Making Sense of Immersive XR Learning in Secondary Instruction

XR ASSOCIATION

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Overview

Extended reality (XR) technologies are becoming increasingly present in secondary schools. Many teachers are open to using immersive XR technologies for teaching and learning, but are unclear about how they **strengthen instruction beyond novelty**.

> This paper provides examples of ways it can be incorporated in secondary classrooms, **supporting spatial reasoning, disciplinary thinking, academic discourse, and career-connected learning.** It draws from research to help to decide when and where it belongs in your instruction.

Photo Credit: ReframeXR

Where 3D Spatial Reasoning Strengthens Learning

The most common area where immersive learning can improve student outcomes is in three-dimensional systems reasoning, where students move through systems, manipulate their components, and examine structural relationships from multiple angles and perspectives. That matters most in subjects where structure and spatial relationships drive understanding.

Experiential learning research shows that experience supports learning when it is followed by reflection and conceptualization[1]. Immersive technologies provide direct interaction with three-dimensional systems. **The learning happens when teachers connect it to explanation, modeling, discourse, and assessment.**

Meta-analyses of immersive learning report moderate positive effects on learning when experiences are brief, aligned to clear objectives, and paired with instructional guidance.[2,3] The strongest gains appear in areas that rely on spatial reasoning and systems thinking. Research on spatial cognition shows that students perform better when they can manipulate and inspect three-dimensional relationships directly rather than relying solely on mental transformation[4,5]. This is particularly relevant in subjects where understanding depends on how parts relate within a whole system.

In secondary classrooms, this includes:

- **Chemistry** topics such as molecular geometry, bond angles, and intermolecular forces
- **Physics** concepts involving vectors, forces, torque, and field interactions
- **Earth Science** topics like plate tectonics, erosion systems, and atmospheric circulation
- **Mathematics** concepts including rotations, cross-sections, solids of revolution, and coordinate transformations
- **History & Social Studies** topics involving geographic positioning, trade routes, territorial change, and urban development
- **Humanities** units requiring perspective-taking within physical spaces, such as battlefield strategy, migration patterns, or architectural context
- **Career & Technical Education (CTE)** pathways such as nursing (anatomical systems, patient simulation), forensic investigation (crime scene reconstruction, spatial evidence mapping), and emergency response training

In each case, students must reason about structure, orientation, scale, interaction, or positional relationships. Immersive learning can make these relationships visible and interactive. When students can inspect internal components, shift perspectives, or observe how spatial arrangements influence outcomes, they often develop clearer explanations and more accurate interpretations.

In social studies, students can examine how economic, political, and geographic variables interact within a modeled environment. In literature, immersive reconstruction of the setting can support analysis of how the physical environment shapes character decisions and plot development.

> Research does not suggest that immersive learning improves all academic outcomes. **It indicates that immersive learning is particularly effective when the target task requires spatial transformation, relational reasoning, perspective shifts, or understanding interactions within dynamic systems.** [2] [3] [4] [5]

Photo Credit: TransfrXR

Choosing the Right Immersive Modality for the Task

Immersive learning takes many forms in secondary classrooms. We are going to focus on what is considered the XR or Extended Reality immersive learning that typically takes three forms: virtual reality (VR), mixed reality (MR), and augmented reality (AR). Each creates different cognitive and instructional conditions. **The learning objective should determine the modality.**

Virtual Reality (VR)

VR places students inside a fully digital environment using head-mounted displays. VR is most appropriate when full environmental immersion supports the objective. This includes reconstructed historical settings, inaccessible scientific or work environments, and large-scale simulations that benefit from **sustained digital context and reduced physical distraction**.

Mixed Reality (MR)

MR anchors digital content directly within the physical classroom. Students can move around and interact with persistent 3D content while remaining visually connected to peers, teachers, and materials.

MR is especially useful when students need to think spatially while referencing notebooks or text, engage in real-time discussion around shared content, or transition fluidly between digital and physical representations. Because digital content coexists with the environment, MR can **lower cognitive load associated with switching contexts**.

