms, such as Microsoft Teams, Zoom and Google Meet, have dominated online synchronous learning. These platforms, with their user-friendly interfaces and features like video calling and screen sharing, allowed students to connect with their teachers and peers, guaranteeing continuity in their education. However, despite their utility, these platforms have shown to fail to replicate the depth of social interaction found in physical classrooms, leading to what is known as the 'social presence gap' (Daigle & Stuvland, 2021).

Originally defined by Short and colleagues (Short et al., 1976), 'social presence' is the perceived sense of intimacy and immediacy with others during a mediated interaction. In the context of online learning, it is recognized as the sensation of being connected to and actively engaging with others within a digital learning environment, fostering a sense of community (Garrison et al., 1999). Research has established a correlation between social presence and various learning outcomes in online settings, including students' engagement, motivation, satisfaction, perceived learning efficacy (Dennen et al., 2007; Edwards, 2021; Garrison et al., 2010; Hostetter, 2013; Richardson, 2001; Richardson et al., 2017; Szeto & Cheng, 2016; Turk et al., 2022) and learning gains (Guo et al., 2021; Joksimović et al., 2015; Wei et al., 2012). It is therefore crucial for researchers and educators to explore solutions that can bridge the social presence gap and improve students' experience and performance in online synchronous learning formats.

When students feel connected to their peers and teachers, they are not only more likely to be motivated and engaged in the learning process but also to experience positive emotions such as interest and enjoyment (Molinillo et al., 2018). Students' emotional experience during learning plays an essential role in education. According to Pekrun's control-value theory (Pekrun, 2006), various emotions can be experienced during an educational activity, including enjoyment, relaxation, anger, frustration and boredom. These emotions, known as activity emotions, along with other relevant emotions like shame, anxiety, interest (Pekrun, 2016) and awe (Gail Jones et al., 2022), can influence students' commitment to following a lecture and trying to understand its content, consequently affecting their learning outcomes.

In this context, virtual reality (VR) social platforms, such as Spatial, MeetinVR and Engage VR, have recently gathered interest as potential solutions for online learning (Chessa & Solari, 2021; Gomes de Siqueira et al., 2021; Guichet et al., 2022; Holt et al., 2020). These platforms, which can be accessed through either desktop or head-mounted displays (HMDs), provide virtual environments that offer a more interactive experience, enabling students to engage with one another in ways that closely mimic physical presence. By using an avatar to represent themselves, users can experience a sense of physical coexistence in a shared space, facilitating more dynamic interactions (van Brakel et al., 2023). In online education, these platforms can be used to create a learning experience closer to that of a traditional classroom (Chessa & Solari, 2021), encouraging connection and active participation from students. However, VR social platforms still represent unexplored ground for many students and therefore present several challenges, including difficulties in terms of easiness of use. For new users, navigating through a novel, virtual space and interacting with virtual elements can be confusing and overwhelming (Bailenson & Yee, 2006; Han et al., 2022), potentially affecting their overall experience and their ability to focus on the learning content.

Despite the growing interest in VR social platforms for online learning, research on the effectiveness of these solutions is still in its early stages. Therefore, this study seeks to provide a comprehensive analysis of the effects of VR social platforms on students' learning experiences and knowledge acquisition, comparing these impacts with those of traditional VC platforms in the context of online synchronous learning in higher education.

2 | CONCEPTUAL FRAMEWORK

2.1 | Social presence in online synchronous learning

In the digital landscape of higher education reshaped by the COVID-19 pandemic, social presence in online learning has emerged as a critical construct for understanding the efficacy of educational interactions in virtual environments (Whiteside et al., 2023).

Social presence was initially defined as 'the degree of salience of the other person in a communication interaction and the consequent salience of their interpersonal interactions' (Short et al., 1976). In simpler terms, it is the sense of being with another person during a mediated communication, making the interaction feel more immediate and personal. This concept was initially developed in the context of telecommunications technology and has since been widely applied and expanded upon, especially in the context of online and virtual communications, where it captures the sense of being with another person in a virtual space (Biocca et al., 2003), even in the absence of physical proximity.

In the context of online learning, this translates to the sense of being with others, fostering a community of learning (Garrison et al., 1999). Central to this concept is the community of inquiry (CoI) framework, which posits that effective educational experiences are constituted by three interrelated elements: social presence, cognitive presence and teaching presence (Garrison et al., 1999). Social presence, within this framework, is essential for fostering a sense of community and connectedness among learners, enabling them to engage deeply with the content and each other. Social presence in online learning indeed extends its influence beyond the facilitation of information exchange. It encompasses the transmission of emotions, attitudes and a sense of personal engagement, contributing significantly to the overall learning experience (Richardson et al., 2017). In the COI framework, social presence, which fosters a sense of community and emotional engagement, intertwines with cognitive presence, which facilitates deep and meaningful learning through critical thinking and reflection and teaching presence, which acts as a guiding force, structuring and directing the educational process. Together, these elements work with social presence to create a comprehensive and effective learning environment.

Emerging studies have emphasized the importance of social presence in online education in bridging the psychological distance often associated with online forms of learning (Weidlich et al., 2023) and has shown to influence critical learning outcomes, including student engagement, motivation, satisfaction, perceived efficacy in learning and academic achievements (Dennen et al., 2007; Garrison et al., 2010; Hostetter, 2013; Molinillo et al., 2018; Richardson et al., 2017).

The transition to VC platforms like Microsoft Teams, Zoom and Google Meet has highlighted a critical 'social presence gap' in online learning (Daigle & Stuvland, 2021), where despite the technological advancements, students often experience a diminished sense of connection and interaction with their peers and instructors. In their study, Daigle and Stuvland (2021), have highlighted the challenges of achieving social presence in online platforms. Their findings suggest that a diminished social presence in online platforms can lead to feelings of isolation, a sense of detachment from the learning material and even a perceived lack of validation or acknowledgment from peers and educators. This can result in reduced motivation, diminished engagement, and a general feeling of being 'disconnected' from the learning process.

Social presence emerges as a central construct also in the SIPS (sociability, social interaction, social presence, social space) model, which offers a valuable perspective (Weidlich & Bastiaens, 2017) to analyse effective online learning environments. Similarly, to the COI, the SIPS emphasizes the importance of social presence for a supportive and engaging online learning environment. However, while the COI integrates cognitive, social and teaching aspects for a complete educational experience, the SIPS focuses more specifically on the social dimensions and how they are facilitated and experienced in online environments. This model highlights the relationships between four core variables essential to learning environments: sociability, social interaction, social presence and social space. According to this model, the sociability of a system has a positive influence on social interaction, which in turn fosters the development of a sound social space, either directly or through the mediation of social presence. The model highlights the importance for members to interact with each other and perceive their peers as 'real', and to perceive the learning environment as a cohesive social space (Weidlich & Bastiaens, 2019). This insight from the SIPS model highlights a critical pathway for enhancing social presence in online learning: fostering sociability and interaction to create a sense of shared social space (Weidlich & Bastiaens, 2019).

VC platforms, while offering real-time interaction, lack a shared physical space and offer limited non-verbal communication cues, which can hinder the natural flow of conversation and interaction that normally occur in face-to-face scenarios. This limitation highlights the need for innovative solutions that can bridge the social presence gap more effectively.

2.2 | Emotions in online synchronous learning

In the digital context of online education, mediated interactions not only impact social presence but also influence the emotional experience of learners compared to traditional classrooms.

Pekrun's (2006) control-value theory offers a comprehensive framework for understanding these emotions in educational settings, highlighting them as central determinants of the learning process. The theory categorizes emotions into two types: activity emotions and outcome emotions. Activity emotions are those experienced during engagement with learning activities, such as enjoyment, interest, boredom and frustration. For instance, a student might feel enjoyment during an interactive task they find interesting, or boredom during a monotonous lecture. Outcome emotions, on the other hand, are related to success or failure in learning activities, including feelings like pride, shame, hope and anxiety. These emotions are particularly salient in assessment contexts and can greatly influence a student's approach to learning and performance. Positive outcome emotions, like pride and hope, can foster resilience and a growth mindset, while negative emotions, such as shame and anxiety, may hinder learning and academic achievement. The theory is applicable in both traditional and online learning environments, with similar emotions experienced in both (Daniels & Stupnisky, 2012).

As concern online learning, a recent systematic review (Wu & Yu, 2022) explored how achievement emotions affect online learning outcomes, examining both positive (e.g., enjoyment, pride) and negative emotions (e.g., anxiety, boredom). The findings indicated that positive achievement emotions positively impact online learning motivation, whereas negative emotions have an adverse effect. Experiencing positive achievement emotions was associated with more effective interactions and active knowledge construction. Extensive research has indeed shown that achievement emotions have a strong impact on student engagement and learning outcomes (Artino Jr, 2012; Berweger et al., 2022; Cleveland-Innes & Campbell, 2012; Daniels & Stupnisky, 2012; Marchand & Gutierrez, 2012; Pentaraki & Burkholder, 2017; Vo, 2021).

