ALIGNING THE AFFORDANCES OF IMMERSIVE VIRTUAL REALITY WITH EDUCATIONAL OBJECTIVES THROUGH THE IVRPM

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Abstract

This study presents the Immersive Virtual Reality Pedagogical Model (iVRPM), a framework that aims to support the planning of educational experiences in immersive virtual environments. The model proposes the alignment between the affordances of Immersive Virtual Reality (iVR)—such as immersion, interactivity, and embodiment—and specific educational objectives. It also proposes the alignment between task typology and the technological features of immersive environments, linking interactivity levels to Bloom's revised taxonomy. These levels guide educators in designing activities that are consistent with educational objectives, task complexity, motor skill development, and students' familiarity with immersive technologies.

Introduction

The integration of emerging technologies into education has created new opportunities to enhance teaching and learning processes. Among these innovations, Immersive Virtual Reality (iVR) has stood out for its potential to provide interactive experiences through digital environments that simulate real-world contexts or even transport users to hypothetical, imagined, or historically reconstructed scenarios. As Wu et al. (2020) state, this technology has been widely used to create realistic, situated learning contexts that students would not usually have access to.

iVR technology enables users to interact naturally within three-dimensional environments using devices such as head-mounted displays (HMDs), motion sensors, handheld controllers, and advanced graphics processors. These tools allow for real-time motion tracking and continuous stereoscopic image generation, resulting in highly interactive and embodied environments (Won et al., 2023). With advancements such as hand tracking and more intuitive controllers, both fidelity and freedom of movement have significantly improved, enhancing the user experience. In this context, it becomes essential to understand how content is encoded, experienced, and retained in these environments (Johnson-Glenberg, 2018).

Despite its potential, the pedagogical integration of iVR still presents a challenge, particularly due to the lack of conceptual models that guide its application in alignment with teaching and learning demands. The so-called “immersion principle” asserts that immersive virtual environments lead to better learning outcomes when they incorporate effective instructional design principles (Makransky, 2021). In other words, the author argues that immersion alone does not guarantee improved learning performance, but the use of well-designed instructional methods within these environments can enhance cognitive processes such as selection, organization, and integration of information.

This study presents the Immersive Virtual Reality Pedagogical Model (iVRPM), a framework designed to support the planning of immersive educational experiences by aligning the interactive features of the technology with Bloom’s revised taxonomy (Anderson et al., 2001). Developed through a Design-Based Research (DBR) approach, the model connects levels of interactivity to proposed tasks and the corresponding dimensions of knowledge, enabling the progressive development of psychomotor skills required for the use of the technology, as well as advancement through the cognitive levels of learning.

Affordances of Immersive Virtual Reality

In educational practice, iVR has emerged as a promising technology capable of creating interactive simulations that replicate real-world processes and situations (Merchant et al., 2014). These simulations provide a personalized experience, allowing students to engage more deeply with the content (Wu et al., 2020).

As Makransky (2021) highlights, traditional multimodal learning—based on words and images—has evolved into more dynamic forms through the use of emerging technologies, such as animations and, more recently, immersive virtual environments. Virtual reality enables students to interact with pedagogical agents in three-dimensional contexts that would not be possible in the physical world and are significantly more realistic than videos or computer-based simulations.

As Zilles Borba (2023) noted, immersive devices also profoundly transform the ways in which digital content is produced and consumed. According to the author, iVR constitutes an advanced human-computer interaction interface, structured by transparency mechanisms that eliminate the perception of technological mediation, creating the illusion of presence within the digital environment. This sense of immersion and presence, experienced in 360° scenarios, allows individuals to see, hear, and interact with digital content through natural sensations, characterizing a communicational process distinct from that provided by conventional screens (Zilles Borba, 2023).

The combination of real-time motion tracking and stereoscopic image generation has enabled the creation of more immersive, interactive, and embodied digital environments. These spaces provide students with opportunities to interact with the content, allowing them to engage actively—not merely as observers, but as participants in the experience.