Augmented Reality (AR)

AR overlays digital content onto physical materials using tablets or phones. It integrates easily into existing lessons and works well for layering spatial information onto labs, diagrams, or texts with minimal setup.

> **All three modalities support reasoning and collaboration.** VR emphasizes immersion within a digital environment. MR emphasizes interaction between digital content and physical space. AR emphasizes lightweight enhancement of existing materials.

Suggested Time in Head-Mounted Displays

Immersive segments are typically **most effective when limited to 5–20 minutes** within a larger lesson. Short, focused sessions preserve time for discussion and analysis and reduce fatigue. Longer sessions do not consistently produce stronger learning gains.[2] [3] Immersive learning functions best as part of a structured instructional sequence.

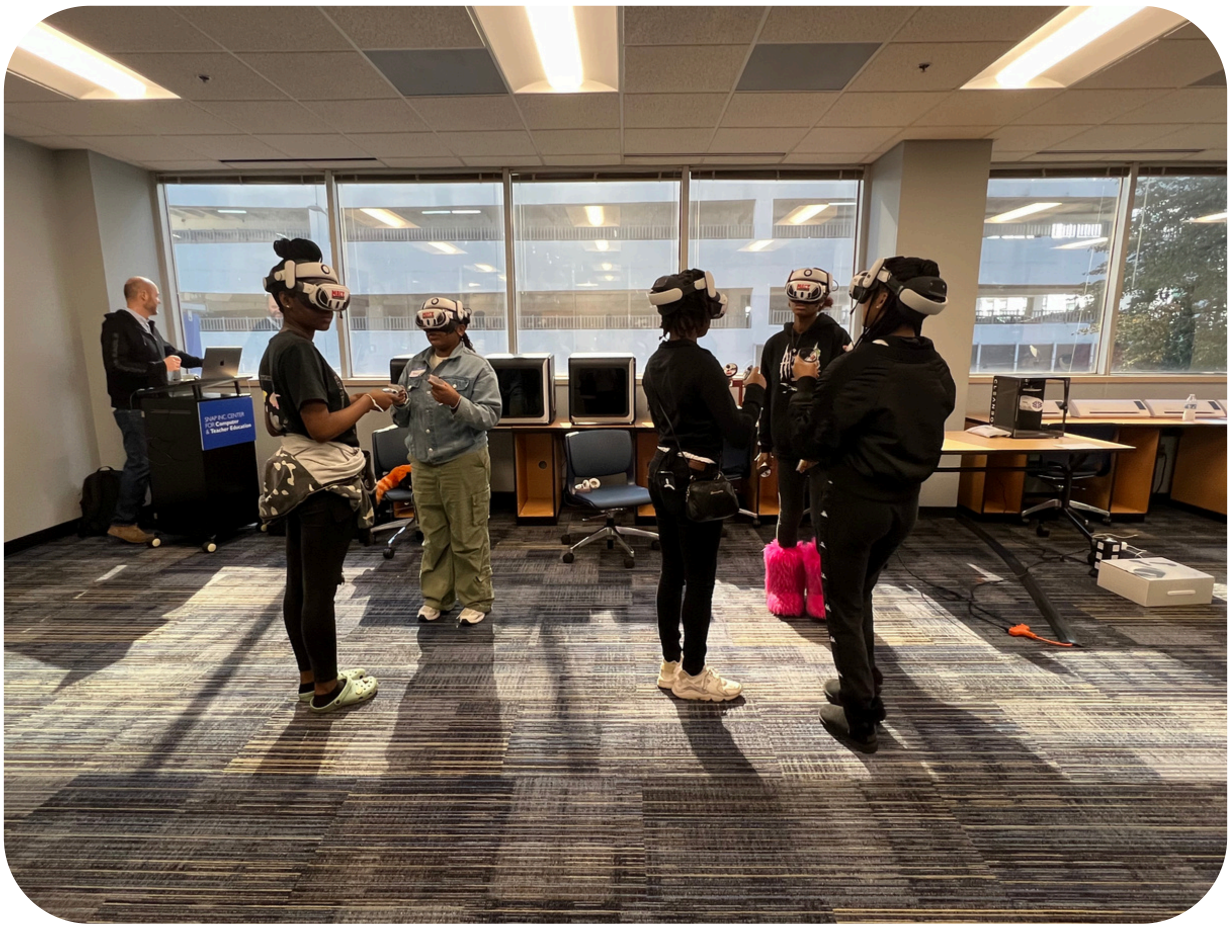

Photo Credit: XR Association

Turning Immersive XR Learning into Academic Discourse

Immersive XR learning can better support deeper understanding when students interpret and explain what they are exploring while the representation is still available to them.

Research on working memory and cognitive load shows that **learning improves when students can reference information directly** rather than reconstruct it from memory later.[7] This is especially important for multilingual learners and neurodiverse students, for whom extended recall demands can increase cognitive load and reduce precision in explanation. Research on academic discourse similarly shows that structured, evidence-based conversation strengthens **conceptual understanding and technical language development**.[6]

In practice, this means supporting explanations as closely as possible to the XR experience.

- In multi-user experiences, **students can collaborate** inside the immersive environment and reference elements as they explore.
- In single-user experiences, teachers can shorten immersive segments and follow them immediately with **structured prompts** tied to specific observed features.

Across modalities, students benefit when they are asked to:

- **Explain** what they observed
- **Compare** models or scenarios
- **Construct** claims supported by evidence
- **Apply** concepts to new problems

> Aligning immersive XR learning with **real-time observation and structured discourse** supports stronger reasoning than relying on delayed recall alone.

The DICE Framework:
A Guide to Decide When Immersive XR Learning Fits