Activity emotions are particularly crucial in online learning environments, as they significantly influence information processing (Artino Jr & Jones II, 2012). In their study, Artino Jr and Jones II (2012) explored the relations between activity emotions (boredom, frustration and enjoyment) and self-regulated learning behaviours in an online course. The authors found that enjoyment was a positive predictor of elaboration and metacognition, while boredom was negatively correlated with elaboration and metacognition. Similar results were found by Dai (2023), revealing that boredom negatively predicted elaboration and metacognition during online courses.

The role of emotions in online learning extends beyond learning performance to include aspects such as the learner experience. As Artino (Artino Jr, 2012) emphasizes, emotions can profoundly influence learners' motivation and their ability to stay engaged with the content, thereby directly impacting their academic achievement. Positive activity emotions like enjoyment and interest are linked to increased motivation, enhanced learning strategies and better academic performance. The joy and the curiosity that a multimedia module might evoke, all contribute to the holistic online learning experience. On the other hand, negative activity emotions like boredom and frustration can lead to disengagement and poorer learning outcomes.

Recognizing this, affective e-learning models have been developed to better understand the emotional needs of learners. These models, as highlighted by Sandanayake and Madurapperuma (2013), not only identify the emotions of learners but also explore the intricate correlation between these emotions and their overall learning performance. This includes examining how different emotional states can either hinder or enhance the learning experience.

In analysing the emotional landscape of online learning through VC platforms, especially during the pandemic, some studies have indicated that students experience higher levels of negative emotions such as anger, anxiety and boredom and lower levels of positive emotions, such as enjoyment and interest, while participating in online synchronous VC learning (e.g., Murphy et al., 2020; Petillion & McNeil, 2020; Unger & Meiran, 2020). Research has indeed shown that, in online learning scenarios, negative emotions such as boredom and anxiety are not only more prevalent but also perceived more intensely by students than in face-to-face educational contexts (Stephan et al., 2019). This heightened perception of negative emotions in an online setting can have a detrimental impact on students' academic performance. It suggests that the lack of direct, personal interaction and the limitations of digital communication channels in VC systems may exacerbate feelings of disconnection and disengagement, thereby intensifying negative emotional experiences.

2.3 | The opportunities and challenges of desktop-based VR social platforms in online synchronous learning

VR social platforms are online spaces where people can interact with each other in a virtual environment using an avatar as a representation of the self. These platforms can be accessed through either non-immersive, desktop-based, or immersive VR technology, like HMDs. Desktop-based VR refers to virtual experiences that are accessible on standard desktop or laptop computers. The virtual environment is displayed on a regular computer screen and can be navigated using traditional input devices like a keyboard and mouse. According to research by Makransky and Petersen (2019), desktop-based VR can enhance both affective and cognitive engagement in educational settings. This form of VR is particularly valuable due to its accessibility as it does not require the costly and specialized equipment, like HMDs, associated with immersive VR setups.

Before the advent of advanced VR social platforms, Second Life has been the most explored desktop-based VR social platform in education (e.g., Inman et al., 2010; Pellas, 2014; Warburton, 2009). Previous studies have consistently demonstrated Second Life's effectiveness in enhancing social presence and emotional engagement in online learning environments. Research Mansour and colleagues (2009, 2010) found increased levels of social interaction and presence among students using Second Life. Pellas (2014) revealed higher motivation and social presence in Second Life compared to traditional learning systems. Further, works by Artino Jr (2012) and Ma (2009) emphasized its benefits in collaborative learning and digital game education. Additionally, Reinsmith-Jones and colleagues (2015) and Richardson (2001) highlighted the positive effects on learning outcomes and student satisfaction due to enhanced social presence. However, it has also been noted that, despite the potentialities, it may not be as effective as face-to-face interaction yet (e.g., Gao et al., 2009; Sutcliffe & Alrayes, 2012).

New VR social platforms like Spatial, MeetinVR and Engage VR offer more immersive experiences, with advanced avatar interactions aiming to bridge the social presence gap more effectively and recent studies have begun to explore the potential of desktop-based VR social platforms in higher educational settings (e.g., Chessa & Solari, 2021; Gomes de Siqueira et al., 2021; Guichet et al., 2022; Holt et al., 2020).

Chessa and Solari (2021) compared students' experience while using traditional VC systems (Microsoft Teams) and a VR social platform (Mozilla Hubs). Feedback from participants indicated that while the VC platform felt more like watching a video than attending a live lecture, the Mozilla Hubs platform offered elements that enhanced the sense of 'being really there', such as a virtual environment resembling real classrooms and the ability to explore the virtual space. Similarly, Holt et al. (2020) observed that ecology students using Mozilla Hubs for presentations felt more engaged due to the shared virtual space.

In the study by Gomes de Siqueira et al. (2021), the researchers evaluated Mozilla Hubs as a tool for enhancing student interaction and communication in a VR educational context. During the COVID-19 pandemic, they implemented various virtual rooms and activities in an introductory VR course. The study provides practical guidelines for constructing effective virtual environments aimed at improving collaborative learning and engagement in educational settings. In particular, it emphasizes the importance of optimizing activity duration by setting time limits on virtual room usage and it recommends designing single-room spaces that promote increased proximity among students, thereby enhancing communication and interaction within the virtual learning space.

Finally, one study (Yoshimura & Borst, 2021) examined the experiences of students attending and presenting lectures on VR social platform, comparing the desktop and the immersive experience through HMDs. The authors evaluated aspects like presence, social presence, simulator sickness and communication methods (e.g. hands motions, like raising hands, head movements, the use of emoji, etc.). Although certain discomfort-based symptoms and technical challenges were identified, the overall conclusion was that social VR platforms hold significant promise as an alternative to conventional remote learning methods. The study found that immersive VR had a distinct advantage in fostering a sense of social presence among users. However, desktop-based VR emerged as more favourable in terms of usability and in mitigating the effects of cybersickness, presenting a balanced option for remote educational settings.

These and other studies (e.g., Barreda-Ángeles et al., 2023) suggest that VR social platforms offer promising opportunities to foster a sense of social presence and community in online learning facilitating a more natural and spontaneous communication compared to traditional VC tools (Barreda-Ángeles et al., 2023). Furthermore, preliminary results indicate that VR social platforms have the potential to significantly enhance students' emotional engagement, with students reporting higher enjoyment and interest in learning within a VR collaborative environment rather than via VC platforms (Jeong et al., 2022; Sriworapong et al., 2022). Whether through fully immersive devices (Makransky & Lilleholt, 2018), or desktop applications (Makransky & Petersen, 2019), this heightened emotional engagement could be attributed to the interactive nature of VR, which creates stimulating learning experiences where learners become active participants in their educational activities, rather than being passive recipients of information.

While these studies have been instrumental in analysing students' experiences with new VR social platforms, there has not been yet a comprehensive exploration of the specific learning gains, such as knowledge acquisition, that is how effectively students can absorb new information and knowledge retention, that is how well they can retain this information over time. This exploration should consider that the enhanced user experience offered by VR social platforms may stimulate students' attention far beyond what traditional learning tools can achieve, potentially boosting learning gains. At the same time, it is important to recognize that while VR can indeed motivate students to invest more effort in the learning process, the actual learning gains are significantly influenced by an individual's interest in the subject matter. This interest, reflecting a student's personal liking and curiosity about a particular topic (Schiefele, 2009), drives deeper engagement with the content, improving both the absorption and retention of information (Schiefele et al., 1992). Therefore, despite VR's ability to enhance the learning experience, the effect on educational achievements is also affected by the student's individual interest for the subject. A comprehensive exploration in this area would provide valuable insights into the educational efficacy of VR social platforms.

Furthermore, another key aspect to be considered in this exploration is that transitioning to VR poses challenges in usability. Usability refers to the quality and accessibility of the technology in use, and it is measured by perceived usefulness, that is the degree to which the learners believe that using the platform will enhance their performance, and perceived ease of use, that is the extent to which the learners experience the technology as being easy or difficult to use (Davis, 1989; Lee et al., 2010). These constructs have been extensively explored within the context of using VR in educational settings (e.g., Barrett et al., 2020; di Natale, Repetto, et al., 2024; Huang & Liaw, 2018; Luo & Du, 2022). Learners' perceived easiness of use plays a crucial role in this case. For many students, initial interactions with VR social platforms may be somewhat non-intuitive, largely attributed to the novelty of the medium. The shift from traditional online learning platforms to a VR environment can be indeed challenging for first-time users unfamiliar with 3D navigation and controls. This unfamiliarity can stem from the unique ways in which these platforms enable interaction and navigation within a virtual environment, differing significantly from traditional digital interfaces. Moving around in a virtual 3D space is fundamentally different from scrolling through a 2D webpage and include a variety of controls and interactions that can be overwhelming for first-time users. Students might struggle with understanding spatial orientation, determining where they need to go, or even how to get there. This can lead to feelings of frustration and disorientation and may lead students to focus more on how to move around and control the avatar than on the lecture. Research highlights the importance of designing VR environments that are intuitive and easy to use to increase learning benefits (Makransky & Petersen, 2019) and achieving a balance between and interactive and engaging experience and user-friendliness is key to enhancing learning outcomes and boosting learners' self-efficacy, thereby contributing to the overall effectiveness of VR in education (Clark & Mayer, 2023).