Among the affordances of immersive virtual reality (iVR), key features include the ability to promote immersion, the spatial manipulation of three-dimensional objects, the experimentation with situations that go beyond physical reality, and the active involvement of the student's body in the experience (Johnson-Glenberg, 2018; Makransky & Petersen, 2021; Won et al., 2023).

As observed by Won et al. (2023), the technological capabilities of iVR influence the creation of authentic sensory stimuli capable of inducing the sensation that virtual objects and environments are real, thereby enhancing sensory and representational fidelity. The authors also emphasize that these technologies allow users to act naturally and intuitively in virtual environments, through coherent and fluid actions.

Two central affordances of iVR, Immersion and Interaction, operationalized through aspects such as representational fidelity and immediacy of control — refer to how well simulations replicate real-world environments not only in appearance but also in the emotional, cognitive, and behavioral responses they evoke in users (Harris et al., 2021; Petersen et al., 2022). They also include the range of learner interaction modes (Dalgarno & Lee, 2010), supporting active involvement.

Supported by other authors, Makransky & Petersen (2021) indicated that iVR is characterized as a complex media system capable of providing sensory immersion and sophisticated content representation. Immersion is directly tied to the degree of vividness offered by a system, which is an objective measure of its ability to exclude the outside world. This vividness depends on factors such as the number of senses activated and the quality of the hardware used (Cummings & Bailenson, 2016). Dalgarno and Lee (2010) suggested that immersion should not be treated as a standalone property but as dependent on other aspects present in an immersive learning experience. In this sense, immersion can be described as "a psychological state characterized by the perception of being enveloped, included, and interacting with an environment that offers a continuous flow of stimuli and experiences" (Agrawal et al., 2020, p. 277).

Zilles Borba (2023), building on the work of previous authors, proposed a dynamic structured around three pillars — realism, interactivity, and involvement — which together form the concept of believability, associated with the perception of reality in iVR experiences. In this framework, involvement refers to the quality of the narrative and the ability of the storyline to capture attention and evoke emotions (Zilles Borba, 2023, p.78). According to the author, these pillars are closely related to the concept of plausibility, originally defined by Slater et al. (2009) as the user's acceptance of the virtual environment as credible, which enables realistic behaviors even in simulated contexts, depending on narrative coherence and meaningful responses to events. Additionally, involvement may also be influenced by individual factors such as attention, motivation, prior experiences, and immersive potential, a term proposed by Agrawal et al. (2020) to describe the user's subjective predisposition to engage in virtual environments.

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Technological factors can influence embodiment, which may have a positive effect on learning outcomes (Klingenberg et al., 2024). Embodiment, as highlighted by Johnson-Glenberg (2018), refers to the idea that learning is enhanced when students actively engage with the content using their bodies through gestures, physical movements, or object manipulation in virtual environments. In virtual reality, this sensation typically occurs when the participant looks down from a first-person perspective and sees a virtual body replacing their own — especially when that virtual body is programmed to move synchronously with the participant's real movements (Klingenberg et al., 2024). In addition, it is important to consider that the development of psychomotor skills, such as the dexterity and coordination required to navigate and interact within the virtual environment, also plays a crucial role in the learning process. The learner's ability to operate the technology can influence both how they interact with the experience and their capacity to engage immersively in the activities (De Freitas et al., 2010).

Methodology

This study adopts the methodological approach of Design-Based Research (DBR), which is structured in three phases. DBR is characterized by iterative cycles of design, implementation, analysis, and redesign, aiming both at the development of practical solutions and the advancement of theoretical understanding in real educational contexts (Zheng, 2015). As highlighted by Tinoca et al. (2022), this approach is recognized for its capacity to promote innovation and transformative interventions, particularly through authentic and integrated teaching and learning practices. A more detailed account of the iterative process followed in this research is available elsewhere (Bicalho et al., 2023). The phases of this study are described below:

(1) A systematic literature review (Bicalho et al., 2024), which identified gaps and opportunities in the use of immersive technologies in education, offering insights for the construction of pedagogical frameworks.
(2) The development and validation of the iVRPM (Bicalho et al., 2025), which aligns key affordances of immersive environments with educational objectives.
(3) The planned implementation and validation of the framework through an educational prototype with higher education students.

