# The Virtual Lens: Reframing Human Learning

## Using Evidence From Non-Immersive Virtual Reality (VR) in STEM Education to Reveal Principles of Effective Human Learning

**Author**: Ella Haskins | **Supervisor:** Dr Clare Tweedy

**Research Question:**

### What can the effectiveness of non-immersive VR in STEM education indicate about how humans learn?

**Aims:**

- Map the evidence of the effectiveness of non-immersive VR in STEM education
- Identify the experiential learning mechanisms associated with positive learning outcomes
- Explore what these mechanisms suggest about human learning

## Background

- Effective STEM learning requires learners to actively engage with and apply concepts
- Experiential Learning Theory proposes that learning occurs through active participation and experience
- Non-immersive VR is an accessible technology, providing interactive experiences that improve STEM learning outcomes
- Non-immersive VR remains relatively under-studied
- Existing research prioritised investigating non-immersive effectiveness over the learning processes it supports


## Methods

**Identification of studies via databases and registers**

**Identification**

1025 studies were identified from 6 databases:
Scopus (n = 433)
PubMed (n = 209)
Web of Science (n= 189)
ERIC= (n= 20)
Dimensions (n= 34)
OVID= (n= 242)

**Records removed before screening:**
Duplicate records removed (n = 101)
Records marked as ineligible by automation tools (n = 0)
Records removed for other reasons (n = 0)

**Screening**

Records screened (n = (924) → Records excluded** (n = (837)

Reports sought for retrieval (n = (87) → Reports not retrieved (n = 9)

Reports assessed for eligibility (n = (78) → Reports excluded n = (27)

**Included**

Studies included in review (n = 51)
Reports of included studies (n = 51)

## Results

### Theme 1- Learning through action: The role of embodiment:

**Active, embodied interaction supported conceptual understanding, retention and practical performance**

- Active interaction, procedural practice and concept enactment supported learning
- Higher embodiment was associated with increased agency, engagement, and learning performance
- Linking abstract concepts to meaningful physical actions enhanced retention and concept application
- **Key Statistic:** 8.07 vs 3.15 agency score for high vs low embodiment

### Theme 2- Spatial Cognition: Seeing, Navigating, Understanding:

**Spatial cognition shapes how learners construct, manipulate and apply knowledge**

- Spatial representations and visualisation supported spatial reasoning and understanding
- Mental model construction enabled learners to understand relationships and complex systems
- Visual cues supported memory encoding and knowledge application
- **Key Statistic:** Spatial ability scores increased from 7.1 to 9.33 following non-immersive VR training

### Theme 3 – Learner Agency: Self-Directed Learning:

**Self-regulation and autonomy promoted reflection, motivation and achievement**

- Learner control and autonomy promoted active learning, reflective thinking, and motivation
- Metacognitive regulation supported learning through evaluation and self-monitoring.
- Confidence and self-efficacy were associated with greater engagement and persistence
- **Key Statistic:** Metacognitive regulation accounted for approximately 1/3rd of knowledge gains

### Theme 4 – Design Matters: Guidance, Load, Inclusion:

**Implications of design on cognitive load, attention and learning**

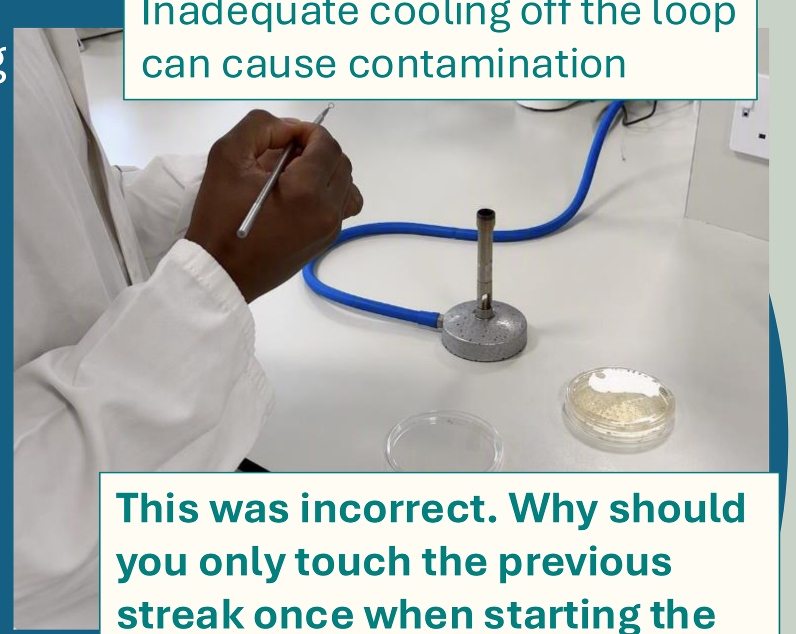
- Learning outcomes were influenced more by instructional design than the technology itself
- Scaffolded guidance and instructional prompts improved attention, reflection, and knowledge transfer
- Accessible learning environments managed cognitive demands and supported diverse learners
- **Key Statistic:** Structured instructional guidance increased knowledge retention from 45 to 65%

| Learning principle | Recommendations |
|---|---|
| Active Learning | Prioritise active learning experiences that require learners to manipulate, apply, and interact with material |
| Cognitive Load | Minimise cognitive load and focus attention to relevant information |
| Accessibility | Use visual-spatial representations and interactive manipulation to support the application of mental models |
| Mental Models | Design learning environments that accommodate individual differences in spatial ability, attention, and sensory processing |
| Self-regulation | Embed opportunities for self-monitoring, reflection, and learner control |
| Self- Efficacy | Incorporate strategies that build learner confidence |
| Instructional Guidance | Use scaffolded discovery rather than unguided exploration during complex learning tasks, gradually reducing support as understanding develops |

## Evidence to Action

1. **Perform procedure** - Active Learning
2. **Receive feedback** - Instructional Guidance
3. **Reflection**- Self-Regulation
4. **Focus on relevant information** - Cognitive Load

**Wrong, Try Again:**
Inadequate cooling off the loop can cause contamination



**This was incorrect. Why should you only touch the previous streak once when starting the next section?**

- ❑ To make bacteria grow more quickly
- ❑ To dilute bacteria progressively so individual colonies can form
- ❑ To spread as many bacteria as possible across the plate

## Conclusion: Next Steps

**Key Takeaway:**

- Effective STEM learning is supported by active engagement, spatial exploration, learner agency, and appropriate scaffolding

**Why It Matters:**

- Designing learning around these principles could support more inclusive and effective STEM education

**What next:**

- Continue to translate evidence into the design of accessible, inclusive and engaging real-world STEM education

Reference List: