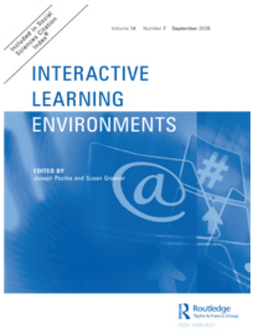

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Students' social, cognitive, and affective experiences in immersive learning modules (MetaLabs): two descriptive cases in higher education

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ABSTRACT

Extended Reality (XR) technologies offer innovative learning experiences, yet their curricular integration remains challenging due to limited structured frameworks. The MetaLab framework addresses this gap, offering a psycho-pedagogical approach for designing XR-based learning modules (MetaLabs). This study presents the first application of this framework, adopting an exploratory case study design to describe students' experiences across two MetaLabs conducted within an authentic university course on "Virtual Reality Techniques and Metaverse for Well-Being". Twenty-seven students enrolled in the course participated and completed post-experience self-report questionnaires assessing social presence, extraneous cognitive load, concentration, and epistemic emotions. Data were analysed using descriptive statistics, overlap indices, and individual trend visualizations to capture both group-level patterns and individual variability. Results showed moderate-to-high social presence, low extraneous cognitive load, and strong concentration across both MetaLabs, as well as a predominance of positive emotions like curiosity and enjoyment over negative emotions such as frustration and confusion. These findings suggest that MetaLabs can support socially engaging, cognitively manageable, and emotionally positive XR learning experiences. However, individual variability underscores the need for adaptable XR designs to address diverse learner needs. Future research should explore the long-term impact of MetaLabs and their scalability across educational contexts.

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extended reality; virtual reality; social presence; cognitive load; epistemic emotions; higher education

1. Introduction

1.1. Social, cognitive and affective dimensions of learning with VR social platforms

In recent years, the rapid emergence of Extended Reality (XR) technologies, which encompass virtual reality, augmented reality, and mixed reality, has generated significant interest in their potential applications within education (Alnagrat et al., 2022). These technologies promise to revolutionize teaching and learning by enhancing engagement, providing hands-on virtual experiences, and enabling access to content that is otherwise difficult to replicate in traditional classrooms. This aligns with the principles of Education 4.0, which emphasizes personalized, experience-based learning approaches, marking a shift from memorization methods to more interactive, skill-oriented approaches (Mukul & Büyüközkan, 2023).

Among XR technologies, immersive virtual reality (VR) has emerged as a powerful tool for education (Di Natale et al., 2020; Jensen & Konradsen, 2018; Marougkas et al., 2023; Pellas et al., 2021; Poupard et al., 2025; Radianti et al., 2020). Most research and educational applications of immersive VR technologies focus on individual learning experiences, where students interact with virtual environments either through non-immersive (desktop or mobile-based) or immersive (head-mounted displays) systems. These applications are widely used in science, medicine, engineering, and skill-based training, enabling hands-on learning in simulated settings.

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Beyond individual learning, immersive VR has evolved into social and collaborative learning spaces (van der Meer et al., 2023). In this context, VR social platforms garnered particular attention due to their capacity to merge immersive environments with interactive and collaborative learning (Chessa & Solari, 2021; Mystakidis et al., 2021). These platforms create shared virtual spaces where users interact through avatars facilitating real-time communication and collaboration and allowing students to engage in role-playing, simulations, or group problem-solving tasks. This expands the traditional boundaries of learning by enabling new ways of knowledge construction that leverage both social and experiential dimensions. To fully understand the potential of virtual social platforms in educational contexts, it is crucial to consider how these technologies impact key psychological dimensions that shape the learning process: social, affective, and cognitive.

The social dimension refers to the extent to which learners feel connected to others within an educational environment. A key aspect of this dimension is *social presence*, which encompasses both the perception of co-presence, that is being in the same space with others, and the deeper sense of personal connection and psychological proximity, often described in terms of intimacy and immediacy (Kreijns et al., 2022; Short et al., 1976). Social presence is a central aspect to consider when learning takes place in VR social platforms. In these platforms, whether students are remote or co-located, their interactions occur in an online environment, which is fundamentally different from traditional face-to-face setting. Research on online learning has highlighted challenges in maintaining social presence, particularly due to the absence of physical cues and the lack of a shared physical space. However, much of this research has primarily focused on conventional platforms, such as videoconferencing, which may limit the depth and quality of social interaction due to reduced nonverbal communication, spatial awareness, and embodied engagement (Di Natale, Repetto et al., 2024). In contrast, immersive VR environments have the unique potential to overcome these limitations and foster higher levels of social presence. Even though participants engage online, VR social platforms enable interactions within a shared virtual space, where communication occurs through embodied avatars which can replicate nonverbal cues, gestures and spatial dynamics. This allows participants to experience a heightened sense of co-location and makes interactions feel more natural and intuitive, akin to being in the same physical room. Studies have shown that participants in immersive VR environments experience a heightened sense of being "together" with others compared to traditional online settings (Barreda-Ángeles et al., 2023; Ozonur et al., 2018; Steinicke et al., 2020; Yilmaz et al., 2016) and more comparable to traditional face-to-face settings (Smith & Neff, 2018; Uhl et al., 2023). This heightened sense of co-presence in immersive VR creates an ideal setting for promoting collaboration, which in turn reinforces social presence in a reciprocal relationship (Johnson & Johnson, 2009).

The cognitive dimension focuses on how learners engage with educational content and process information. Cognitive load, in particular, refers to the mental effort required to process information and must be carefully managed to avoid overwhelming learners (Paas & Sweller, 2014). It comprises three components: intrinsic load (the effort directly related to the complexity of the learning task), extraneous cognitive load (effort imposed by how the information is presented), and germane cognitive load (effort related to integrating new information with existing knowledge or developing strategies for problem-solving). According to the Multimedia Learning Theory, students' cognitive load is deeply influenced by the way information is presented (Mayer & Moreno, 2003). In this context immersive VR present challenges in properly managing cognitive load, especially *extraneous cognitive load* (Meccawy, 2022; Poupard et al., 2025). Poorly designed immersive VR environments can inadvertently introduce unnecessary distractions, such as overly complex interfaces, irrelevant visual or auditory stimuli, or an overwhelming number of interactive elements (Skulmowski & Xu, 2022) that can overwhelm learners, especially novices, leading to cognitive overload (Frederiksen et al., 2020; Frithioff et al., 2020; Makransky et al., 2019; Parong & Mayer, 2021a; Parong & Mayer, 2021b). These distractions can impair learning outcomes and disrupt learners' *concentration,* diverting their focus of attention away from the primary learning task, negatively impacting their ability to learn effectively (Skulmowski & Xu, 2022). To mitigate these issues, strategies such as minimizing visual complexity (Rettinger et al., 2024) and employing the segmentation principle (Klingenberg et al., 2023; Parong & Mayer, 2018), breaking content into manageable, smaller sections, are essential to prevent learners from becoming overwhelmed and to optimize cognitive resources.

The affective dimension involves the emotional experiences that learners go through during the learning process (Pekrun, 2006). *Epistemic emotions*, such as curiosity, surprise, confusion, and frustration, can significantly impact learning processes and outcomes (Arguel et al., 2018; Muis et al., 2018). VR social platforms offer promising opportunities for experience-based *active learning* and the cultivation of positive epistemic emotions, such as curiosity as they offer interactive environments and inquiry-based hands-on activities that encourage active *exploration*, experimentation, and discovery (Alnagrat et al., 2022; Taheri & Aguayo, 2022). Unlike traditional videoconferencing platforms, which may limit emotional engagement due to passive content delivery and reduced interactivity, immersive VR enables learners to immerse themselves in dynamic, participatory learning experiences, enhancing emotional involvement in the educational process. Although research on the emotional impact of VR social platforms is still emerging, recent studies comparing them to traditional videoconferencing platforms suggest that virtual environments elicit higher levels of positive affect (Lønne et al., 2023; Olmos-Raya et al., 2018) even when accessed through non-immersive desktop setups (Di Natale, Repetto et al., 2024). However, it is equally important to recognize that these technologies can also provoke negative emotions, such as frustration, particularly if the activities are overly complex or not sufficiently intuitive. Managing this emotional balance is critical to optimizing VR learning environments and ensuring that they support, rather than hinder, the learning process.

It is clear that to truly understand immersive VR technologies and VR social platforms learning potential, educators must consider a structured framework to identify the key points and priorities of the educational experience that align with the social, cognitive, and emotional dimensions of the learning experience. Studies have shown that well-designed immersive VR pedagogical experiences can balance immersion, cognitive engagement, and structured pedagogy, ensuring that learners not only feel present in the environment but also develop meaningful skills and knowledge (Keskitalo & Saukkoriipi, 2025; Paulsen et al., 2024). This reinforces the idea that immersive VR learning should not rely solely on the novelty of the technology but should be embedded in a structured pedagogical framework that prioritizes learning outcomes over technological fascination.