3 | PRESENT STUDY

The aim of this study was to analyse the potential of a VR social platform (Spatial) compared to a traditional VC platform (Microsoft Teams) for online synchronous learning, offering valuable insights into the potential of emerging technologies for student's learning experience (social presence, emotions and ease of use) and learning outcomes. While both platforms offer core functionalities essential for synchronous online learning (e.g., real-time communication, content sharing and group interaction), they present differences in some key characteristics that may influence learners' experiences (see Table 1 for a summary).

First, as concern the type of environment, in Microsoft Teams, participants join meetings from their private physical environments (e.g., at home). This setup can limit the sense of being together as a group, as each participant is isolated in their own space. The physical

TABLE 1 Key differences between Microsoft Teams and Spatial.

	Microsoft teams	Spatial
Environment	• Private physical space	• Shared virtual space
	• No spatial audio	• Spatial audio
Visual self-representation	• 2D video feeds	• 3D full body avatar
Interaction	• Structured, turn-based	• Fluid, natural
	• Mainly verbal	• Gesture and proxemic

separation can make it challenging to create a cohesive group dynamic, as the feeling of being in a shared space is absent. This may lead to a less engaging experience, where participants might feel disconnected from one another, affecting the quality of interactions. On the other hand, Spatial offers a shared virtual space that closely mimics a physical gathering. In Spatial, participants enter a common virtual environment where they can see and interact with each other as avatars. This shared space can significantly enhance the sense of physical co-presence, making participants feel as though they are in the same room. The interactive nature of the virtual environment fosters a stronger sense of togetherness and can lead to more natural and spontaneous interactions (Ferrer & Fujiwara, 2022; Franceschi et al., 2009; Steinicke et al., 2020).

Furthermore, as concern the audio, Microsoft Teams lacks spatial audio, which means that all sounds are transmitted from one point, potentially making the conversation feel less natural and more fatiguing, as users must rely heavily on visual cues to reveal speaker location and intent. Spatial, on the other hand, incorporates full 3D spatial audio, enhancing the realism of conversations and making it easier for users to identify who is speaking based on sound direction (Nowak et al., 2023).

Second, the visual self-representation of users in Microsoft Teams and Spatial varies considerably, impacting non-verbal communication and social dynamics in distinct ways. In Microsoft Teams, participants are shown as 2D video feeds, typically focusing on the upper body. This representation gives participants the opportunity to see others' real faces and facial expressions, potentially leading to enhanced social connection and fostering active participation, as they are aware of being observed by others (Daly-Jones et al., 1998; Sederevičiūtė-Pačiauskienė et al., 2022). However, the focus on the upper body limits nonverbal cues mainly to facial expressions, while the visibility of other non-verbal cues, such as full-body gestures and posture, is reduced (Ayache et al., 2021). To this matter, research has demonstrated that participating in a video conference session requires increased visual, auditory and vocal efforts as well as cognitive load, all of which create exhaustion or the so-called 'Zoom fatigue' (Bonanomi et al., 2021; Döring et al., 2022; Fauville et al., 2021).

In contrast, Spatial utilizes full-body 3D avatars to represent participants, which leads to different social dynamics. Full-body avatars can mimic a wider range of non-verbal cues, including posture, movement and gestures, enhancing the sense of presence and making interactions feel more natural and lifelike (Bailenson et al., 2006). Additionally, the ability to move around as avatars in a shared space can create more dynamic social interactions. Participants can approach each other, form groups and engage in side conversations, much like in a physical setting. This fluidity can enhance collaboration and spontaneity, fostering a more interactive and engaging learning environment (McVeigh-Schultz & Isbister, 2021). Furthermore, representing oneself through avatars in Spatial can reduce self-consciousness and encourage participation from those anxious about being on camera (Kang & Watt, 2013). However, the anonymity provided by avatars may also lead to reduced accountability and potential disengagement (Han et al., 2023).

Additionally, the interaction styles facilitated by Microsoft Teams and Spatial represent two distinct paradigms in online learning environments. Teams' grid-like presentation of participants fosters a more structured, turn-based interaction style. This layout naturally encourages a formal communication pattern where participants often wait for clear pauses before speaking, leading to organized but potentially less spontaneous discussions. Furthermore, fixed positioning and limited non-verbal cues in Teams can make interactions feel more rigid, with a heavier reliance on verbal communication. In contrast, Spatial's shared virtual environment, where users can move freely, opens up possibilities for more fluid conversations (Sawada et al., 2021). This favours a less formal structuring, mimicking real-world social behaviours, though it could also generate overlap in terms of speaking turns. Furthermore, the ability to physically (although virtually) approach or distance oneself from others enables more natural non-verbal communication, potentially making interactions feel less constrained and more engaging. This dynamic environment may encourage more active participation and exploration, keeping learners more involved in the process. However, it should be noted that Spatial may limit the ability to read facial expressions clearly, which may impact the depth of emotional connection and comprehension during interactions. Despite this limitation, the overall interactive nature of Spatial presents an interesting alternative to more traditional, structured platforms like Teams, providing a combination of engagement and flexibility in online learning environments.

These differences provide a unique opportunity to explore how varying degrees of technological characteristics and novel interaction and communication paradigms might influence the effectiveness of online education. Through this comparison, we can better understand the potential benefits and challenges of integrating more immersive technologies into educational settings, informing future developments in online learning platforms.

3.1 | Research questions

This study was structured around two primary research questions, aiming to explore different aspects (learning gains and students' experience) of online synchronous learning through a VC platform and a VR social platform.

> **RQ1.** The first goal of our study was to compare the impact of VC and VR platforms on students' learning gains, by analysing their immediate knowledge acquisition and long-term knowledge retention. Drawing from the literature, showing the immersive and interactive capabilities of VR social platforms (Chessa & Solari, 2021; Gomes de Siqueira et al., 2021; Holt et al., 2020; Yoshimura & Borst, 2021), which are posited to enhance learning effectiveness (Merchant et al., 2014), we hypothesized that:
>
> **H1a.** Students will demonstrate greater immediate knowledge gains when learning through the VR social platform rather than the VC platform.

H1b. Students will exhibit better knowledge retention over time when the learning content is presented through the VR social platform rather than the VC platform.

Additionally, recognizing the role played by individual interest in the topic on learning outcomes (Hidi & Renninger, 2006), our analysis also includes an examination of how students' inherent interest in the topic addressed interacts with the platform used to mediate both knowledge acquisition and retention.

RQ2. The second objective of our study was to examine how experiences with VR social platforms diverge from VC platforms by exploring key constructs integral to the online learning experience. In particular, this investigation focused on three key aspects: social presence, ease of use and emotional experience. Within this objective, we developed the following hypotheses and research question:

H2a. Based on prior studies, showing the potentiality of VR social platforms to foster a strong sense of presence and community (Chessa & Solari, 2021; Gomes de Siqueira et al., 2021; Holt et al., 2020; Yoshimura & Borst, 2021), we hypothesized that VR users will report higher social presence than VC users.

H2b. Considering the novelty of VR social platforms or online learning, which can pose challenges due to their unfamiliarity and complexity (Clark & Mayer, 2023), we also hypothesized that students might find VC platforms to be easier to use than VR social platforms.

RQ3. Understanding the critical role that emotions play in learning processes (Pekrun, 2006), our third research question concerns the exploration of the emotional experiences of students, encompassing both positive emotions (such as enjoyment and interest) and negative emotions (like boredom and frustration).

Students' experiences were further explored through in-depth interviews to gather insights on students' subjective experiences with VR social platforms and VC platforms as learning environments.

4 | MATERIALS AND METHODS

4.1 | Research design

In line with previous research (Geana et al., 2023), this study adopted a mixed-methods approach, incorporating both quantitative techniques and a qualitative exploration of students' experience. Specifically, questionnaires were administered to assess students' experiences, capturing aspects such as social presence, emotional experience (i.e., activity emotions experienced during the lesson) and perceived ease of use. Knowledge acquisition and retention were evaluated using a multiple-choice questionnaire. Additionally, in-depth interviews were conducted to gain deeper insights into participants' perceptions and learning experiences with the platforms.

The study followed a within-subject design, with each participant engaging in two lecture modules delivered through different platforms: one via a VC platform and the other via a VR social platform. The study was approved by the Local Ethical Committee of the Department of Psychology of the Università Cattolica del Sacro Cuore, Milano.

4.2 | Participants

As an approximation of the present analysis using linear mixed-effects models, the sample size of this study was calculated a-priori with G*Power, and it was found that 34 participants were needed to detect a difference between two means with 80% power with a medium effect size ($f = 0.25$) in a repeated measure design. However, calculating power for linear mixed models is inherently more complex (Brysbaert, 2019). To address this, we used the SIMR package (Green & MacLeod, 2016) to calculate post-hoc power simulations for our LMMs used in testing H1a and H1b, concerning the effect of the platform on students' learning outcomes. However, since the platform variable was part of an interaction with individual interest, we assessed its impact by comparing the full model, which includes the interaction effect, to an alternative model that does not include the platform variable. This approach allowed us to test if the platform had a meaningful effect, particularly through its interaction with individual interest. We used the fcompare function of the SIMR package to specify this alternative model and ran 100 simulations with a significance level of $\alpha = 0.05$. The results showed that we have an 82% chance of correctly detecting the effect of the platform when it interacts with individual interest.

