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From Experience to Practice: A Lightweight XR Interface for Skill-Building Across Devices

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Abstract. Immersive learning environments are increasingly adopted across educational contexts; however, many XR implementations remain costly, platform-dependent, or insufficiently aligned with pedagogical goals. This extended abstract introduces a cross-platform XR User Interface (XUI), a lightweight pedagogical overlay designed to support skill development, learner well-being, and self- and co-regulated learning across mobile, tablet, desktop, and VR devices. The XUI integrates goal-oriented navigation, embedded "Insight Zones," progress indicators, and facilitator materials within QR-accessible 360° environments. Seven skill-building XR activities demonstrate how the framework transforms immersive environments into structured practice spaces rather than passive experiences. Across museum, classroom, and community deployments (n ≈ 180 learners), practice-based evidence suggests increased engagement, sustained participation, and improved educator confidence. This work contributes a scalable, accessibility-oriented interface model that decouples pedagogical scaffolding from hardware constraints and advances equitable immersive learning implementation.

Keywords: Accessible XR, Self-Regulated Learning, 360° Learning Environments, Skill Development, Cross-Platform Design.

1 Introduction

Immersive learning technologies are increasingly integrated into classrooms, museums, and informal learning environments. Despite their promise, many XR implementations remain limited by high hardware costs, platform fragmentation, technical complexity, and insufficient pedagogical integration [6, 9]. These constraints disproportionately affect under-resourced institutions and historically underrepresented learners.

This paper introduces the XR User Interface (XUI), a reusable, cross-platform pedagogical overlay for 360° immersive environments. Rather than emphasizing high-fidelity hardware, the XUI centers instructional scaffolding, self-regulated learning, and learner well-being across devices. The framework reframes immersive environments as structured practice spaces in which learners explore, make decisions, monitor progress, and reflect.

The contribution of this work is threefold:

1. A modular XR interface architecture decoupled from hardware constraints
2. Integration of self- and co-regulated learning principles into immersive interaction design
3. Demonstration of cross-context deployment through seven applied skill-building module

2 The XR User Interface (XUI): Core Contribution

2.1 Architectural Overview

The XUI functions as a pedagogical overlay applied to 360° media environments. It does not require proprietary headsets or specialized development platforms. Experiences are deployable via URL or QR code and function across mobile, tablet, desktop, and VR browsers.

Unlike platform-locked immersive systems, the XUI separates immersive media (360° imagery, video, 3D objects), instructional scaffolding (interface components), and facilitation layers (educator support materials). This modular structure enables portability, scalability, and educator adaptability across contexts. Fig. 1 illustrates the layered architecture of the XUI and its core interface components.

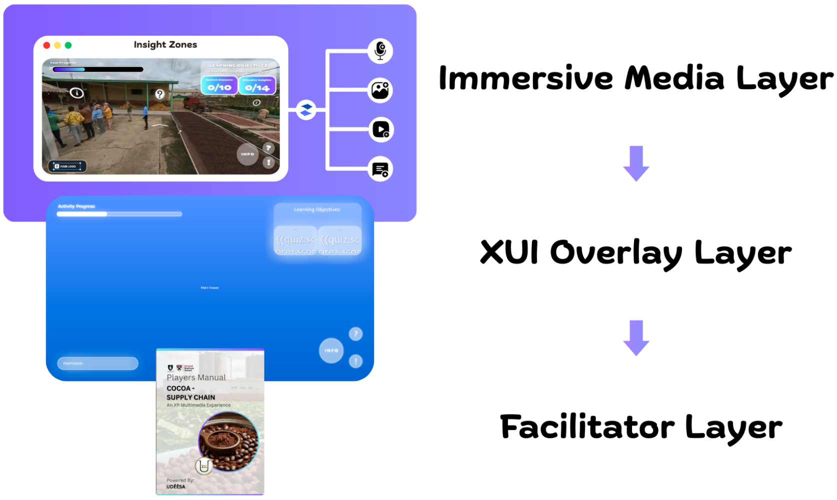

Fig. 1. XR User Interface (XUI) Architecture.

This modular design enables portability and scalability.

2.2 Core Interface Components

The XUI consists of four reusable components:

Goal-Oriented Navigation. Learners are presented with explicit objectives that frame exploration as task-based rather than passive observation.

Insight Zones. Embedded interactive nodes within the 360° environment that include:

1. Informational prompts
2. Multiple-choice questions
3. Collectables
4. Reflection cues
5. Embedded media

Insight Zones are aligned with curricular goals and skill pathways.

Progress Indicators. Visual feedback systems (e.g., question counters, completion meters) support monitoring and pacing, consistent with self-regulated learning research [12].

Facilitator Materials. Each module includes:

1. URL-based deployment instructions
2. Structured “Player Manuals”
3. Reflection prompts for group discussion
4. This reduces educator technical burden and supports classroom integration.

2.3 Cross-Device Portability

The XUI is browser-based and device-agnostic. Portability is achieved through:

1. WebXR compatibility
2. Lightweight interface overlays
3. QR-based access
4. No dependency on high-end GPUs

This architecture reduces economic barriers while preserving immersive affordances.