1.2. The metalab framework

Given the growing recognition of how social, cognitive, and affective factors shape the learning experience in VR social platforms, it is essential to develop structured instructional design frameworks that guide the effective integration of immersive technologies into educational settings. While immersive VR environments offer unique affordances for interaction and engagement, their implementation must be guided by pedagogical principles that prioritize learning objectives over technological novelty. Without a structured approach, VR-based learning risks becoming a passive or overwhelming experience rather than an opportunity for deep and meaningful engagement.

To address these challenges, Gaggioli and colleagues (Gaggioli et al., 2024) developed the “MetaLab” framework, a learner-centered model for designing XR-based educational experiences. The framework emerged from interdisciplinary research at the Università Cattolica del Sacro Cuore by a team of psychologists, instructional designers, and XR specialists. While several instructional design frameworks have been proposed for XR-based learning in higher education, the MetaLab farmwork offers a distinctive contribution that sets them apart from existing models. Radianti and colleagues (2020), in their systematic review of immersive VR in higher education, identified a set of common design principles, including presence, interactivity, and learner control, but noted that most implementations remain technology-driven and lack explicit pedagogical scaffolding grounded in learning theory. Similarly, social VR education models, such as those explored by Mystakidis and colleagues (2021) and van der Meer and colleagues (2023), demonstrate the collaborative potential of shared virtual spaces but typically focus on platform affordances rather than offering a structured, replicable instructional design process. Bower and colleagues’ (2017) immersive learning design framework emphasizes the alignment between activity, technology, and environment, yet does not systematically address the affective and epistemic dimensions of the learning experience. Unlike these existing tech-driven models that focus primarily on the affordances of virtual and augmented reality, the MetaLab framework adopts a learner-centered approach, to emphasize pedagogical outcomes, ensuring that technology serves as a means to enhance learning rather than dictate its structure. In particular, MetaLabs integrate social, cognitive, and affective dimensions within a coherent co-design process distinguishing them from frameworks that either prioritize technological affordances over pedagogical outcomes or treat learning dimensions in isolation.

MetaLabs are envisioned as "transformative virtual learning spaces" that leverage varying levels of virtualization to foster students' sensory, emotional, and cognitive engagement. MetaLabs encourage active learning by enabling students to explore complex concepts through direct experience, collaboration, and reflection. Crucially, MetaLabs are technology-agnostic, meaning they do not rely on a single XR modality but instead utilize the full range of the XR spectrum to accommodate students' diverse needs and levels of technological access. This flexibility allows educators to tailor the level of immersion to specific learning objectives, student preferences, and institutional resources, ensuring that technological constraints do not limit educational impact. From a theoretical standpoint, the design principles of MetaLabs are rooted in Mezirow's Transformative Learning Theory (2018) and Kolb's Experiential Learning Theory (2014). Both frameworks highlight the importance of critical reflection, shifts in perspective, and hands-on learning based on direct experience. Mezirow's transformative learning theory (2018) posits that learning occurs when individuals encounter a perspective-altering experience, often a "disorienting dilemma," that challenges their existing beliefs. This confrontation prompts a process of reflection and reassessment, leading to cognitive and emotional transformation. While Mezirow primarily emphasizes rational reflection, Dirkx (2001) extends this idea by suggesting that emotions, intuition, and imagination also play a crucial role in transformation. MetaLabs operationalize these principles by designing immersive experiences that encourage self-reflection, perspective shifts, and deep emotional engagement.

Kolb's experiential learning cycle (2014) provides a complementary framework by outlining four stages necessary for effective learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. MetaLabs integrate these stages by offering students direct engagement with immersive experiences, structured opportunities for reflection, theoretical contextualization, and real-world application of learned concepts. This design ensures that learning extends beyond passive content consumption, requiring students to actively construct and apply knowledge in meaningful ways.

The MetaLab framework operationalizes this process through three key phases, profiling, consolidation, and testing, which guide the development and implementation of immersive learning experiences:

(i) *Profiling*: this phase establishes the pedagogical foundation of the MetaLab by engaging educators and stakeholders in a co-design process. It involves experiential workshops where specialized figures, known as Immersive Learning Designers (ILeaD) and instructors define learning objectives, explore the affordances of XR, and collaboratively shape immersive learning scenarios. The primary responsibility of the ILeaD is to guide the co-design process, working closely with instructors to ensure that immersive learning experiences are pedagogically and effectively implemented. Key tasks include defining learning goals, selecting appropriate XR technologies, designing interactive and engaging content, and ensuring accessibility and inclusivity. This stage ensures that XR is not merely an add-on but is meaningfully integrated into the curriculum, aligned with specific educational goals and tailored to student needs. The profiling process also assesses the available technological infrastructure, ensuring that immersive learning remains inclusive and accessible across different levels of technological access.

(ii) *Consolidation*: once learning objectives and technological parameters are established, the consolidation phase focuses on refining and structuring the immersive learning experience. This step involves selecting and adapting XR content to balance engagement with cognitive load management. Activities are designed with a progression from individual exploration to collaborative engagement, incorporating elements such as problem-solving tasks, guided simulations, and interactive storytelling to maintain student engagement. The emphasis on *epistemic emotions*—curiosity, wonder, and surprise—plays a crucial role in ensuring that the XR experience fosters deep cognitive and emotional involvement, reinforcing key learning outcomes.

(iii) *Testing*: before full-scale implementation, the MetaLab undergoes a rigorous validation phase. Prototype versions of the immersive experience are tested in controlled environments with a sample of students and instructors, assessing usability, engagement, and pedagogical effectiveness. This iterative refinement process integrates qualitative and quantitative feedback, ensuring that the final implementation is both technically robust and educationally meaningful. Testing also allows for the identification of potential barriers to inclusivity and accessibility, addressing issues such as cognitive overload, device ergonomics, and technological constraints before wider deployment.

1.3. Present study

While the possibilities seem boundless, it is important to recognize that the current integration of XR technologies into educational curricula remains limited as most scientific studies conducted so far have been experimental in nature, and only a few were applied to real curricular settings (Han et al., 2022). Educational institutions and researchers are actively exploring whether the integration of XR technologies is not only feasible but also pedagogically effective.

This study contributes to the field by extending research beyond controlled experimental settings to explore students' learning experiences within the authentic context of two MetaLabs embedded in a university course. The objectives (Os) of this study were to investigate: (O1) students' learning experiences, focusing on social, cognitive, and emotional responses, and (O2) individual variations in how students experienced the two MetaLabs. Specifically, we:

- Describe students' perceptions of *social presence*, assessing whether two MetaLabs elicited comparable social experiences and exploring individual-level variability to identify patterns in how participants perceived social presence across the two sessions.
- Describe students' levels of perceived *extraneous cognitive load* and *concentration*, evaluating whether the two MetaLabs were consistent in terms of managing cognitive demands and maintaining focus, and investigating individual-level variability to understand differences in participants' cognitive engagement.
- Describe students' emotional experiences in terms of *epistemic emotions*, evaluating whether the two MetaLabs elicited comparable emotional responses and examined whether students' overall emotional experiences were predominantly positive or negative.

By addressing these objectives, the study aimed to provide an overview of the students' learning experiences within MetaLabs. Given the emerging nature of this field and the limited availability of immersive VR devices in higher education, this research is a pioneering work, like studies conducted at Stanford University (Han et al., 2023) and represent a first case in the Italian context. This study aims to build upon and extend the current understanding of students' attitudes towards immersive VR in education (Di Natale, Bartolotta et al., 2024), by exploring the critical factors that shape learning experiences provided by these technologies. The objective is to provide institutions and educators with insights for the effective incorporation of XR technologies into educational practices.

2. Method

2.1. Research design

This study adopts a descriptive, exploratory case study design aimed at characterizing students' social, cognitive, and affective experiences within MetaLabs embedded in an authentic higher education course. The study seeks to provide an in-depth, context-sensitive understanding of how learners experience MetaLabs across multiple psychological dimensions. This approach is grounded in a pragmatic and naturalistic perspective, which prioritizes the examination of educational phenomena as they occur in real-world settings. A descriptive case study specifically aims to describe the phenomenon within the context in which it occurs, distinguishing it from explanatory designs that seek causal links (Yin, 2018). Given the emerging nature of XR integration in higher education and the limited availability of structured implementations in curricular contexts, a descriptive design was considered appropriate to generate foundational insights and identify patterns of experience that can inform future experimental and longitudinal research. The choice of a case-based, descriptive methodology aligns with the study objectives, which focus on (O1) describing students' learning experiences and (O2) exploring individual variability across two MetaLab implementations, rather than testing intervention effects. Accordingly, the study employs quantitative descriptive analyses and data visualization techniques to capture both group-level trends and individual differences within a natural educational environment.