A total of 44 individuals were invited through email among university students. However, only 34 participants completed both conditions. Ages spanned from 19 to 29 years, with an average age of 22 (SD = 3.20). The sample was predominantly female, constituting 88% (30 females, 4 males). A significant 77% came from the psychology domain, followed by 9% from education, 6% from business and marketing, and 3% each from biology, engineering and sports science. Notably, 88% (30) had no prior experience with VR social platforms. Of the remaining 12% (4), all had experimented with such platforms primarily for entertainment, while only 1 previously had experience in the context of education.

4.3 | Platforms

In our study, we evaluated one VC platform and one VR social platform for their online educational implications. We used Microsoft Teams, a widely adopted VC tool, which offers functionalities like video calls and screen sharing, facilitating communication and

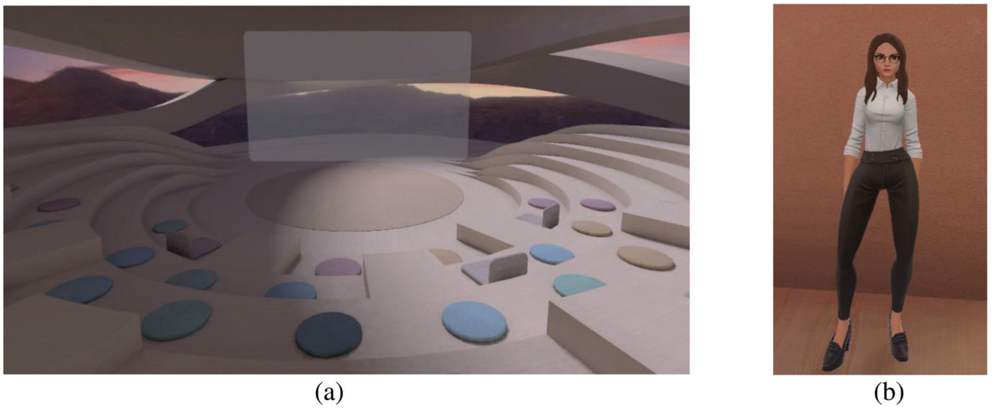

FIGURE 1 The Spatial VR environment (a) and the avatar of the teacher (b) used for the experiment.

teamwork. On the other hand, we integrated Spatial, a VR social platform tailored for hosting online meetings, lectures and events with multiple attendees. Though Spatial is designed to possibly offer an immersive experience via VR headsets, our participants accessed it using desktop mode on their computers. Upon entry, participants could choose their avatar among a set of 21 pre-selected non-customizable avatars and then entered the room.

Following Gomes de Siqueira and colleagues' guidelines (Gomes de Siqueira et al., 2021), the room was selected among others, to be a single confined space where users could take seats next to each other (Figure 1a) and interact with the teacher (Figure 1b). Detailed guidelines were provided to ensure that participants could navigate and use both platforms.

4.4 | Lecture and modules

A lecture on computational thinking and coding was divided into two modules: Module 1 and Module 2. In Module 1, students were introduced to fundamental theoretical concepts and practical examples related to computational thinking. Moving on to Module 2, the focus shifted towards the theoretical foundation and application examples of coding and educational robotics activities. The lectures were conducted in a conventional lecture-style format, featuring a teacher delivering the content with the aid of presentation slides.

The choice of this topic was motivated by two primary factors. First, we needed a subject matter suitable for the administration of a multiple-choice test as part of the knowledge assessment. Second, we chose a topic that had not been covered in the courses attended by the invited participants (see '4.2. Participants' Section). However, recognizing that individual interest can influence attentional processes and potentially impact learning outcomes, we decided to measure participants' dispositional interest in the topic (see '4.5.1. Individual interest in the topic' Section). Our methodology is designed to not only quantify the pre-existing interest levels in computational thinking and coding among participants but also to explore how this interest interacts with the learning gains observed over the course of the study.

Following Gomes de Sequeira and colleagues' (Gomes de Siqueira et al., 2021) guidelines, highlighting the need for short, concentrated sessions to increase the likelihood of student engagement in the virtual space, each module lasted approximately 30 min. These modules were presented on consecutive days at a consistent time. On both platforms, the same assistant was available to aid participants with any technical challenges during the session. In the VC condition (Microsoft Teams) the assistant was visually present among participants in the call, and in the VC condition she was represented by an avatar and joined to room with participants.

4.5 | Measures

4.5.1 | Individual interest in the topic

To evaluate interest in the subject, we used an Italian-adapted version of the Academic Interest Scale's engagement subscale (Luo et al., 2019). This scale evaluates the inclination to participate in specific learning activities related to the subject (e.g., 'I would like to know more about [the topic]'). The scale consists of seven items, each rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). We calculated the overall interest score by averaging these item scores ($a = 0.91$, $w = 0.91$; Peters, 2014). Higher average scores reflect greater interest in the subject.

4.5.2 | Social presence

We assessed social presence using an Italian-adapted version of the social presence subscale from the Multimodal Presence Scale (Makransky et al., 2017), consisting of five items (e.g., 'I felt like I was in the presence of other people in the online environment.') Items were measured on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The mean value of the items was used to calculate the scale's total score ($\alpha = 0.79$, $\omega = 0.80$; Peters, 2014), with higher scores indicating a stronger sense of social presence.

4.5.3 | Activity emotions

Activity emotions were measured by asking participants to evaluate the degree to which they experienced each specific emotion during the lesson using a visual analogue scale, ranging from 0 (not at all) to 10 (a lot). This study retrospectively assessed activity emotions (Pekrun, 2006) (enjoyment, relaxation, anger, frustration, boredom) and other ad-hoc emotions that are relevant in learning contexts (two positives: interest and awe; two negatives: shame and anxiety). The choice to include specific emotions such as interest, anxiety, awe and shame in the analysis of emotions during educational activities in VR is strategically significant. Interest and anxiety are typical emotions investigated in educational settings (Hidi & Renninger, 2006; Pekrun et al., 2002); interest enhances focused attention towards the object thus sustaining student engagement, while anxiety can negatively affect learning and the overall experience. The inclusion of awe and shame, on the other hand, reflects an innovative approach specific to the VR environment. VR offers immersive experiences that can elicit awe, a positive emotion, which stimulates curiosity and potentially enhances learning and engagement. Shame, on the other hand, may be more relevant in VR social platforms, where participants interact through their avatars. This virtual representation might impact the way individuals perceive and experience social interactions, including the feeling of shame, making this emotion a unique aspect worthy of exploration.

4.5.4 | Perceived ease of use

Perceived ease of use was measured using an Italian-adapted version of the items previously used by Lee and colleagues (Lee et al., 2010) to test the effectiveness of desktop VR for learning, consisting of four items ($\alpha = 0.82$, $\omega = 0.84$) (Peters, 2014); example item: 'Overall, I think this platform is easy to use.'. Items were measured on a 7-point Likert scale (1: strongly disagree; 7: strongly agree). The mean value of the items was used to calculate the scale's total score. Higher scores indicate stronger perception of easiness of use.

4.5.5 | Knowledge acquisition and retention

In this study, students' prior knowledge was initially assessed using 10 multiple-choice questions focused on the content of Module 1 and 10 multiple-choice questions related to Module 2. The questions presented four possible answer choices, and the sequence of questions was randomized. After completing each module, students' knowledge acquisition was measured using the same10 multiple-choice questions referring to the module. Furthermore, to understand delayed knowledge retention over time, an assessment was conducted one-week after using an identical set of 10 multiple-choice questions related to Module 1 and 10 multiple-choice questions concerning the contents of Module 2. The questions aimed to primarily assess factual knowledge (e.g., definitions, historical facts, key figures in the field) and conceptual understanding (e.g., principles and components). For analysis, answers were coded dichotomously: 1 for correct and 0 for incorrect and a sum score was calculated. Given the dichotomous nature of the responses internal consistency was calculated using the Kuder–Richardson Formula 20 (KR-20) for the pre-test (KR-20 = 0.78) and post-test (KR-20 = 0.82) separately, indicating acceptable reliability for our measures.

4.5.6 | In-depth interview

Upon the completion of the study and both lessons, participants were invited to take part in an in-depth interview aimed at delving into their experiences with the platforms. The interviewer initiated the conversation with a broad theme, such as, 'Can you describe your overall experience participating in the lectures on the two platforms?' Participants were then encouraged to freely elaborate on their experiences. While the interviewer aimed to keep the discussion focused on relevant topics, she avoided being overly restrictive. Audio were recorded and transcribed. Following previous approaches (e.g., Bressler & Bodzin, 2013; Stevanović et al., 2021; Yildiz Durak, 2018), students' responses during the interview, prompted by open questions, were analysed to gain insights into their experiences with the platforms. These insights have been expressed in the form of statements. Within these statements, specific themes related to students' perspectives on learning platforms emerged. These themes were further categorized using codes, and the frequency of each code was documented.