3 Pedagogical Foundations

The XUI is grounded in three intersecting research domains:

3.1 Self- and Co-Regulated Learning

Self-regulated learning (SRL) involves goal-setting, monitoring, and reflection [11, 12]. Co-regulated learning extends this process socially [5]. The XUI operationalizes SRL through:

1. Explicit learning objectives
2. Visible progress tracking
3. Structured reflection prompts
4. Facilitator-guided discussion

3.2 Learner Well-Being and Responsible Innovation

The framework draws from the RITEC-8 principles for responsible technology design for children [4]. Design priorities include:

1. Emotional safety
2. Achievable challenges
3. Transparent feedback
4. Age-appropriate scaffolding

3.3 Accessible Immersive Learning

Systematic reviews note that XR effectiveness depends on pedagogical integration rather than technological novelty [6, 9]. The XUI aligns with calls for accessibility-focused immersive design [1, 8].

4 Demonstration Modules

Seven XR skill-building activities illustrate the XUI's adaptability. Three are described in detail below.

4.1 Rockthrower: Problem-Solving and Perseverance

Learners explore a 360° historical environment where they must identify strategic decision points. Insight Zones prompt evaluation of contextual evidence before proceeding. Progress indicators track completed challenges. Reflection cues encourage learners to articulate reasoning. This module emphasizes iterative reasoning and persistence.

4.2 Roadbuilder: Cooperation and Systems Thinking

This experience situates learners within a collaborative infrastructure scenario. Insight Zones require identification of interdependent system components. Facilitator prompts support group-based discussion, reinforcing co-regulated learning.

4.3 Anansi XR Storybook v1.2: Cultural Storytelling and Skill Transfer

Embedded cultural storytelling integrates multiple Insight Zones aligned with adaptability, reflection, and cooperation. Collectables reinforce narrative comprehension while supporting skill generalization.

Four additional modules (Foresight, RiverDrinker, Searskinner, Cushion) apply the same XUI scaffolding across distinct thematic contexts, demonstrating framework consistency.

5 Practice-Based Evidence

The XUI has been deployed across six institutional contexts including museums, K–12 classrooms, and community youth programs (n ≈ 180 learners, ages 10–17). Evidence collection included:

1. Facilitator surveys
2. Structured observational field notes
3. Completion tracking analytics
4. Post-activity reflection discussions

Educators reported:

1. Increased sustained participation relative to prior non-immersive lessons
2. Higher completion rates of structured tasks
3. More frequent peer discussion during reflection phases
4. Increased confidence implementing XR without technical support

While not derived from controlled experimental trials, these deployments provide practice-based evidence of feasibility and scalability. Fig. 2 shows a representative XUI-enabled educator-curated interactive 360-media experience following the supply chain of shea.

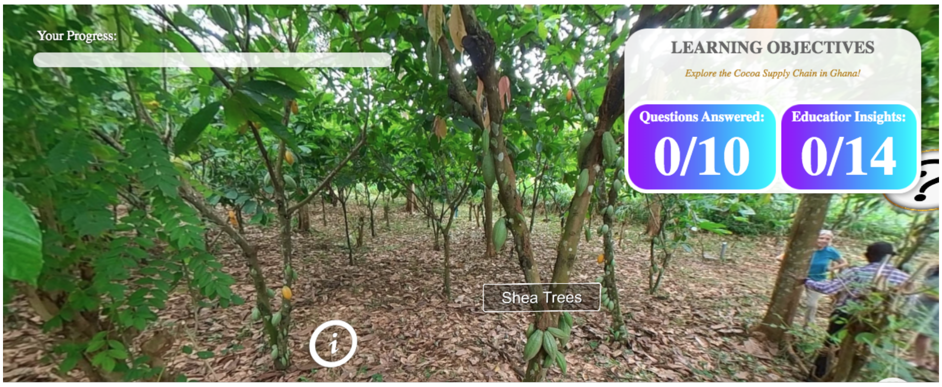

Fig. 2. An educator curated interactive 360-media experience following the supply chain of a shea.

6 Limitations and Trade-Offs

This work presents a practice-based framework rather than results from randomized controlled studies. Future research should include longitudinal and comparative experimental designs to measure skill transfer and retention outcomes.

The lightweight architecture prioritizes accessibility over high-fidelity interactivity; therefore, certain forms of embodied simulation may not be supported. Additionally, effective implementation depends on facilitation quality, particularly in classroom contexts.

Scalability across diverse institutional infrastructures may require further optimization of bandwidth and device compatibility.

7 Conclusions and Recommendations

This work suggests that effective immersive learning depends more on pedagogical scaffolding than on hardware sophistication. Key recommendations include:

1. Designing XR interfaces as instructional scaffolds rather than visual layers
2. Decoupling pedagogical architecture from proprietary hardware
3. Supporting educator co-creation
4. Evaluating immersive learning through learner agency and regulation, not novelty

The XUI offers a scalable model for equitable immersive learning adoption across formal and informal contexts.

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