2.2. Ethical approval

The study was approved by the Loacal Ethical Committee of the Department of Psychology (Università Cattolica del Sacro Cuore, Milan, Italy) and all participants provided informed consent electronically via Qualtrics platform prior to participation. To ensure confidentiality and data protection, participants created pseudo-anonymous codes, which were used to match responses across the two MetaLab sessions. No personal data were collected.

2.3. Participants

The study employed a convenience sampling approach, consisting of all students enrolled in the "Virtual Reality Techniques and Metaverse for Well-Being" master's degree course at Università Cattolica del Sacro Cuore (Milan, Italy), who voluntarily agreed to participate. Out of 30 students enrolled in the course, 27 participated in the study completing both MetaLabs and filling both questionnaires (see Table 1 for participants' information).

2.4. The metalabs

The MetaLab framework was systematically applied to design the two immersive learning experiences analysed in this study, following three core phases: profiling (defining learning objectives and aligning XR tools with course goals), consolidation (co-designing and refining XR activities to balance engagement and cognitive load), and testing (piloting the experiences to ensure usability, pedagogical alignment, and technical functionality). As a result, two MetaLabs were implemented, both utilizing immersive VR headsets (Oculus Quest 2) and the VR social platform Engage VR (https://engagevr.io/).

The format of the MetaLabs consisted of a hands-on immersive experience, where students engaged with a VR social platform to explore and interact within the virtual environment. Each immersive session was divided into three parts: individual, pair-based, and group-based activities. This was followed by a debate session, allowing students to reflect on their experiences, discuss key insights, and share perspectives. Finally, the session concluded with a lecture-based theoretical overview, delivered through traditional slide presentations, to contextualize the experience within relevant academic frameworks and consolidate learning (see Figure 1).

The Embodiment MetaLab (see Figure 2) focused on using embodiment techniques in immersive VR to foster a positive body image. To facilitate students' understanding of the concept of embodiment, the immersive experiential session comprised three tasks: an individual *embodiment task* where students replicated movements demonstrated by the instructor, thus promoting a closer identification with their virtual avatars; a *theatre mirror play*, a paired exercise designed to have participants mimic each other's actions, in an effort to explore the possibility of embodying another body; a *proxemics exploration task*, a group activity aimed at navigating and understanding the spatial dynamics and boundaries associated with one's virtual body.

The Creativity MetaLab (see Figure 3) focused on creativity and its application for wellbeing and used the same format of the Embodiment MetaLab, with three distinct activities. The first activity was an individual *3D pen task*, where students, following the instructor's demonstration, used a 3D pen to explore personal experimentation and artistic expression with this innovative three-dimensional creative tool. Next, students engaged in a pair-based creative activity, using a 3D pen and other tools to collaboratively *craft an artifact* symbolizing their journey through the course. This exercise facilitates meaningful dialogue and shared

Table 1. Description of the sample.

Age, M(SD)	24.44 (3.26)
Sex	Females: 19
	Males: 8
	Prefer not to say: 0
Immersive VR experience*	*Never*: 3
	Rarely (once or twice): 13
	Sometimes (but non regularly): 7
	Often: 1
	Every day: 0
VR social platform experience*	*Never*: 15
	Rarely (once or twice): 6
	Sometimes (but non regularly): 3
	Often: 0
	Every day: 0

* Note. Three participants did not fill the experience section of the questionnaire.

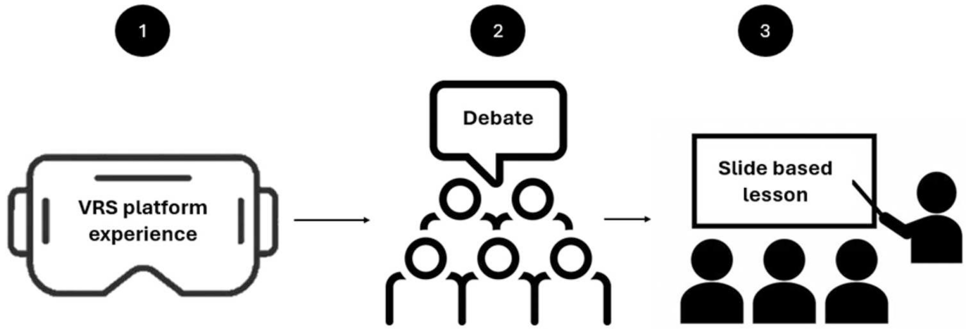

Figure 1. MetaLabs format.

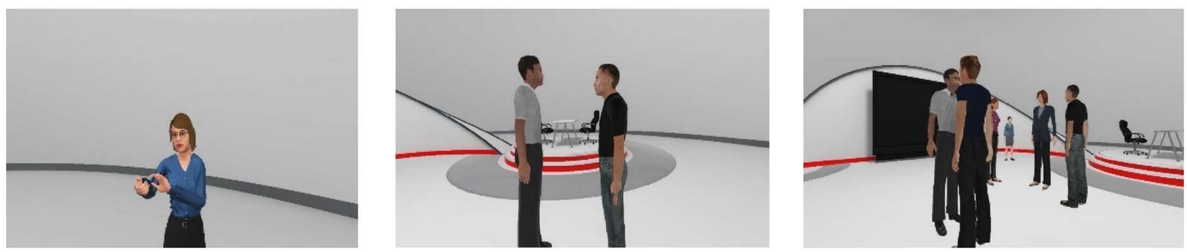

Figure 2. Embodiment MetaLab. Note. On the left a screenshot of the individual task, in the center a screenshot of the paired task, on the right a screenshot of the group task.

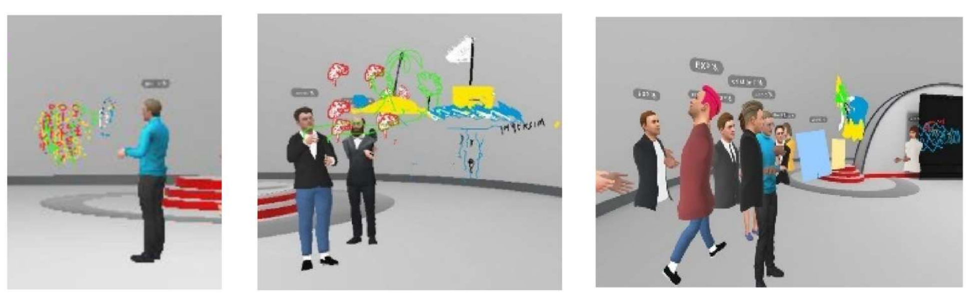

Figure 3. Creativity MetaLab. Note. On the left a screenshot of the individual task, in the center a screenshot of the paired task, on the right a screenshot of the group task.

reflections, culminating in a shared artistic expression of their experiences. Finally, a collective *gallery walk*, wherein students explored and discuss their creations, promoting a shared reflective dialogue.

Although the two MetaLabs had different learning objectives, embodiment in the first and creativity in the second, they were deliberately designed to elicit similar user experiences. This intentionality stems from MetaLab's broader aim to provide students with learning experiences that holistically support their educational journey, considering the interconnected social, cognitive, and affective dimensions of learning. By engaging in these carefully curated activities, we aimed to elicit social presence, reduce extraneous cognitive load and promote concentration on the learning task, and foster positive emotions (see Table 2).

Table 2. Key dimensions, constructs and design elements of the MetaLabs.

Dimension	Construct	MetaLab design
Social	Social presence	Students interacted through *embodied avatars* in a *shared virtual space* where they completed *collaborative tasks*.
Cognitive	Extraneous cognitive load Concentration	Students were immersed in a *minimal virtual environment* with few distractions and completed three *segmented tasks*.
Affective	Epistemic emotions	Students engaged in *hands-on tasks* that encouraged *exploration* and *self-expression*.

2.5. Measures

Students who agreed to take part in the study provided their informed consent and completed three questionnaires implemented in Qualtrics. he first questionnaire (T0) was completed independently one week before the start of the "VR Techniques and Metaverse for Well-Being" course. The remaining two questionnaires (T1) were completed immediately after each MetaLab session. At this point, the instructor left the room, and the researchers provided a QR code to facilitate the T1 questionnaire's completion. Those who refused to participant could leave the room.