This article focuses on Phase 2, specifically on demonstrating how the iVRPM framework enables the alignment between iVR affordances and educational activities. It presents a mapping strategy that links different levels of interactivity to specific learning objectives and task types, grounded in Bloom's revised taxonomy (Anderson et al., 2001) and supported by recent literature on immersive learning.

Developed within the scope of a DBR methodology, the iVRPM framework integrates three main theoretical references: (i) the Cognitive-Affective Model of Immersive Learning (CAMIL) (Makransky & Petersen, 2021); (ii) the XR ABC Framework (Lion-Bailey et al., 2019); (iii) Bloom's Revised Taxonomy (Anderson et al., 2001).

The following section details the iVRPM, emphasizing its underlying logic and how it organizes the articulation between immersive virtual reality affordances and educational objectives.

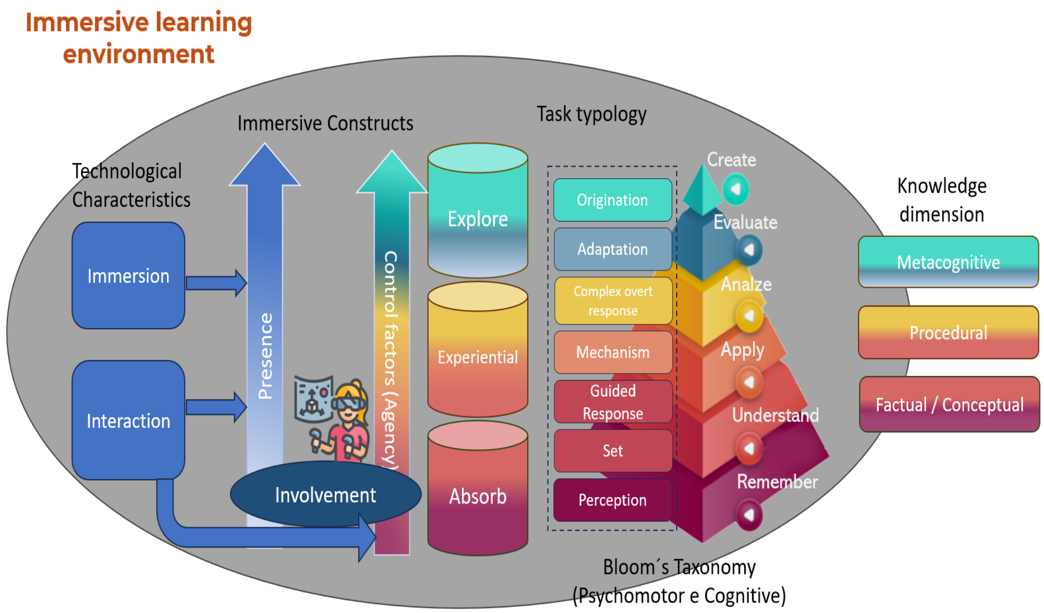
iVRPM - Immersive Virtual Reality Pedagogical Model

The iVRPM was developed to guide pedagogical planning in iVR environments, addressing the theoretical gap identified in the literature regarding the lack of structured models that integrate their technological aspects of iVR with educational goals (Bicalho et al., 2024; Radianti et al., 2020).

The proposed framework establishes a relationship between technological features of virtual environments, such as Immersion and Interaction, and educational objectives, using the revised Bloom's Taxonomy as its foundation (Anderson et al., 2001). Figure 1 illustrates its core components.