4.6 | Procedure

One week before the experimental phase, researchers sent participants a link to a survey, built on Qualtrics, aimed at gathering sociodemographic data (age and sex) and to evaluate their prior knowledge on the lesson topics. They then engaged in two online lecture modules: one via the VC platform, Microsoft Teams and the other through the VR social platform, Spatial, both accessed in desktop mode (see Figure 2a,b).

Participants were assigned to groups based on their availability for the dates offered, employing a convenience sampling method. To maintain manageable group sizes for effective tutoring and support, each group was capped at 10 participants with a minimum required group size of 5. A total of 5 groups were formed (group 1: 6 people; group 2: 7 people; group 3: 6 people; group 4: 10 people; group 5: 5 people). To ensure unbiased comparison a counterbalanced order was used that one group of participants started with the VC platform and then switched to the VR social platform for the second module. The other half followed the reverse order. As a result, groups 1, 3 and 5 (total participants: 17) completed module 1 on the VC platform and module 2 on the VR social platform, while groups 2 and 4 (total participants: 17) completed module 1 on the VR social platform and module 2 on the VC platforms. Within each group, modules were scheduled consecutively, at the same time on two successive days, ensuring consistency with the same lecturer and identical materials. For a detailed description of each module, such as content and timing, please see Section 4.4. 'Lecture and mEodules.'

Immediately after the completion of the module, researcher sent participants a link to a survey, built on Qualtrics, where they could

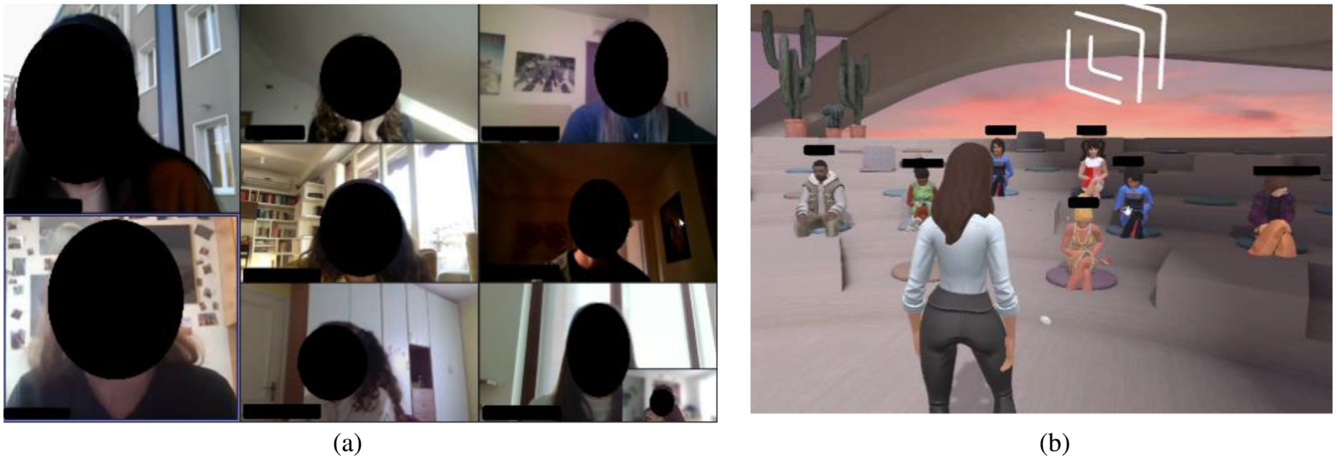

FIGURE 2 A screenshot from the Microsoft Teams setting (a) and from the Spatial VR setting (b).

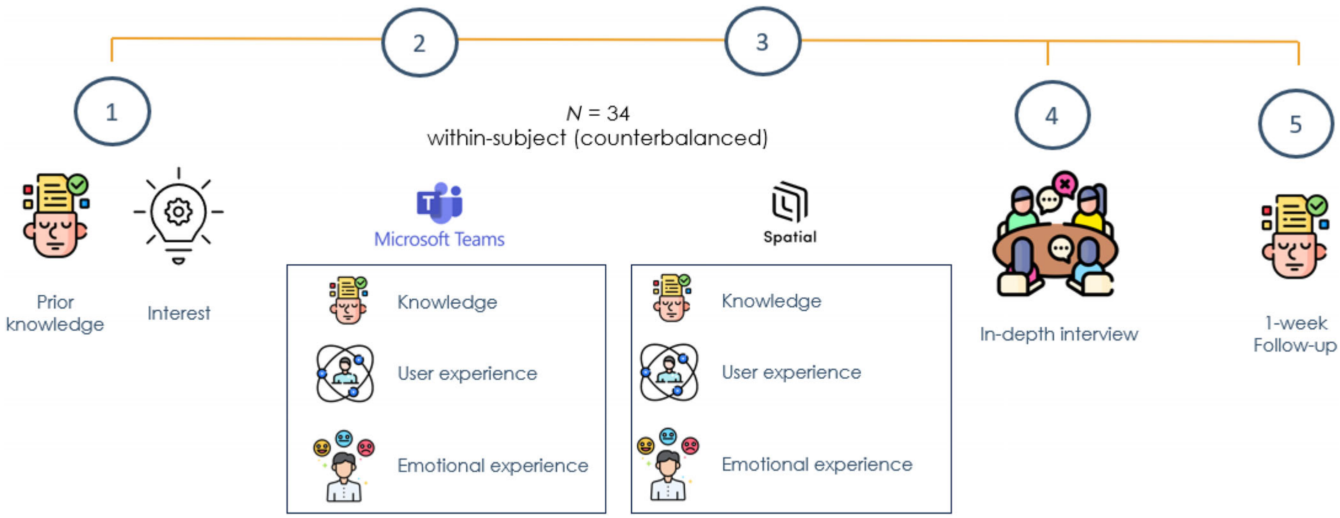

FIGURE 3 The procedure of the study.

(a) answer the 10 online multiple-choice questions to evaluate knowledge retention; (b) complete the post-experience online questionnaires assessing physical and social presence, emotional experience and platform ease of use. Once the questionnaire was completed participants could rejoin the online session, where an online in-depth interview was conducted, allowing participants to elaborate on their experiences with the two platforms.

After 1-week participants were sent a link to a survey, built on Qualtrics, where they could complete the 10 multiple-choice questions related to Module 1 and Module 2 again.

The procedure is shown in Figure 3.

4.7 | Statistical analysis

In our examination of knowledge acquisition and retention, we aimed to assess the impact of the platform, while further exploring its interaction with dispositional interest towards the learning topic. Therefore, considering the inclusion of multiple predictor variables (platform and interest), alongside accounting for individual variability, for this analysis we employed a linear mixed modelling approach, using the **lmer()** function in R. Knowledge acquisition and retention were quantified using raw gain scores, defined as the change in performance scores, or delta (Δ) scores (Westphale et al., 2022). This involved computing the difference between post-module test scores and the initial pre-module test scores, for knowledge acquisition and the difference between the follow-up test scores (administered 1 week later) and the post-module scores for knowledge retention. For instance, a shift from a score of 6 in the pre-test to 8 in the post-test yielded a raw gain of +2 in *knowledge acquisition*. Similarly, if a student's score on the follow-up test for Module 1 was 7, and their immediate post score was 6, then their Δ score for knowledge retention would be +1. This offers insight into how effectively students were able to retain the knowledge they acquired from the modules over an extended period.

We opted for raw gains because they provide a direct and unambiguous measure of the knowledge a student has acquired from a module. While other metrics, like normalized gains (Westphale et al., 2022), offer relative measures of improvement, raw gains present an absolute increase in scores, making them straightforward and easy to interpret. This absolute measure directly quantifies the actual number of new concepts or facts a student has grasped after exposure to the module, accurately capturing the extent of knowledge acquisition after exposure to the content regardless their starting point or their potential of learning. This score was then associated with the specific platform (VC or VR) on which they completed that module. So, if the student attended Module 1 using the VC platform and showed a delta score of +2 compared to prior knowledge at baseline, this change in knowledge acquisition would be attributed to the VC condition.

It is noteworthy that an independent t-test performed on the results of the initial assessment (T0) between Modules 1 and 2 did not exhibit significant differences ($t = 1.96$, $\text{df} = 32$, $p > 0.05$), leading us to treat them as equivalent in subsequent analyses.

In conclusion, to investigate the effect of the platform (VC vs. VR) and of participants' interest on Δ scores, we used the following formula:

$$\text{lmer}(\Delta - \text{platform}^{*}\text{interest} + (1/\text{ID})).$$

Participants were treated as a random effect to account for the individual variability in repeated measures. Unlike the analysis of student experience, where the emphasis was on capturing the breadth and depth of feelings and perceptions, the analysis of knowledge acquisition was centred on analysing exact learning outcomes. In this context, outliers could significantly skew results and misrepresent true learning trajectories. Thus, it was crucial to identify and exclude such outliers. Outliers were identified through a boxplot analysis. This graphical method provides a visual means to detect observations that lie significantly outside the typical range of data points, as delineated by the interquartile range. One participant was identified as an outlier and removed from the dataset. Consequently, the analyses concerning knowledge acquisition and retention were carried out with a revised cohort of 33 participants.