2.5.1. Pre-MetaLab questionnaire (T0)

This initial survey collected the following data:

- Sociodemographic information, including age and sex.
- Prior VR experience. Participants were asked to indicate the frequency of their prior engagement with immersive immersive VR environments (e.g. headsets) using a five-point Likert scale (1: never; 5: everyday). Participants also reported their familiarity with VR social platforms (e.g. Spatial, Engage VR) on the same five-point scale. Table 1 above provides a detailed summary of participant responses across these measures.

2.5.2. Post-MetaLab questionnaires (T1)

This questionnaire included measures of different social, cognitive and affective aspects of their learning experience:

- *Social presence*: Social presence was assessed using the 3-item subscale of the Multidimensional Presence Scale (Makransky et al., 2017). The items were translated into Italian using the back-translation method and have been previously used in similar studies (Di Natale, Repetto et al., 2024). Internal consistency was good in both the Embodiment MetaLab ($\alpha = 0.71$) and Creativity MetaLab ($\alpha = 0.74$)
- *Extraneous cognitive load*: Extraneous cognitive load was measured using the scale developed by Parong and Mayer (2021a). This scale evaluates the extent to which participants perceived unnecessary or irrelevant distractions during the learning tasks. The items were translated into Italian using the back-translation method. Internal consistency was good in both the Embodiment MetaLab ($\alpha = 0.77$) and Creativity MetaLab ($\alpha = 0.81$).
- *Concentration*: Concentration on the task was measured using ad-hoc items adapted from the concentration sub-scale of Flow State Scale validated in Italian (Diana et al., 2012). These items focused on the extent to which participants felt fully absorbed in the activities and maintained focus throughout the MetaLab experience. Internal consistency was acceptable in both the Embodiment MetaLab ($\alpha = 0.60$) and Creativity MetaLab ($\alpha = 0.61$).
- *Epistemic emotions*: Epistemic emotions were measured using the 21-item Epistemically Related Emotion Scales (Pekrun et al., 2017). This instrument evaluates seven distinct emotions: three positive (surprise, curiosity, enjoyment) and four negatives (confusion, anxiety, frustration, boredom), with each emotion assessed using three descriptive adjectives. The items were translated into Italian and verified using the back-translation method to ensure accuracy and equivalence and have been previously used in similar studies (Di Natale, Repetto et al., 2024). Internal consistency was acceptable to good for each emotion in both MetaLabs: surprise (Embodiment $\alpha = 0.78$, Creativity $\alpha = 0.84$), curiosity (Embodiment $\alpha = 0.60$,, Creativity $\alpha = 0.76$), enjoyment (Embodiment $\alpha = 0.60$, Creativity $\alpha = 0.70$), confusion (Embodiment $\alpha = 0.77$, Creativity $\alpha = 0.85$), anxiety (Embodiment $\alpha = 0.76$, Creativity $\alpha = 0.79$), frustration (Embodiment $\alpha = 0.78$, Creativity $\alpha = 0.79$), boredom (Embodiment $\alpha = 0.67$, Creativity $\alpha = 0.67$).

While most scales demonstrated acceptable to good reliability, some subscales yielded alpha values around .60. Although this level is often classified as marginal under conventional rules of thumb, the methodological literature suggests that this value may be acceptable for exploratory, early-stage research (Hair et al., 2010; Nunnally & Bernstein, 1994). Additionally, Cronbach's alpha is known to be sensitive to the number of items, and shorter scales tend to yield lower coefficients even when construct representation is adequate (Taber, 2018). Given these considerations, the observed reliability values were considered acceptable for the purposes of this exploratory study, though results should be interpreted with appropriate caution and warrant further validation with larger samples.

2.6. Data analysis

The data analysis for this study was designed to align with the study's objectives, focusing on characterizing overall learning experiences and exploring individual variations in how students experienced the two MetaLabs. The following approaches were employed:

- *Descriptive statistics* were used to summarize and describe the main features of the collected data, offering a clear and straightforward overview of participants' experiences during the two MetaLabs. Measures such as means, medians, standard deviations, and frequencies were calculated to evaluate key variables, such as social presence, cognitive load, and emotional engagement. Special attention was given to the theoretical midpoint of the scales (e.g. 3 on a 5-point Likert scale) to interpret whether participants' experiences leaned toward positive or negative evaluations. This approach aligns with established practices in educational research to contextualize learners' subjective experiences against a neutral reference point (Georgiou et al., 2021; Huang, 2011; Huerta et al., 2017; Kuo et al., 2014; Li et al., 2023; Ma et al., 2022; Moni, 2024; Pribeanu et al., 2017; Teo & Noyes, 2014).
- *Paired sample t-tests* were conducted before examining distributional patterns and individual variability, to assess whether each MetaLab experience differed in terms of central tendency across all measured dimensions. Paired-sample t-tests were performed for each variable, and *p*-values were adjusted using the Benjamini–Hochberg procedure to control for multiple comparisons.
- *Overlapping index (η)* (Pastore & Calcagni, 2019) was used to assess the degree of similarity between the two MetaLabs. This method quantifies the extent to which the distributions of measured variables, such as social presence, cognitive load and concentration, and emotions overlap across participants. Unlike descriptive statistics alone, the overlap index provides a deeper understanding of consistency in participant responses, offering insights into whether the MetaLabs elicited comparable learning experiences.
- *Data visualization techniques* were employed to illustrate individual trends and group-level patterns. Scatterplots were used to map participants' scores across the two MetaLabs, allowing for the identification of individual variability, such as participants who consistently reported high or low levels of the variables of interest. In particular, for each variable of interest (e.g. social presence, extraneous cognitive load, concentration), participants' scores in the Embodiment MetaLab were plotted on the x-axis, while scores from the Creativity MetaLab were plotted on the y-axis. Each point therefore represents an individual participant's paired responses across the two sessions. Additionally, a radar chart was used to provide a comparative visualization of students' emotional experiences *a radar chart* highlighting the distribution of positive and negative emotions across the two MetaLabs. These visual representations offered an intuitive way to interpret differences and similarities in students' responses.

3. Results

This study aimed at observing key features related students' learning experience while participating in two MetaLabs. Specifically, our goal was to observe students' social, cognitive and affective responses, analysing sense of social presence, the degree of extraneous cognitive load encountered, their concentration on the task and their emotional states during two MetaLabs integrated in a psychology university course.

3.1. Social dimension

Social presence scores for both MetaLabs were summarized using measures of central tendency, dispersion, and distribution characteristics (see Table 3).

Participants generally reported moderate to high levels of social presence, with mean scores above the theoretical midpoint of 3 on a 5-point Likert scale for both the Embodiment MetaLab ($M = 3.55$, SD = 0.64) and the Creativity MetaLab ($M = 3.73$, SD = 0.59). These results suggest that participants consistently felt a

Table 3. Social dimension – descriptive data, paired t-test and overlap index of the two MetaLabs.

		Percentiles							
	mean (sd)	25	50	75	sk	kur	t	*p*	*η*
Social Presence									
E-MetaLab	3.55 (0.64)	3.30	3.60	4.00	−0.52	3.09	−1.72	0.19	0.87
C-MetaLab	3.73 (0.82)	3.40	3.80	4.00	−0.20	3.05			

Note. E-Metalab stands for embodiment MetaLab and C-MetaLab for creativity MetaLab.

sense of connection and co-presence during the sessions, with no significant difference in perceived social presence between the Embodiment and Creativity MetaLabs ($t = -1.72$, $p = .19$), indicating a high degree of consistency across conditions. Furthermore, the distributions of social presence scores for the two MetaLabs were strikingly similar, as confirmed by the overlap index ($\eta = 0.87$). This indicates that despite differences in content and focus, the MetaLab design effectively fostered comparable levels of social presence across sessions (see Figure 4(a)).

To explore participants' consistency in reported social presence across the two MetaLabs, we categorized individuals based on their Embodiment MetaLab and Creativity MetaLab scores and visualized results through a scatterplot (see Figure 4(b)). Participants were categorized into three groups: High-High (scores > 3 in both MetaLabs), Low-Low (scores ≤ 3 in both MetaLabs), and Mixed (scores > 3 in one MetaLab and ≤ 3 in the other). Most participants were consistently categorized as either High-High (n = 22) or Low-Low (n = 3), demonstrating stable perceptions of social presence across sessions. A smaller subset of participants fell into the Mixed category (n = 2), reflecting variability in their experiences.

Overall, the results indicate that both MetaLabs elicited consistently moderate-to-high levels of social presence, with a high degree of similarity across sessions and limited individual variability. These findings suggest that the MetaLab design effectively supports a stable perception of co-presence and interpersonal connection, regardless of the specific learning content.