Figure 1

Pedagogical Framework - iVRPM: Immersive Virtual Reality Pedagogical Model (Bicalho et al., 2025)



The iVRPM establishes a positive relationship between the technological characteristics of immersion and interaction, highlighting how the combination of sensory fidelity (realism) and the interactive capabilities of the environment contribute to the construction of the sense of Presence. In addition, the framework suggests that the degree of alignment between the user's movements and the virtual environment's response enhance the sense of Control (Agency). These dimensions are strongly associated with student involvement, understood as a psychological state in which focus and energy are directed toward specific stimuli or activities (Shadiev et al., 2021). The framework proposes that involvement increases as Presence and Agency are intensified, and in turn, reinforces these sensations, generating a cycle that amplifies the immersive experience. This cycle is directly aligned with the concept of believability, as proposed by Zilles Borba (2023), which synthesizes the perception of reality as the result of the interplay between the sensory, interactive, and subjective aspects of the experience.

Based on this foundation, the iVRPM suggests that educational activities in iVR can be structured into different levels, depending on the affordances offered by the environment, with an emphasis on interaction. This approach takes into account recent technological advancements, such as increased visual fidelity, hand tracking, more intuitive controllers, and greater freedom of movement, that make immersive environments more responsive and sensitive to user actions. This stratification is justified by the limitations of the traditional binary division between low and high immersion, commonly applied to immersive technologies, which does not fully account for the variety of possible experiences within highly immersive environments. Although "high immersion is typically associated with the exclusion of the physical world and multisensory stimulation" (Cummings & Bailenson, 2016), different combinations of Immersion and Interaction can result in qualitatively distinct educational experiences.

To this end, the iVRPM proposes a stratification of immersive experiences into three levels based on the user's ability to control, interact with, and influence the virtual environment. These levels are:

- **Absorb**: Passive participation, limited interaction, minimal feedback, and no significant bodily involvement.
- **Experiential**: Active participation, object manipulation with congruent gestures, immediate feedback, and partial bodily involvement.
- **Explore**: Autonomous participation, creation and modification of the environment, full bodily engagement, and immediate, responsive feedback.

This proposal is further enriched by the sensory and action-related elements described by Won et al. (2023), which include aspects such as visual and auditory fidelity and responsiveness to user actions.

The dimensions of *Participation*, *Feedback/Assessment*, and *Engagement Strategy*, as proposed by Mystakidis and Lympouridis (2024), are used as a supportive reference to enrich the description of the levels in the iVRPM. These dimensions help articulate how users engage with the simulation (Participation), how the system responds to their actions (Feedback), and how the experience maintains user motivation (Engagement). *Participation* (Dimension (Dim.) 12) ranges from passive observation to active content creation. *Feedback / Assessment* (Dim. 13) includes various levels of system responsiveness, from no feedback to automated evaluations and post hoc expert reviews. *Engagement Strategy* (Dim. 14) encompasses methods such as task-only execution, gamified elements, storytelling, and world-building. To operationalize this alignment, each iVRPM level can be described through these dimensions:

- **Absorb –** Observation, None or Basic Mediation, Task only
- **Experiential –** Guided/Unguided Practice, Automated Feedback, Gamification/Narration
- **Explore –** Content Authoring, Immediate Feedback/Debriefing, World Building

The revised Bloom's taxonomy is structured as a bidimensional matrix, combining cognitive processes (such as remembering, applying, or creating) with types of knowledge (factual, conceptual, procedural, and metacognitive). In the context of the iVRPM, this structure is preserved by associating each interaction level with both a cognitive level and a knowledge dimension. Rather than establishing rigid classifications, the framework identifies predominant combinations that tend to emerge from the affordances activated at each level. This approach allows educators to align immersive tasks with pedagogical intentions more precisely, ensuring that interaction design supports the type of learning expected in each activity.