Student's experience was analysed in terms of social presence, emotional experience (i.e., activity emotions experienced during the lesson) and platform's ease of use. In this case we only had one predictor (platform: VR vs. VC) and therefore opted for a simpler model. For normally distributed data, we conducted Student's paired t-tests using the **t.test()** function in R to assess the differences. In cases where the data did not follow a normal distribution, we employed the Wilcoxon rank-sum test using the **wilcox. test()** function in R. When dealing with tied observations or instances where differences equated zero, we applied the Wilcoxon rank-sum test with continuity correction (Lehmann, 1975), which is a normal approximation applied when exact probability cannot be computed because of ties in the absolute values of the differences. Furthermore, to account for multiple comparisons, as we conducted a total of 11 tests (including social presence, 9 emotions and ease of use), we applied the Bonferroni correction to adjust the p-values accordingly.

5 | RESULTS

5.1 | Knowledge acquisition

Investigating the impact of condition on knowledge acquisition scores, we employed a linear mixed-effects model with 'online platform' and individual interest' as fixed effects and participants as a random effect. The model examined the interaction between online platform (VR vs. VC) and students' interest in the topic. The analysis revealed a significant main effect of platform used on knowledge acquisition scores ($\beta = 7.22$, $\text{SE} = 2.23$, $\text{df} = 31$, $\text{t} = 3.237$, $p < 0.01$) with the VR platform leading to higher scores compared to VC platform ($M_{vr} = 4.27$, $SD_{vr} = 2.05$; $M_{vc} = 4.18$, $SD_{vc} = 2.20$). Moreover, interest was found to significantly predict knowledge acquisition scores ($\beta = 0.89$, $\text{SE} = 0.39$, $\text{df} = 54.6774$, $t = 2.28$, $p < 0.05$). Importantly, there was a significant interaction between the platform condition and interest ($\beta = -1.43$, $\text{SE} = 0.4420$, $\text{df} = 31$, $t = -3.24$, $p < 0.01$). Given that we were interested in understanding how the relationship between the platform and knowledge acquisition could differ depending on students' interest, we probed the interaction by exploring how the knowledge acquisition differs between conditions at varying values of students' interest. To do that we conducted Bonferroni-corrected pairwise comparisons for each level of individual interest in the topic. At lower levels of individual interest in the topic (interest levels 1 to 4), participants exhibited significantly lower knowledge acquisition scores in the VC condition compared to the VR condition ($p < 0.05$). However, as dispositional interest increased, this trend reversed. At interest level 5, there was no significant difference between the two conditions ($p = 0.91$), indicating comparable outcomes. Notably, at higher levels of dispositional interest (interest levels 6 and 7), participants in the VC condition demonstrated significantly higher knowledge acquisition scores than those in the VR condition ($p < 0.05$). This shift from a negative to a positive contrast with increasing dispositional interest underscores the complex interplay between individual interest levels and platform conditions in shaping learning outcomes (see Figure 4).

5.2 | Knowledge retention

To investigate the influence of the online platform (VC vs. VR) on students' knowledge retention, as indicated by the change in scores (Δ) during the retention phase, we conducted a linear mixed-effects analysis. The model accounted for participants' interest in the topic and treated participants as a random effect. The analysis revealed no significant main effect of the learning platform on the change in retention scores (condition: VR, $t = 0.178$, $p > 0.05$) and no significant interaction between the platform and participants' mean interest in the topic (condition: VR × mean interest, $t = -0.272$, $p > 0.05$).

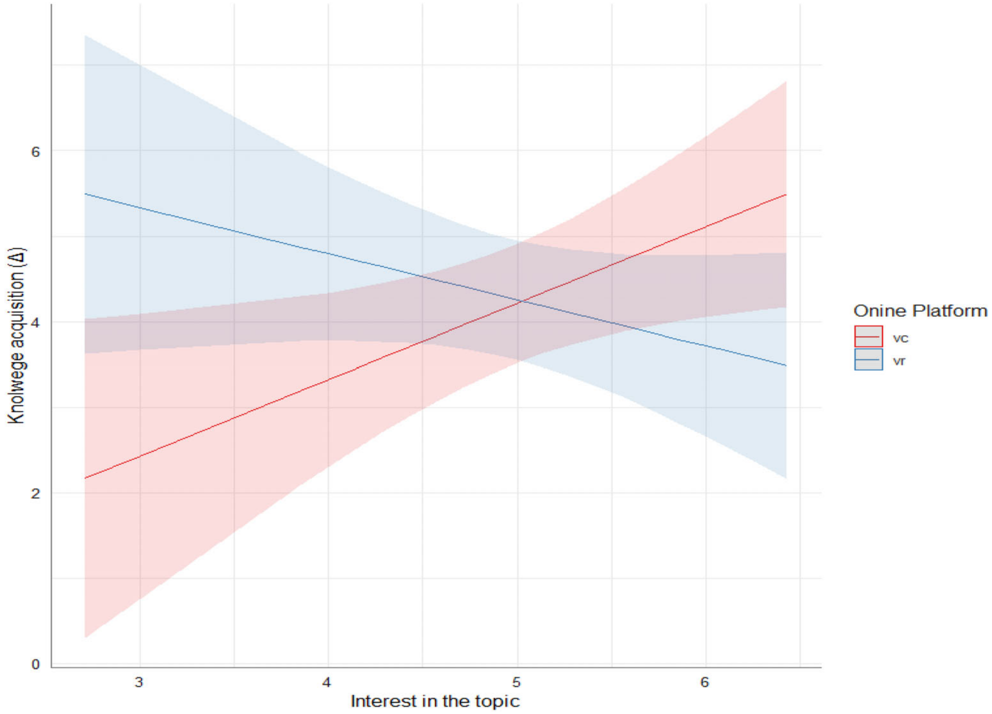

FIGURE 4 Interaction plot.

TABLE 2 Comparison of students' experience on the two platforms.

Normally distributed variables (paired Students' *t*-test, *t*)				
		VC	VR	
		M (SD)	*M* (SD)	*t* (33)
Social presence		4.66 (1.03)	4.48 (1.40)	0.61
Emotions	Fun	3.94 (2.40)	7.06 (2.23)	−6.14**
	Relax	5.76 (2.50)	6.00 (2.61)	−0.46
	Awe	1.76 (2.57)	5.88 (3.25)	−5.86**
	Interest	6.18 (2.41)	7.94 (1.72)	−3.44*
Non-normally distributed variables (Wilcoxon test, *w*)				
		VC	VR	
		M (SD)	*M* (SD)	w
Emotions	Anger	0.56 (1.76)	0.24 (0.55)	20
	Frustration	0.65 (1.87)	0.97 (1.55)	31.5
	Boredom	1.76 (1.79)	0.91 (1.42)	198.5**
	Anxiety	1.06 (2.28)	0.76 (1.39)	55
	Shame	1.41 (2.19)	0.76 (1.35)	88.5
Ease of use		6.07 (0.63)	5.01 (1.09)	455**

$^*p < 0.05$; $^{**}p < 0.001$.

5.3 | Students' experience

Students' experience was evaluated in terms of social presence, easiness of use and perceived emotions. Table 2 presents a summary of the key findings from comparing the VR social platform and the VC platform.

5.3.1 | Social presence

A paired-samples *t*-test was conducted to detect potential differences on students perceived social presence while attending a lecture on a VC platform or on a VR social platform. The analysis revealed no significant difference on students' perceived social presence between the platforms, t (33) = 0.61, $p > 0.05$, with students reporting only slightly higher feelings of social presence in the VC platform ($M = 4.66$, SD = 1.03) than in the VR platform ($M = 4.48$, SD = 1.40).

5.3.2 | Perceived ease of use

Regarding perceived ease of use, the VC platform surpassed VR with a mean score of $M = 6.07$, SD = 0.63. Conversely, the VR platform scored notably lower with $M = 5.01$, SD = 1.09. This divergence was statistically significant, $W = 455$, $p < 0.001$, suggesting students found the VC platform more intuitive and user-friendly than its VR counterpart.

5.3.3 | Emotional experience

When diving into the emotional experiences of students on both platforms, distinct patterns emerged.

For normally distribute emotions (fun, relaxation, awe and interest) a paired-sample *t*-test was performed. Results revealed that students reported significantly more fun in the VR platform ($M = 7.06$, SD = 2.23), than in the VC platform ($M = 3.94$, SD = 2.40), t (33) = −6.14, $p < 0.001$. Similarly, feelings of awe were markedly heightened in the VR environment ($M = 5.88$, SD $= 3.25$) compared to the VC platform ($M = 1.76$, SD $= 2.57$), t (33) $= -5.86$, $p < 0.001$. The VR platform also saw greater levels of interest ($M = 7.94$, SD $= 1.72$), than the VC platform ($M = 6.18$, SD $= 2.41$), $t(33) = -3.44$, $p < 0.05$. The emotion of relaxation did now show any significant difference between the two platforms.

For non-normally distributed emotions (anger, frustration, boredom, anxiety and shame), a Wilcoxon rank-sum test with continuity correction was performed. The data revealed that the VC platform significantly elicited higher feelings of boredom ($M = 1.76$, SD $= 1.79$) compared to the VR platform ($M = 0.91$, SD $= 1.42$), $W = 198.5$, $p < 0.001$. Anger, frustration, anxiety and shame were not significantly different between the two platforms.