3.2. Cognitive dimension

Extraneous cognitive load and concentration scores for both MetaLabs were summarized using measures of central tendency, dispersion, and distribution characteristics (see Table 4).

Participants reported low to moderate levels of extraneous cognitive load, with mean scores that did not significantly differed ($t = 0.45$, $p = 0.91$) between the Embodiment MetaLab ($M = 2.74$, SD = 0.81) and the

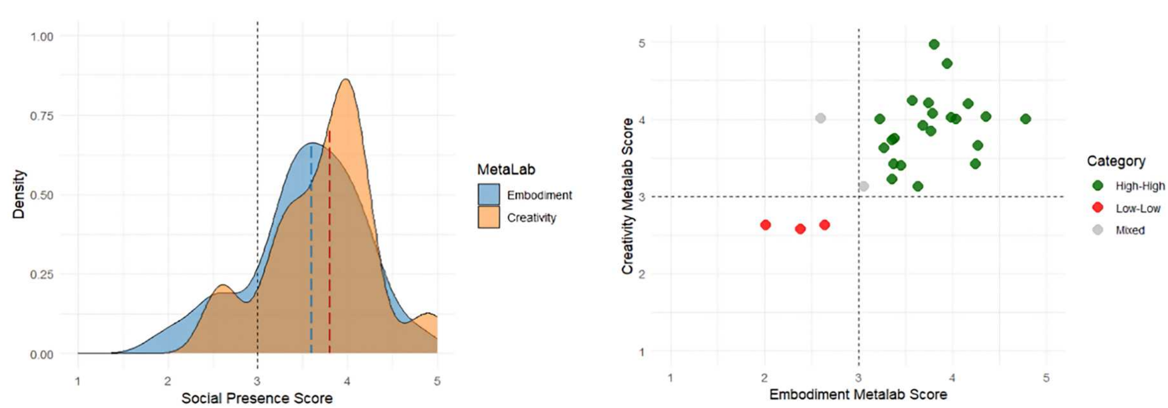

Figure 4. Social presence scores. Note. On the left the social presence scores distribution. The density plot shows the distribution of social presence scores for the Embodiment (blue) and Creativity (orange) MetaLabs. The dashed vertical black line at a score of 3 represents the theoretical midpoint of the scale. The blue and red dashed lines correspond to the median values of social presence scores for the MetaLabs. On the right individual trends in social presence. This scatterplot displays individual social presence scores in the Embodiment MetaLab (x-axis) and Creativity MetaLab (y-axis), categorized into three groups: high social presence in both MetaLabs (high-high, green) low social presence in both MetaLabs (low-low, red) or different experiences in the two MetaLabs (mixed, gray).

Table 4. Cognitive dimension – descriptive data, paired t-test and overlap index of the two MetaLabs.

		Percentiles							
	mean (sd)	25	50	75	sk	kur	t	*p*	*η*
Cognitive load									
E-MetaLab	2.74 (0.81)	2.00	2.67	3.33	0.14	2.74	0.45	0.91	0.90
C-MetaLab	2.76 (0.87)	2.16	2.67	3.16	0.28	2.80			
Concentration									
E-MetaLab	3.74 (0.49)	3.50	3.75	4.00	−0.21	4.54	−0.76	0.57	0.85
C-MetaLab	3.84 (0.44)	3.50	4.00	4.00	−0.45	3.33			

Note. E-Metalab stands for Embodiment MetaLab and C-MetaLab for Creativity MetaLab.

Creativity MetaLab ($M = 2.77$, SD = 0.87). The overlap index ($\eta = 0.90$) confirmed a high degree of similarity in cognitive load perceptions across both sessions (see Figure 5(a)).

Individual-level scatterplots (figure 5(b)) revealed that most participants exhibited differences in cognitive load across the two MetaLabs, suggesting that the task design and virtual environment were perceived differently between the sessions. However, these differences occurred in varying directions, some participants reported lower cognitive load in the Creativity MetaLab and higher in the Embodiment MetaLab, while others exhibited the opposite pattern. Interestingly, a significant number of participants clustered near the midpoint, indicating relatively balanced cognitive load perceptions across both sessions. The remaining participants predominantly fell into the low-low category, indicating that they experienced low extraneous cognitive load in both MetaLabs, while only few participants reported being in the high-high category, indicating high extraneous cognitive load across both sessions.

Concentration levels were consistent across the two MetaLabs. The mean scores were moderately high for both the Embodiment MetaLab ($M = 3.23$, SD = 0.64) and the Creativity MetaLab ($M = 3.12$, SD = 0.60), indicating that participants were able to remain focused on the tasks, with no significant difference between the two MetaLabs ($t = -0.76$, $p = 0.57$). Overlap analysis ($\eta = 0.88$) supported the observation of similar concentration levels between the two (see Figure 6(a)).

Individual-level scatterplots (see Figure 6(b)) revealed that most participants concentrated well during the bot the Embodiment and Creativity MetaLab, with only a few participants displaying variability in concentration.

Taken together, the cognitive results suggest that the MetaLabs were successful in maintaining relatively low extraneous cognitive load and high levels of concentration across both sessions. While some individual variability in perceived cognitive load was observed, overall patterns indicate that the instructional design effectively balanced engagement with cognitive demands.

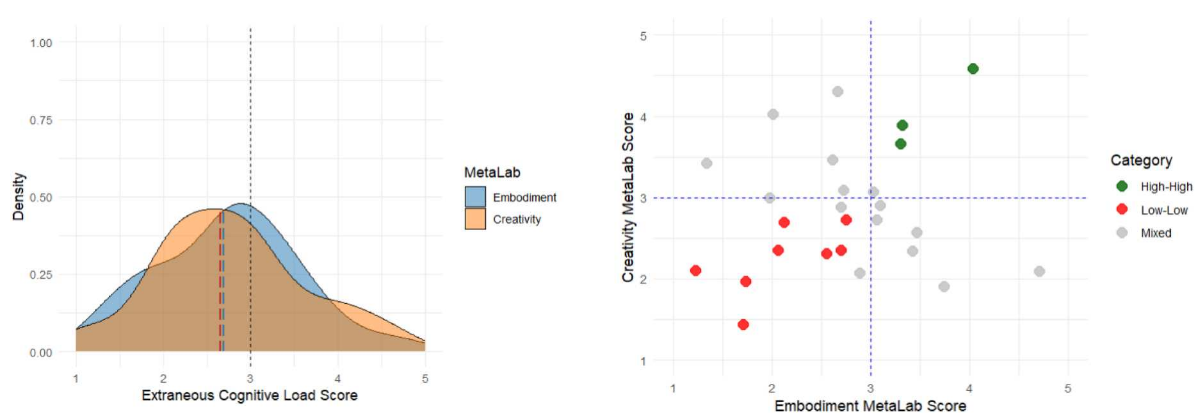

Figure 5. Extraneous Cognitive Load. Note. On the left extraneous cognitive load scores distribution. The density plot shows the distribution of extraneous cognitive load scores for the Embodiment (blue) and Creativity (orange) MetaLabs. The dashed vertical black line at a score of 3 represents the theoretical midpoint of the scale. The blue and red dashed lines correspond to the median values of extraneous cognitive load scores for the MetaLabs. On the right individual trends. This scatterplot displays individual extraneous cognitive load scores in the Embodiment MetaLab (x-axis) and Creativity MetaLab (y-axis), categorized into three groups: high extraneous cognitive load in both MetaLabs (high-high, green) low extranous cognitive load in both MetaLabs (low-low, red) or different experiences in the two MetaLabs (mixed, gray).