Building on this association, the level of interactivity in immersive activities can help educators align specific learning objectives with Bloom's revised taxonomy and the corresponding types of knowledge involved. At the **Absorb** level, tasks are designed to support the *Remember* and *Understand* stages of the cognitive domain, involving simple navigation and content interpretation, and are associated with factual and conceptual knowledge. The **Experiential** level corresponds to *Apply* and *Analyze*, offering moderate interactivity through object manipulation and simulations that promote conceptual and procedural knowledge. Finally, the **Explore** level aligns with the *Evaluate* and *Create* stages of Bloom's taxonomy, supporting high interactivity, learner autonomy, and active involvement through the construction and modification of content within the virtual environment. This progression also highlights the psychomotor demands of immersive environments, requiring learners to engage cognitively while navigating and interacting through embodied action.

In addition to aligning interactivity levels with cognitive objectives, the iVRPM also considers the activation of psychomotor processes, based on Simpson's taxonomy (Simpson, 1972). Each proposed level entails increasing demands in terms of motor skills and the degree of embodiment required from the learner. In the initial stages, perceptual involvement and guided gestures are sufficient, whereas more advanced levels require greater coordination, spatial awareness, and full-body involvement. Moreover, the effective execution of immersive tasks depends on the learner's familiarity with the devices, which directly influence agency and performance.

Table 1 summarizes how the psychomotor levels proposed by Simpson (1972) can be interpreted within the context of the iVRPM, illustrating the progression of motor and embodied demands across the three interaction levels.

Table 1

Interpretation of Simpson's Psychomotor Levels in the Context of iVRPM

	Simpson's Psychomotor Levels *(1972)*	Description
Absorb	1. Perception	Recognition of simple sensory stimuli in the virtual environment, with minimal bodily interaction.
	2. Set	Initial readiness for action with basic tasks and visual guidance.
	3. Guided Response	Execution of basic actions with support, including trial and error.
Experiential	4. Mechanism	Confident execution of actions, with greater motor integration and precision.
	5. Complex Response	Advanced motor skills with increased control and coordination.
Explore	6. Adaptation	Autonomous adjustment of movements in response to the complexity of the environment.
	7. Origination	Creation of novel motor solutions and fully integrated actions with complete freedom.

Thus, the iVRPM proposes a structure that relates levels of interactivity to educational goals, taking into account technological affordances, task complexity, and the skills required for the use of iVR. The framework aims to support the planning of educational experiences in immersive environments by providing criteria to organize activities according to learning objectives.

Conclusion

Designed as a theoretical contribution, the iVRPM offers a conceptual structure to support the alignment between the affordances of immersive virtual reality and educational objectives. By organizing immersive learning experiences into three interactivity levels (Absorb, Experiential, and Explore), the framework helps to map tasks to different stages of Bloom's Revised Taxonomy (Anderson et al., 2001), ranging from recognizing and understanding content to applying, analyzing, evaluating, and creating within virtual environments.

This alignment is reinforced by the concept of believability (Zilles Borba, 2023), which frames the virtual experience as the result of the integration of realism, interactivity, and involvement. These dimensions contribute to the perception of reality by combining sensory fidelity with the immersive environment's ability to focus and sustain learner attention, thereby influencing presence and agency.

Within the iVRPM, these dimensions are reflected in the definition of interactivity levels, which are associated with both cognitive processes and dominant knowledge types (factual, conceptual, procedural, and metacognitive). By helping educators to balance technological affordances with pedagogical intent, the framework supports the design of meaningful and coherent immersive learning experiences, taking into account task complexity and learner capabilities. In addition, the framework considers the psychomotor aspects involved in immersive learning, incorporating the development of embodied skills. By proposing this articulation, it offers a theoretical contribution aimed at guiding pedagogical design in immersive environments.

Future research should investigate its practical application in real educational contexts, exploring its effects on student performance and the effectiveness of the planned immersive experiences.

Notes

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