5.3.4 | Learners' insights and experiences of the platforms

A total of 33 people participated in the in-depth interview. The audio recordings of the interview were transcribed and translated in English (see Appendix A). The interviews were used to enrich the understanding of the data and provide a more qualitative explanation of participants' experiences with the two different platforms. Participants statement mainly referred to four main themes.

The first theme was related to the 'familiarity and ease of use' of the platforms. This captures the importance of how intuitive and user-friendly a platform is perceived to be. It reflects participants' preferences for interfaces that are easy to navigate and require minimal learning to use effectively. As regard this theme, some people ($n = 18$) reported their preference for Teams because of familiarity and ease of use compared to Spatial (e.g., Group3, Participant 2: '[…] it took me a while to figure out how it worked'). Nevertheless, some participants reported ($n = 7$) their interest in the novelty of Spatial, however recognizing the need for training and repeated exposure to overcome initial challenges and get used to it (e.g., Group 1, Participant 2: '[…] However maybe I think by using this one [Spatial] more sooner or later you learn and then it becomes more interesting to learn in this way').

The second theme that emerged was related to the 'immersion, engagement and interactivity' of the platforms. This focuses on the degree to which a platform can create a sense of presence and highlights the platforms' capabilities to facilitate an immersive experience that captures users' attention and encourages active participation. In this respect, some people ($n = 16$) reported greater involvement in Spatial due to interactivity (e.g., Group 1, Participant3: 'This platform [Spatial] is very interesting, because it is interactive and makes you feel more participatory, more in a group') and immersive experience (e.g., Group 5, Participant 3: '[…] the advantage of Spatial is that it is much more immersive'), also reporting more positive emotions, such as fun (e.g., Group 2, Participant 1, 'I found it fun [Spatial]'), awe (Group 4, Participant 5: '[…] it amazed me') and interest (e.g., Group 2, Participant 6: 'I would also propose activities with avatars, that was very interesting'). However, some ($n = 5$) also reported higher feeling of involvement and interaction in Teams thanks to the possibility of seeing other people (e.g., Group 2, Participant 3: '[…] I did not feel this great interaction either with the professor or the other classmates. […] [Teams], on the other hand, because of the camera, […] can promote more interaction between classmates, because you see each other and you are more present').

In this respect, another theme raised was related to the use of 'avatars versus real appearances'. This explores users' preferences regarding the visual representation of participants within the platform, whether through avatars or real-life appearances. It explores how these representations can influence feelings of comfort, distraction and the overall sense of connection among participants. About this issue, people ($n = 14$) reported their preference for seeing the real appearance of people for a feeling of closeness in Teams (e.g., Group 2 Participant 6: '[…] it is still nice to have the avatar, but it is still better to see them, I mean, I find closer, to feel people closer if I actually see them as they are.'). However, some ($n = 6$). reported their preference for the use of avatars in Spatial to feel more comfortable and reduce distractions, deriving from wondering how you look like and by looking at other cameras (e.g., Group 2, Participant 2: 'I followed […] more easily [in Spatial] than in Microsoft [Teams] like today. Because then I'm someone who maybe even looks at other people's cameras, I get distracted).

Finally, one considered theme was related to the 'technical issues'. This addresses the stability and reliability of platforms. This theme outlines the challenges users might face while navigating the technology. It encompasses the frequency and nature of technical problems encountered and their impact on the user experience. Technical issues were reported more frequently ($n = 5$) in Spatial (e.g., Group 2, Participant 4: '[…] [In Spatial] also the technical problems were many'), despite some occasional issues were reported also for Teams ($n = 2$).

Overall, the statements show that, while Teams is generally preferred for its familiarity and ease of use, as well as the ability to see what people actually look like, Spatial is valued for its interactivity and the immersive experience it provides. However, Spatial also presents greater technical challenges than Teams.

6 | DISCUSSION

The aim of this research was to compare a traditional VC platform (Microsoft Teams) and a VR social platform (Spatial) as possible online learning solutions, focusing on students' learning experience and knowledge gain and retention. For this purpose, we invited students to attend two lectures, each delivered on either one of the two platforms, and we quantitatively evaluated their experiences in terms of social presence, activity emotions, perceived ease of use using self-reported questionnaires and we further assessed their immediate and delayed learning gains using multiple-choice tests delivered immediately after and one-week after the lectures. An in-depth interview was also conducted to qualitatively understand students' perceptions on their learning experience with the two platforms. Results provide interesting insights into the interplay of several factors in the success of online learning.

Our primary research question (RQ1) regarded the evaluation of the effectiveness of VR social platforms in enhancing learning outcomes within online educational contexts.

As concern students' learning gains, the study confirmed our hypothesis (H1a) showing a significant effect of the platform used (VC vs. VR) on immediate knowledge acquisition and a significant interaction with students' interest in the topic, suggesting that students' prior interest could modulate the effectiveness of the platform used. The significant main effect of platform use on knowledge acquisition scores, with VR outperforming VC overall, aligns with the hypothesis that even desktop-VR environments can enhance learning through their engaging and interactive features (Makransky & Petersen, 2019; Merchant et al., 2014). However, the interaction between platform condition and student interest presents a trend indicating an inverted relationship as dispositional interest increases. Initially, for students with lower levels of interest (levels 1 to 4), VR significantly enhances knowledge acquisition compared to VC. This effect can be attributed to VR's ability to captivate attention and provide a novel learning experience, which is particularly beneficial for learners who might not be inherently motivated by the subject matter. As dispositional interest increases, however, this advantage diminishes, and at the highest interest levels (6 and 7), VC becomes more effective for knowledge acquisition than VR. This shift suggests that for students already highly interested in the topic, the immersive features of VR might act more as distractions than aids, possibly because these students do not require additional sensory engagement to focus on the content. This trend underscores the complex interplay between technology, individual differences in interest and learning outcomes. It suggests that while VR has the potential to significantly enhance learning for those less engaged with the content, its benefits are not uniform across all learners. For those with high dispositional interest, simpler VC platforms may be more effective, possibly due to fewer distractions and a focus on content delivery.

Despite the immersive and engaging nature of VR, and its potential benefits for immediate knowledge acquisition as seen in earlier sections, its influence on long-term knowledge retention does not significantly differ from that of VC platforms, therefore rejecting our initial hypothesis (H1b). This outcome indicates that the type of platform used—whether immersive VR or traditional VC—does not have a discernible impact on students' ability to retain information over time. This suggests that the engaging features of VR, which are effective in capturing attention and enhancing immediate learning outcomes, may not translate into long-term retention advantages. This could be due to the nature of memory consolidation processes, which are influenced by factors beyond initial engagement, such as the depth of processing, rehearsal and the application of generative learning strategies (Klingenberg et al., 2020; Makransky et al., 2021). The VR experience might facilitate a deeper initial engagement with the material, but this does not inherently guarantee improved retention without the integration of strategies that promote durable learning.

Beyond learning gains, our second research question (RQ2) concerned students' learning experiences with the two proposed platforms (VC and VR).

Regarding students' feelings of social presence, we did not find a significant difference between the VC and VR platforms. This finding does not support our hypothesis (H2a) that VR social platforms might offer a more interactive environment, fostering a greater sense of intimacy and immediacy. Feedback from the in-depth interview suggest that this result might possibly be due to the fact that although the VR platform was perceived as more interactive and immersive than the VC platform, the representation of users through avatars, as opposed to their real appearances, might have diminished the perception of intimacy and closeness.

This preference is deeply rooted in the social presence theory (Short et al., 1976) and the media richness theory (Daft & Lengel, 1986). The social presence theory, for instance, posits that the sense of 'being there' with others is heightened when the medium allows for a full spectrum of nonverbal cues, such as facial expressions and gestures. This is where VC gains an edge, offering a 'richer' medium (Daft & Lengel, 1986) than desktop-based VR social platforms that often lack the depth of human expressions (e.g. face movements, natural gesture, posture, etc.), leading to a potential reduction in empathetic connections. Seeing real faces, facial expressions and emotional cues promotes social bonding, which can lead to better collaboration and knowledge sharing (Ayache et al., 2021; Bailenson et al., 2006). Furthermore, visibility of participants' real faces makes them more likely to stay attentive, participate actively and adhere to social norms, as they are aware of being observed by others (Daly-Jones et al., 1998; Sederevičiūtė-Pačiauskienė et al., 2022). However, students are often reluctant to activate their camera with concerns about personal appearance are the main reasons students turn off their video cameras (Castelli & Sarvary, 2021; Petchamé et al., 2022). In contrast, Spatial uses full-body 3D avatars to represent participants, which brings different dynamics to the interaction. While the inability to visualize others may diminish the sense of being together, using avatars can significantly reduce self-consciousness among participants, as those who might feel shy or anxious about being on camera may find it easier to engage when their real faces are not visible. It has been recently demonstrated that avatars have the potential bridge the gap between audio-only and video representations (Higgins et al., 2021; Panda et al., 2022). In such contexts, social presence could be promoted through preliminary meetings, where participants have the occasion to see each other's real appearances. Sutcliffe and Alrayes (2012) observed in their study that many participating groups emphasized the importance of having initial interactions offline before engaging in online collaboration. These preliminary encounters could be facilitated through online platforms (such as Teams) or in a traditional face-to-face setting. Future research should explore the long-term effects of these preliminary interactions on the effectiveness of VR and VC platforms in fostering social presence and collaborative learning.