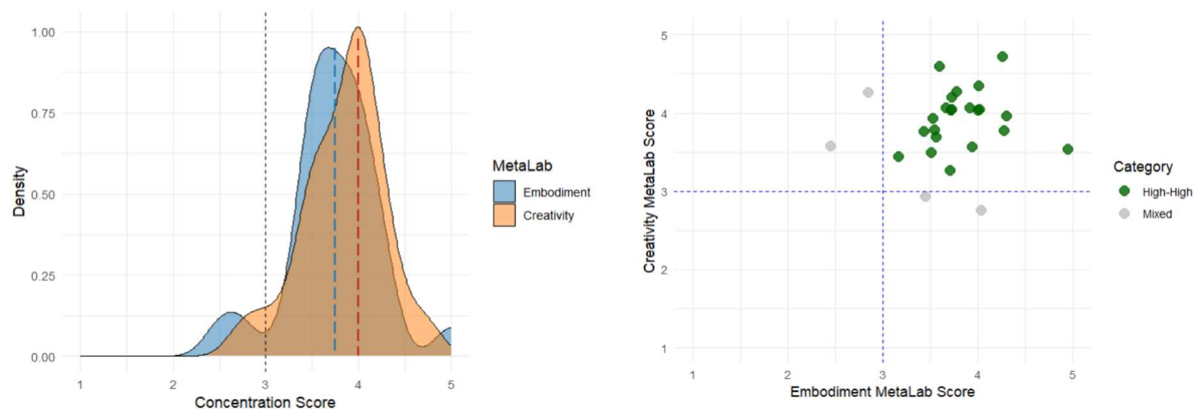

Figure 6. Concentration scores. Note. On the left concentration scores distribution. The density plot shows the distribution of concentration scores for the Embodiment (blue) and Creativity (orange) MetaLabs. The dashed vertical black line at a score of 3 represents the theoretical midpoint of the scale. The blue and red dashed lines correspond to the median values of concentration scores for the MetaLabs. On the right individual trends. This scatterplot displays individual social presence scores in the Embodiment MetaLab (x-axis) and Creativity MetaLab (y-axis), categorized into three groups: high concentration in both MetaLabs (high-high, green) low concentration in both MetaLabs (low-low, red) or different experiences in the two MetaLabs (mixed, gray).

3.3. Affective dimension

Participants' emotional experiences were analysed for seven epistemic emotions (Table 5).

The emotional experiences of participants revealed a predominance of positive emotions across both MetaLabs (see Figure 5). Curiosity (Embodiment: $M = 4.24$, Creativity: $M = 3.98$), enjoyment (Embodiment: $M = 3.83$, Creativity: $M = 3.14$), and surprise (Embodiment: $M = 3.52$, Creativity: $M = 3.61$) were the most frequently reported emotions, reflecting the positive experience activated. These emotions were particularly pronounced in the Embodiment MetaLab. In contrast, negative emotions such as confusion ($M < 2.5$ for both MetaLabs), anxiety ($M < 2.5$ for both MetaLabs), frustration ($M < 2.5$ for both MetaLabs), and boredom ($M < 2.5$ for both MetaLabs) were reported at low levels. No statistically significant differences emerged between the two MetaLabs for any of the emotional dimensions (all ps > 0.05). The radar chart (see Figure 7) highlighted the emotional profiles for both sessions, showing positive emotions dominated participants' experiences, while negative emotions were minimal.

Table 5. Affective dimension – Descriptive data and paired t-test of the two MetaLabs.

		Percentiles						
	Mean (sd)	25	50	75	sk	kur	t	*p*
Surprise								
E-MetaLab	3.52 (0.60)	3.00	3.67	4.00	−0.47	2.15	−0.50	.69
C-MetaLab	3.61 (0.75)	3.00	3.33	4.00	0.30	2.35		
Curiosity								
E-MetaLab	4.24 (0.42)	4.00	4.00	4.50	0.05	2.43	1.97	.15
C-MetaLab	3.98 (0.60)	3.50	4.00	4.50	−0.06	2.37		
Enjoyment								
E-MetaLab	3.83 (0.54)	3.00	3.33	3.67	−0.03	2.91	1.50	.24
C-MetaLab	3.14 (0.72)	3.00	3.00	3.33	0.79	4.54		
Confusion								
E-MetaLab	2.02 (0.63)	1.67	2.00	2.33	0.23	2.44	−2.89	.07
C-MetaLab	2.42 (0.79)	1.83	2.67	3.00	0.05	2.61		
Anxiety								
E-MetaLab	1.35 (0.51)	1.00	1.00	1.50	1.72	5.68	−0.98	.48
C-MetaLab	1.47 (0.59)	1.00	1.33	1.83	1.38	4.75		
Frustration								
E-MetaLab	1.37 (0.53)	1.00	1.00	1.67	1.64	5.15	−2.65	.07
C-MetaLab	1.63 (0.67)	1.00	1.33	2.00	1.02	3.15		
Boredom								
E-MetaLab	1.35 (0.48)	1.00	1.00	2.50	1.38	3.88	−2.22	.12
C-MetaLab	1.56 (0.47)	1.00	1.56	2.00	0.36	2.34		

Note. E-Metalab stands for embodiment MetaLab and C-MetaLab for creativity MetaLab.

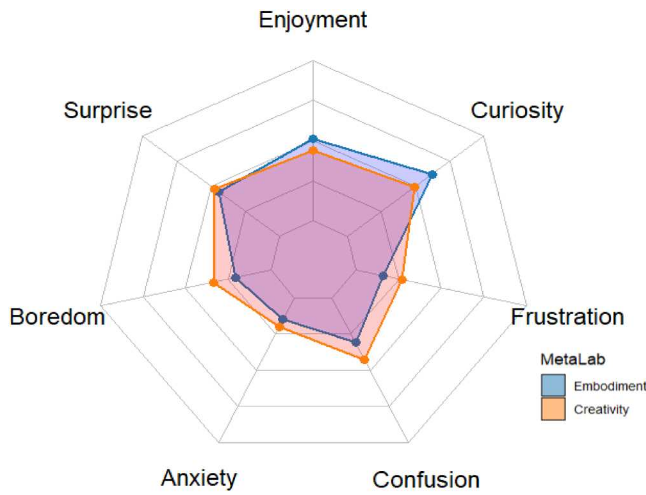

Figure 7. Radar chart for epistemic emotions.

Overall, the affective results indicate that the MetaLabs elicited a predominantly positive emotional profile, characterized by high levels of curiosity and enjoyment and relatively low levels of negative emotions such as anxiety and frustration. This pattern was broadly consistent across both MetaLabs, suggesting that the immersive and experiential design supported positive emotional engagement.

4. Discussion

MetaLabs are innovative XR-based learning environments designed to provide students with interactive, and collaborative experiences that transcend traditional classroom learning. Combining theoretical instruction with hands-on activities, MetaLabs aim to enhance students' learning experiences by fostering key psychological dimensions such as social presence, cognitive engagement, and positive emotions.

In this study, we analysed two MetaLabs embedded within a university course titled "VR Techniques and Metaverse for Wellbeing," which was designed to explore the applications of XR technologies in promoting mental and emotional well-being. The two MetaLabs were collaboratively co-designed with the instructor, resulting in two immersive experiences conducted on a VR social platform. Although the two MetaLabs had differing content and learning objectives, they were intentionally designed to elicit similar types of learning experiences in terms of social presence, cognitive engagement and emotional response. Both MetaLabs followed a structured format that included individual, paired, and group-based activities, encouraging students to actively engage with the virtual environment and collaborate with peers. They were also designed to minimize extraneous cognitive load through simple, intuitive interfaces and clearly segmented tasks. Moreover, they leveraged epistemic emotions, such as curiosity and enjoyment, to enhance engagement and motivation. This shared structure provided a unique opportunity to examine both the consistency of students' responses and the individual variability in how they engaged with each MetaLab. Notably, this study represents one of the first investigations of XR labs embedded in a university course, alongside similar pioneering efforts at Stanford University (Han et al., 2022). The findings provide valuable insights into how students perceive and engage with XR-based learning environments, addressing the study's objectives of evaluating the overall quality of the experiences, comparing the two MetaLabs, and identifying individual trends in social, cognitive, and emotional dimensions.

Our first objective (O1) was to analyze students' overall experience within the Metalabs, focusing on how the designed XR learning environments supported social presence, cognitive engagement, and emotional involvement. The second objective (O2) aimed to highlight possible individual variations in these experiences, exploring how different students experience the two Metalabs. In the following sections, we will discuss these objectives for each analysed dimension, presenting both the general trends observed in the group as a whole and the individual differences that emerged.

As concern social presence, the results demonstrated consistently moderate-to-high levels of social presence across both MetaLabs, with mean scores exceeding the theoretical midpoint of 3 on the 5-point Likert scale. This suggests that participants generally felt connected and engaged in the learning environment. Additionally, the overlap analysis revealed a high degree of similarity in the social presence distributions between the two sessions. This indicates that the MetaLab design effectively fostered comparable levels of connection and co-presence, irrespective of the specific content focus (embodiment vs. creativity). The consistently high social presence observed in this study underscores the potential of VR social platforms to replicate the interpersonal connections and sense of immediacy typically associated with face-to-face learning. This is particularly relevant considering the importance of social presence in increasing active participation, collaboration, engagement, and ultimately learning gains in online forms of learning (Richardson et al., 2017; Weidlich & Bastiaens, 2017). It should be noted that participants were physically present in the same room while interacting within the virtual space. This hybrid setup, where learners share a physical space while engaging in a virtual environment, may have favoured their sense of social presence. Prior research indeed suggests that co-location can enhance feelings of connection and immediacy, as it allows for peripheral awareness of others, and informal interactions before and after the virtual experience (Christopoulos et al., 2017).