Research from Stanford's Virtual Human Interaction Lab suggests that immersive XR learning is most effective when it is used to provide access to experiences that are **difficult or impractical to replicate** in the real world.[8] The DICE framework offers a practical lens for identifying those opportunities:

Dangerous
Situations that would pose safety risks in real life

Impossible
Environments or scales that cannot be accessed physically

Counterproductive
Real-world scenarios that would significantly disrupt instruction

Expensive
Experiences that require prohibitive cost or resources

Use DICE as a decision filter during lesson planning. Start with the learning objective—not the tool—and ask whether the experience students need meaningfully falls into one of the four categories:

- *Does the objective require students to engage with something **dangerous** to replicate in real life?*
- *Does it involve phenomena that are **impossible** to access because of scale, time, or location?*
- *Would attempting it physically be **counterproductive** to instruction?*
- *Or would providing authentic access be **expensive** beyond normal classroom constraints?*

If the answer is yes to one or more of these, immersive XR experiences can be a great amplifier to any lesson.

> DICE is not a checklist for adding technology; it is a clarity tool for matching modality to purpose. The stronger the DICE alignment, the stronger the instructional rationale for immersive XR learning. When correctly evaluated, XR becomes a **purposeful way to give students structured access to experiences that would otherwise remain abstract, inaccessible, or impractical.**

Final Consideration

The examples throughout this paper are not a comprehensive list of where immersive XR learning belongs. They illustrate patterns of potential usage. When learning requires students to reason about three-dimensional structure, navigate systems, examine scale, or access experiences that meet a DICE condition, immersive XR can strengthen clarity and depth of understanding.

> **The key is alignment.** Immersive experiences should be tied to a clearly defined objective, integrated into a structured lesson sequence, and followed by explanation, discussion, and application. When XR is used to make relationships visible, support evidence-based discourse, and give students access to experiences they otherwise could not examine, it can become a powerful instructional tool.

For more information on how XR can be designed for youth and accessibility take a look at XRA's Developers Guides Chapter Four: Designing Immersive Learning for Secondary Education[9] and Chapter Three: Accessibility & Inclusive Design in Immersive Experiences.[10]

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