Furthermore, Nowak and Biocca et al.'s (2003) research highlighted the significance of visual fidelity in avatars for enhancing social presence in virtual environments. They argued that high-fidelity avatars, which closely resemble their users, can facilitate a stronger sense of social presence and intimacy. This is consistent with the idea that more realistic representations can increase familiarity (Di Natale et al., 2023) and bridge the gap between virtual and face-to-face interactions. In this study, students could only choose among pre-selected avatars, with no possibility to customize them, a feature that has been recently indicated as essential in promoting stronger sense of social presence in online communication (Higgins et al., 2021). Furthermore, Spatial offers more cartoon-like avatars (see Figure 1b), suggesting that these low realistic representations may be a barrier to achieving the same level of social presence and intimacy as platforms that use real appearances or eventually more realistic avatars, like Engage VR (https://engagevr.io/).

Therefore, while VR social platforms' immersive qualities provided a novel and engaging experience, the lack of real appearances in Spatial appeared to counteract these benefits in terms of fostering social connectivity, diminishing the perception of intimacy and closeness in VR. This finding suggests a complex interplay where the immersive and interactive benefits of VR are to some extent neutralized by the lack of visual human connection, bringing VR platforms comparably effective as traditional VC tools in fostering social presence.

In terms of ease of use, self-reported quantitative data indicated that students found the VC platform more intuitive and user-friendly compared to the VR social platform. The substantial difference in perceived ease of use confirms hour hypothesis (H2b) that while VR social platforms may offer a rich environment, their interface or controls might pose challenges for some students. Several participants experienced different kinds of technical issues and found it difficult to understand how the platform worked, how to control the avatar and navigate the environment. In this regard, however, some participants suggested that with more experience and training, the use of VR could become more intuitive and engaging. This feedback indicates that while initial adoption of VR platforms may be challenging, their rich, interactive environment has the potential to become a valuable tool in learning with increased familiarity. Research in the field of educational technology adoption supports this idea (Granić, 2023). Over time, as users become more familiar with a technology, their comfort level and post-adoption self-efficacy increase and they tend to find it easier to use (Di Natale, Bartolotta, et al., 2024; Li et al., 2023; Stoel & Hye Lee, 2003).

Concerning students' emotions experienced during the lectures, the results showed a significant difference in positive activity emotions such as fun, awe and interest, with the VR platform outperforming the VC platform. Conversely, and in line with these findings, the VC platform elicited more boredom. These results were reflected in student's reports in the in-depth interview. Students indeed reported greater fun, awe and interest in the VR environment. These reflections underscore that even in its desktop mode, the VR platform offers an engaging and awe-inspiring experience. This aspect of VR technology is particularly beneficial in educational contexts, where fostering positive emotion and interest is crucial. Such enhanced emotional engagement in the VR setting has the potential to positively impact learning outcomes, especially in online learning scenarios where maintaining student engagement and interest is often challenging (Aini et al., 2020). This finding highlights the unique value of VR platforms in enriching the emotional and experiential aspects of online education.

One possible explanation for this phenomenon relates to the gaming-like aspects of the VR environment. The immersive and interactive nature of VR technology closely resembles the engaging features of video games, which might contribute to the higher levels of fun, interest and awe reported by students when using the VR platform for learning. The game-like environment provided by VR can make learning experiences more dynamic and captivating. In video games, the feeling of being part of a virtual world contribute to a compelling experience. These aspects, when integrated into VR-based educational platforms, can transform traditional learning activities into more interactive and enjoyable experiences. During the in-depth interview, this aspect was underlined (e.g., Group 4, Participant 8: '*The video game format is quite engaging*'). This is in line with previous literature on Massive Multiplayer Online Role-Play Games, which have shown be effective tools for learning, particularly in promoting collaborative learning and engagement (De Freitas, 2006; de Freitas & Griffiths, 2007, 2009; de-Marcos et al., 2016; Yue & Tze, 2015). These tools have been found to enhance student interaction, improve content instruction and create a more dynamic learning environment (Yue & Tze, 2015).

6.1 | Implications

This study contributes to the field by highlighting the impacts of VR and VC platforms on online learning. It underscores the importance of considering the psychological aspects of learning in desktop-based VR environments, particularly how different technologies affect social presence, emotional engagement and learning effectiveness.

For practitioners, this research offers guidance in developing effective online learning experiences by selecting appropriate learning platforms. VR's ability to stimulate interest and overall emotional engagement makes it a powerful tool for subjects that might otherwise be unengaging. However, its complexities necessitate careful consideration and training of both students and teachers in order to familiarize with this tool. These insights can guide educators in optimizing online learning experiences using these technologies.

6.2 | Limitations and future directions

While our study offers essential insights, it is crucial to interpret findings with certain limitations in mind.

First, we implemented a traditional lecture-style approach, with a teacher talking with the support of slides or other materials. While being the most diffused online form of learning, this modality might not fully leverage the capabilities of VR social platforms. These platforms, with their immersive and interactive nature, could potentially be more effective in group work settings, where collaboration is key. Exploring different instructional strategies in VR, such as collaborative projects or interactive discussions, might better reveal the strengths of these innovative platforms in enhancing the online learning experience.

Second, our participants were mainly new users of VR social platforms. This novelty can foster enjoyment, curiosity and interest, contributing to the positive emotional experiences reported by students. However, the novelty of the VR experience might diminish over time (Boot et al., 2008; Hanus & Fox, 2015; Luse et al., 2013; Tsay et al., 2018). Initially, students might be highly engaged due to the newness of the experience, but as the novelty fades, the engagement levels might drop. Furthermore, the novelty effect can also present challenges, especially for those approaching VR for the first time. Difficulty in using this technology, such as navigating a virtual environment or interacting with virtual objects, can cause frustration or confusion in users. These obstacles can result in increased cognitive load and a less positive learning experience. Future research should take into account how the learning experience in VR may vary based on students' familiarity with the technology. An early learning curve can influence both the experience and the outcomes of using VR in educational settings. The implementation of longitudinal studies to observe how users adapt to and engage with VR social platforms over time, could help identify long-term benefits and challenges. Recognizing and adjusting learning activities to account for these factors can help maximize the benefits of VR while reducing potential difficulties encountered by new users.

Third, in the present study we used desktop-based access to the VR social platform. However, accessing the VR social platform via a desktop may not provide an immersive enough experience to significantly enhance the sense of social presence. The immersive mode, indeed, facilitates natural interactions through head movements and hand controllers. Therefore, future studies should explore how the learning through VR social platforms can benefit from immersive features in VR (Al-Ansi et al., 2023), with a particular focus on how more intuitive and natural VR interactions might favour students' online learning experience.

Furthermore, the fundamental differences between Microsoft Teams and Spatial in terms of platforms' characteristics offered, raise important considerations for internal validity. The distinct features of each platform may independently influence the learning experience and outcomes, making it challenging to isolate the effects of VR versus VC as broad categories. For instance, the immersive shared environment in Spatial might enhance engagement, but this effect could be attributed to the novelty of the virtual space rather than VR technology itself. Similarly, the familiar interface of Teams might facilitate ease of use, potentially confounding measures of learning efficiency. While comparing Microsoft Teams and Spatial provides valuable insights into VC versus VR learning experiences, it is important to acknowledge the limitations of this comparison. These platforms were designed for different purposes—Teams for professional collaboration and Spatial for immersive social interaction. This fundamental difference in design philosophy may influence user experience and learning outcomes in ways that are not solely attributable to the VC/VR dichotomy. Future studies could benefit from comparing platforms with more closely aligned design goals or by customizing existing platforms to create more equivalent learning environments. To better account for platform-specific variables in future studies, researchers could, for example, implement a multi-platform approach, comparing several VC and VR platforms to identify consistent trends across technologies, as well as conduct longitudinal studies to assess how familiarity with each platform over time might influence learning outcomes, controlling for the novelty effect of VR.

7 | CONCLUSION

In the rapidly evolving landscape of online education, our findings highlight the potential of VR social platforms for online learning. While VC platforms like Microsoft Teams provide a more intuitive experience, VR platforms, even in desktop mode, potentially offer a more engaging and emotionally rich environment. As educators continue to adapt and innovate, the informed integration of these platforms, leveraging their unique strengths, can enhance the quality of online education.

AUTHOR CONTRIBUTIONS

Anna Flavia Di Natale: Conceptualization; investigation; methodology; visualization; software; formal analysis; project administration; data curation; resources; writing – original draft. **Claudia Repetto:** Formal analysis; supervision; methodology; writing – original draft. **Daniela Villani:** Conceptualization; formal analysis; supervision; methodology; writing – original draft.

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The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

All the studies presented in the paper have been approved by the Local Ethical Committee of the Department of Psychology, Università Cattolica del Sacro Cuore, Milano. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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