At an individual level, most participants reported stable levels of social presence across both MetaLabs, with the majority reporting high social presence in both sessions. However, three participants consistently reported low social presence in both MetaLabs, and two participants reported varying scores between sessions. This variability highlights the need to further explore individual differences that might influence how students experience social presence in immersive VR environments. Individual factors to investigate might include, but are not limited to, computer anxiety and prior experience with immersive VR technologies (Han et al., 2024). Understanding these individual differences will be critical in designing tailored immersive VR experiences that are effective and inclusive for a wider range of learners.

Regarding the cognitive dimension, the focus was on two critical factors: *extraneous cognitive load* and *concentration*. The MetaLabs were intentionally designed to minimize extraneous cognitive load and promote concentration by providing minimalist virtual environments with low visual complexity and by segmenting tasks into manageable phases. This structured design aimed to ensure that students could focus on the primary learning objectives without unnecessary distractions, thereby optimizing their cognitive engagement. The findings indicated low-to-moderate levels of extraneous cognitive load across both MetaLabs, with all scores falling below the theoretical threshold of 3, suggesting that participants found the immersive VR environments manageable and not overly demanding. Correspondingly, concentration levels were also consistent across both sessions, with most participants reporting moderate-to-high focus on the tasks. This reflects the effectiveness of the designed minimalist environments and structured task segmentation (individual, paired, group tasks), which helped sustain attention and minimize cognitive strain. This is in line with prior research on virtual environments, which has highlighted their potential to enhance learner engagement when appropriately designed (Makransky et al., 2019; Parong & Mayer, 2018). Studies have shown that minimalist virtual environments, those with low visual and auditory complexity, enable learners to focus more effectively on relevant tasks (Skulmowski & Xu, 2022). Additionally, task segmentation, a well-established strategy in multimedia learning (Clark & Mayer, 2011; Mayer & Moreno, 2003), likely played a key role in sustaining participants' attention by breaking complex tasks into smaller, more manageable components. This approach reduces the risk of cognitive overload, particularly in novice learners, by providing clear, achievable goals at each phase of the activity (Kirschner et al., 2011). The findings of this study demonstrate that even when immersive, immersive VR environments do not inherently overwhelm learners (Poupard et al., 2025) if designed with cognitive principles in mind.

However, individual-level variability in extraneous cognitive load underscores the need to adapt the design of immersive VR learning environments to better accommodate individual differences. While most participants experienced manageable cognitive loads, the variation observed across sessions suggests that some learners may require additional support to fully benefit from the experience. In this context, the pre-training principle from multimedia learning theory is particularly relevant (Han et al., 2024; Miguel-Alonso et al., 2023; Miguel-Alonso et al., 2024). Pre-training, which familiarizes students with technological tools and interfaces before engaging in tasks, could help mitigate the novelty effect. This preparation ensures that students are not distracted by unfamiliar interfaces and can concentrate on the learning objectives. Several studies have demonstrated the effectiveness of pre-training in enhancing both learning experience and performance in immersive environments (Han et al., 2024; Meyer et al., 2019) and suggest the need of a technology briefing phase to ensure students understand how to use immersive VR tools before diving into learning activities (Keskitalo & Saukkoriipi, 2025).

As concern students' emotional experience while participating in the MetaLabs, results revealed that *positive emotions* played a dominant role in shaping participants' experiences in both MetaLabs. Curiosity, enjoyment, and surprise were the most frequently reported emotions. Simultaneously, negative emotions, including confusion, anxiety, frustration, and boredom, were reported at notably low levels, indicating that the MetaLabs were well-designed to avoid overwhelming or disengaging participants. This aligns with previous research showing that immersive VR environments that foster active and exploratory learning naturally stimulate curiosity, joy and surprise (Allcoat & von Mühlenen, 2018; Cheng, 2023; Dubovi, 2022; Guerra-Tamez, 2023; Poupard et al., 2025; Sun Joo & Lee Jin, 2024). However, it is essential to consider the possible influence of the novelty effect, where students' positive responses might be partially driven by the initial excitement and unfamiliarity of engaging in immersive VR environments rather than the learning content itself (Miguel-Alonso et al., 2024). Studies indicate that first-time immersive VR users often report heightened enjoyment, engagement, and presence simply due to the novelty of the experience rather than its pedagogical value. Over time, this effect may diminish as learners become accustomed to the technology (Miguel-Alonso et al., 2023), necessitating longitudinal studies to examine whether the positive emotional responses observed in the MetaLabs persist beyond the initial exposure.

The findings of this study provide compelling support for the MetaLab framework, emphasizing its learner-centered, pedagogically driven approach to XR-based education. Unlike traditional technology-driven initiatives that prioritize immersive hardware and interactive features, the MetaLab framework underscores the importance of learning objectives, student engagement, and pedagogical inclusivity over technological novelty. By embedding immersive and experiential learning principles into higher education curricula, MetaLabs function as transformative learning environments.

The evaluation of the MetaLabs, which occurred immediately after the immersive session, focused on the three key psychological dimensions: social presence, cognitive engagement, and emotional experience. The results demonstrate that well-structured XR learning experiences effectively foster positive learning outcomes across these dimensions. Social presence was consistently high, highlighting the capacity of VR social platforms to replicate interpersonal connection and collaboration often seen in face-to-face environments. Cognitive engagement was reflected in low extraneous cognitive load and high levels of concentration, suggesting that the minimalist design of the virtual environments and the segmentation of tasks facilitated students' focus and reduced distractions. Emotional responses were dominated by positive emotions, such as curiosity, enjoyment, and surprise, indicating the immersive and interactive nature of the MetaLabs successfully promoted active and meaningful engagement.

In this respect, the MetaLab approach aligns with international XR case studies by confirming that meaningful learning outcomes are not solely driven by immersion itself, but by how different psychological dimensions interact to shape the overall learning experience. This is in line with evidence from a recent international review of XR in higher education (Burke et al., 2025) showing that XR effectiveness depends on the alignment between cognitive, affective, and psychomotor demands, and may be hindered by factors such as cognitive overload or reduced social interaction when poorly designed. This argumentation is also supported by empirical evidence from XR case studies such as Han and colleagues (2023), a large-scale longitudinal investigation conducted in a university-based social VR course, in which participants engaged in repeated collaborative sessions over several weeks. Findings showed the importance of experience design in that core experiential dimensions, including self-, social, and spatial presence, enjoyment, realism, and group cohesion.

Together, these findings reinforce the need for a multidimensional and pedagogically grounded approach to XR design. The MetaLab format strongly aligns with Kolb's Experiential Learning Theory (2014). The hands-on immersive VR session served as the "concrete experience" stage, where students engaged with the virtual environment through individual, paired, and group activities. This phase was critical in providing a multisensory and interactive experience, encouraging learners to explore, experiment, and engage deeply with the material. In this phase the MetaLabs demonstrated this principle by creating environments that elicited strong positive emotional engagement, curiosity, enjoyment, and surprise aligning with Dirkx's (2001) and Mezirow's (2018) view of emotional involvement as a driver of critical reflection and perspective transformation. Indeed, following this experiential phase, the MetaLabs incorporated "reflective observation" through a structured debate session, where students critically discussed and analyzed their experiences, gaining insights from their peers' perspectives. Finally, the "abstract conceptualization" stage was facilitated through a slide-based lecture, offering theoretical frameworks to contextualize the practical activities and consolidate learning. However, it is important to note that while this format effectively integrates Kolb's stages of learning, this study focused exclusively on analyzing the immersive experiential phase. The reflective observation and abstract conceptualization stages, which are crucial for completing the learning cycle, remain areas for future exploration.

4.1. Guidelines for educators and academic institutions

Based on the findings of this study and the MetaLab framework, the following guidelines are proposed for educators aiming to integrate XR technologies, specifically VR social platforms, into their curricula effectively.

Co-design with educators: a collaborative approach to designing XR learning experiences is essential. Co-designing with teachers ensures that the focus remains on achieving meaningful learning outcomes and educational goals rather than simply showcasing the immersive or interactive features of the technology. By aligning XR experiences with course objectives, educators can emphasize the development of critical skills, knowledge acquisition, and deeper understanding. This points to the emerging role of the ILeaD, a figure equipped with both pedagogical and technological expertise to co-develop effective XR learning environments. As XR technologies continue to expand in education, training professionals in immersive learning design will be crucial to ensuring that these tools are used to enhance, rather than replace, evidence-based teaching methodologies.

Adopt a learner-centered and inclusive approach: immersive VR learning environments should be tailored to the diverse needs, preferences, and backgrounds of learners. Flexibility is key, and this can be achieved by offering varying levels of immersion to accommodate different circumstances. For example, fully immersive VR headsets can be complemented with non-immersive alternatives such as desktops or tablets, ensuring inclusivity and accessibility for all students, regardless of their technical or physical constraints.

Address key psychological dimensions of learning: to ensure optimal learning experiences, XR environments should be designed to minimize cognitive barriers. Minimalist virtual environments with low visual complexity, clear navigation paths, and intuitive interfaces are vital to reducing extraneous cognitive load. Tasks should also be segmented into manageable phases, such as individual, paired, and group activities. This structured approach helps maintain focus and avoids overwhelming learners. At the same time, experiences should be designed to evoke positive epistemic emotions such as curiosity, enjoyment, and surprise, which are known to enhance engagement and motivation. Clear instructions and scaffolding during VR sessions further ensure that students can navigate their tasks effectively without unnecessary cognitive strain.

Implement pre-training sessions: pre-training is a critical step in preparing students for immersive experiences. Familiarizing learners with the technology before their first session, through workshops or tutorials, can help mitigate the novelty effect often associated with XR environments. By reducing the distraction caused by unfamiliar interfaces, students can concentrate more fully on the learning objectives. Pre-training also ensures that learners feel comfortable using the VR tools and understand the purpose and structure of the activities they will undertake.

Monitor and adapt for individual differences: recognizing and accommodating individual variability is essential for effective learning. Learners may experience differing levels of cognitive load, social presence, and emotional engagement in XR environments. To address these differences, educators should implement mechanisms for monitoring learner feedback and adapt the design or pacing of tasks to suit diverse needs. Providing personalized scaffolding and support can help ensure that all students, regardless of their starting point, can fully benefit from the XR experience.

For academic institutions, one of the most critical factors in successfully integrating XR technologies into curricula is ensuring teacher buy-in, positive attitudes, and adequate training. Educators are the primary drivers of innovation in the classroom, and their willingness and ability to adopt XR tools are essential for success. Institutions should prioritize efforts to engage teachers by demonstrating the pedagogical value of XR technologies and how they align with their teaching goals. Providing comprehensive training programs is equally important. Teachers need to feel confident using XR tools, designing immersive learning experiences, and managing student engagement in virtual environments. These training sessions should not only focus on the technical aspects of XR but also on the pedagogical strategies for leveraging these technologies effectively. Offering practical workshops, peer-led learning opportunities, and ongoing support can help educators feel empowered to embrace XR tools as an integral part of their teaching practices.

4.2. Limitations and future directions

This study, while offering valuable insights, has several limitations that should be addressed in future research.

First, this study provides only a first snapshot of participants' experiences during the MetaLabs and does not account for the long-term impact of XR-integrated learning in higher education. Future studies should examine the integration of XR technologies into broader curricula to determine their scalability and effectiveness in diverse educational contexts. Within this context, the role of teachers in XR learning environments remains underexplored. The success of MetaLabs likely depends not only on student engagement but also on the instructor's ability to effectively facilitate and integrate these experiences. Future research should account for teacher perspectives, skills, and training requirements when implementing XR technologies in educational settings. Moreover, the focus of this study was on learning experience, leaving aspects such as retention, knowledge transfer, or skill acquisition unexplored. While previous studies have suggested a positive relationship between learning experiences and retention (Goh et al., 2017; Schrader et al., 2024), it would be beneficial for future research to directly assess these outcomes, providing a more comprehensive understanding of XR-based learning.

Second, we identified participants' self-selection as a possible source of bias. The participants in this study were students enrolled in a specialized module on immersive VR technologies. This enrollment may have introduced a self-selection bias due to participants' inherent interest in the subject matter. Such interest could have led to higher levels of enthusiasm and engagement compared to what might be observed in a more general student population. In addition, the use of immersive VR technologies may have introduced a potential novelty effect (Miguel-Alonso et al., 2024), whereby participants' positive responses, particularly in terms of engagement and emotional experience, may be partially influenced by the perceived newness and immersive qualities of the technology rather than solely by the pedagogical design of the MetaLabs. However, several aspects of the study design may have partially mitigated these biases. The MetaLabs were embedded within a formal university course rather than a voluntary experimental setting, reducing the likelihood of strong self-selection driven exclusively by interest in VR. Furthermore, participants' prior experience with immersive VR and VR social platforms was assessed, and the sample was largely composed of individuals with limited prior exposure, suggesting that the findings are not restricted to highly experienced or technology-enthusiastic users. Finally, the use of two MetaLab sessions provided a more stable assessment of students' experiences beyond a single exposure, potentially attenuating short-term novelty effects. To improve the generalizability of findings, future research should broaden the participant pool to include students from diverse academic backgrounds and varying levels of familiarity with XR technologies and should consider longitudinal or controlled designs to better disentangle novelty-related effects from more stable learning outcomes.

Third, while this sample provided us with the opportunity to clearly describe the learning experiences, its small size limited the scope of potential analyses. For example, it prevented us from exploring individual differences, such as computer anxiety (Han et al., 2024) which may play a moderating role in learning outcomes. Understanding such individual factors is essential within the MetaLab framework, which emphasizes inclusivity and adaptability to diverse learner needs. Future research should involve larger and more diverse samples to enable deeper exploration of these variables and their influence on XR-based learning experiences. Moreover, the small sample size also prevented us from examining potential relationships among the analysed dimensions. Prior research has suggested interconnections between constructs such as social presence and cognitive engagement (Dunmoye et al., 2024) social presence and emotional experience (Pfaller et al., 2021) or cognitive engagement and emotions (Dubovi, 2022; Schrader et al., 2024) in collaborative virtual learning environments, influencing the overall learning experience. Future studies should employ advanced statistical analyses to explore these relationships to inform the design of more effective and holistic educational interventions.

Finally, a further limitation concerns the internal consistency of some subscales, which yielded Cronbach's alpha values around.60. While this was considered acceptable given the exploratory nature of the study, the short length of the adapted scales, and established methodological guidance supporting lower thresholds in early-stage research (Hair et al., 2010; Nunnally & Bernstein, 1994; Taber, 2018), these values indicate that the reliability of the instruments should be interpreted with caution. Future research with larger samples and refined or extended scales is encouraged to provide more robust reliability estimates and to validate the findings reported here.

4.3. Conclusion

This study investigated how immersive virtual environments influence key psychological dimensions of learning within structured XR-based educational experiences designed using the MetaLab immersive learning framework. Specifically, the research examined the impact of these experiences on students' social presence, cognitive engagement, and emotional involvement. To explore this question, two MetaLabs were integrated into a university course on "VR Techniques and Metaverse for Well-being." The results indicate that the MetaLabs effectively foster social presence, with students reporting moderate-to-high levels of co-presence and interpersonal connection. Cognitive engagement was supported by low extraneous cognitive load and sustained concentration, facilitated by a structured progression from individual to group-based activities. Emotional responses were predominantly positive, with curiosity and enjoyment playing a central role, reinforcing the importance of engagement-driven learning. Minimal levels of frustration and confusion suggest that well-structured XR experiences can optimize learning while minimizing cognitive overload.

Despite these promising findings, the study has limitations. The small sample size limits generalizability, and the short-term nature of the study prevents an assessment of long-term learning outcomes. Additionally, participant self-selection may have introduced bias, as students enrolled in the course may have had a predisposition toward immersive learning. Future research should investigate MetaLabs' impact on knowledge retention, skill transfer, and engagement across diverse academic disciplines. Longitudinal studies could provide insights into the sustained effectiveness of XR-based learning. As XR technologies evolve, the MetaLab framework may offer a scalable, research-driven model for immersive education, emphasizing pedagogy over technological novelty.

However, beyond the empirical findings, this study contributes to the field by positioning MetaLabs as a replicable instructional design model for the integration of XR technologies in higher education. Unlike approaches that focus primarily on technological affordances or isolated learning outcomes, the MetaLab framework offers a structured, pedagogically grounded methodology that systematically integrates social, cognitive, and affective dimensions of the learning experience. The three-phase structure of profiling, consolidation, and testing provides a flexible yet transferable design logic that can be adapted to different disciplines, learning objectives, and technological contexts. In this sense, MetaLabs should not be understood solely as a specific implementation within a single course, but as a scalable framework that can guide the development of immersive, experience-based learning environments across educational settings. This positions MetaLabs as a bridge between XR innovation and sustainable pedagogical practice.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used ChatGPT 5.3. to support language editing and improve clarity of expression. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Data sharing and data availability statement

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

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