

Learning Experience Assessment Report – WP 2

1. Introduction and Purpose

The Learning Experience Assessment aims to provide a comprehensive understanding of the experiences, needs, perceptions and learning challenges of the primary STEM-IT target groups in relation to the use of **Augmented Reality (AR) and Virtual Reality (VR) in STEM education**.

The assessment has two complementary purposes. First, it investigates users' perceptions of AR/VR-supported learning, with particular attention to **perceived ease of use, accessibility, engagement, motivation, interest and satisfaction**. Second, it identifies STEM concepts and topics that learners find difficult to understand and retain and which could therefore particularly benefit from interactive, immersive and visual forms of representation.

The assessment adopts a **mixed-methods approach**, combining quantitative questionnaire data with qualitative information obtained through open-ended survey questions and in-depth online interviews. A retention assessment on selected STEM topics complements these measures by examining not only participants' immediate learning experience but also the extent to which understanding is maintained over time.

This approach is particularly important in light of the systematic review undertaken within STEM-IT. The review analysed **204 empirical studies** and distinguished between conceptual understanding—*knowing why*—and procedural understanding—*knowing how*. Its findings indicate that secondary students frequently demonstrate procedural competence while their conceptual understanding remains fragmented or unstable.

• 2. Assessment Framework

The Learning Experience Assessment will integrate established constructs from three complementary frameworks:

Technology Acceptance Model (TAM) will inform the assessment of participants' acceptance of AR/VR technologies, particularly their perceptions concerning the usefulness and ease of using immersive technologies for STEM learning.

Instructional Materials Motivation Survey (IMMS) will inform the assessment of the motivational characteristics of the learning experience, including participants' attention, perceived relevance, confidence and satisfaction.

Task Interest Scale (TIS) will contribute to the assessment of participants' situational interest and engagement with the STEM learning tasks supported by AR/VR.

Rather than administering these instruments independently, relevant constructs will be integrated into a **custom STEM-IT Learning Experience Assessment Scale** appropriate to the project's objectives and target groups.

The resulting instrument will investigate four principal dimensions:

Dimension	Indicative focus
Ease of use	Navigation, interaction, clarity, technological effort
Accessibility	Ability to access and interact with AR/VR resources, barriers and support needs
Engagement & interest	Attention, curiosity, immersion, willingness to explore
Satisfaction & perceived value	Enjoyment, perceived usefulness, confidence and willingness to use AR/VR again

The quantitative component will be complemented by qualitative questions designed to explore **why participants respond in particular ways**, what they expect from immersive STEM learning, what difficulties they encounter and what improvements they consider necessary.

• 3. Target Groups and Data Collection

Data will be collected from the project's primary target groups, with **at least 15 participants per partner, except MATH**, in accordance with the project methodology.

UoA will coordinate the development of the assessment instrument by defining the scope of the survey and preparing an initial pool of questions. The proposed items will subsequently be reviewed collaboratively by the project partners to ensure relevance across different national, educational and STEM contexts before the final version is administered.

Data collection will comprise three interconnected stages.

Stage 1 – Initial questionnaire. Participants will complete the custom questionnaire incorporating selected TAM, IMMS and TIS dimensions. This stage will generate quantitative evidence concerning ease of use, accessibility, engagement, interest, motivation, satisfaction and perceived educational value. Open-ended questions will simultaneously allow participants to describe their experiences, expectations and difficulties.

Stage 2 – In-depth online interviews. Selected participants will participate in online interviews designed to explore the questionnaire findings in greater depth. Particular attention will be given to participants' goals, perceived benefits, technological and

pedagogical barriers, accessibility issues and recommendations for improving AR/VR STEM resources.

Stage 3 – Retention assessment. NSM and DDE will conduct a retention test focusing on selected STEM concepts. This component is particularly important because retention remains considerably less investigated than immediate comprehension in existing STEM education research. Of the 204 studies included in the project's systematic review, **200 examined current comprehension and only four explicitly addressed retention.**

• **4. Analysis of Questionnaire and Survey Data**

Quantitative questionnaire data will be analysed both descriptively and, where sample size and data quality permit, comparatively.

For each assessment dimension, responses can be summarised using frequencies, percentages, means and measures of dispersion. Composite scores may subsequently be calculated for the major constructs of the custom scale, provided that the final item structure and psychometric properties support such aggregation.

The analysis should answer questions such as:

How easy do participants find AR/VR resources to use? How accessible are the learning environments? To what extent do immersive activities stimulate attention, curiosity and interest? Do participants perceive AR/VR as educationally useful rather than merely entertaining? Are participants satisfied with the experience and willing to use similar resources in future STEM learning?

Importantly, positive technology acceptance should not automatically be interpreted as evidence of successful learning. The systematic review demonstrates that students can successfully perform procedures while still lacking coherent conceptual understanding. Across STEM disciplines, most studies were classified within the **developing comprehension** category, while genuinely integrated conceptual understanding was comparatively uncommon.

Consequently, user experience data should be interpreted alongside qualitative evidence and, where available, retention results.

• **5. Analysis of In-depth Interviews**

The online interviews will provide the qualitative dimension of the Learning Experience Assessment.

A thematic analysis can be organised around five broad categories:

1. **Perceived educational value** – how AR/VR helps participants understand STEM concepts.
2. **Engagement and motivation** – which characteristics stimulate curiosity, exploration and sustained participation.
3. **Usability and accessibility** – technological, cognitive or practical barriers encountered during interaction.
4. **Conceptual understanding** – whether visualisation and interaction help participants understand *why* a phenomenon occurs rather than simply remembering *how* to perform a task.
5. **Needs and recommendations** – participants' suggestions concerning content, design, support, scaffolding and future AR/VR resources.

Particular attention should be paid to recurring comments concerning concepts that participants describe as **abstract, invisible, dynamic, spatially complex or difficult to visualise**. These responses can directly inform the selection and design of resources developed in WP3.

- 6. Identification of Priority Topics within STEM Subjects

The identification of STEM priority topics should not rely on a single source of evidence. Instead, the Learning Experience Assessment can employ a **triangulation process** combining:

- (a) findings from the systematic review;
- (b) teacher and participant questionnaire responses;
- (c) qualitative evidence from interviews; and
- (d) where available, retention-test performance.

This is particularly well supported by the systematic review. Its third research question specifically investigated which STEM topics students find most difficult to understand and retain, and the analysis coded topics by STEM discipline and by the nature of the difficulty encountered. A_Systematic_Review_of_the_Comp...

Preliminary priority topics identified by the systematic review

The evidence provides an excellent starting point for the STEM-IT topic-selection process.

STEM area	Priority topics identified
Physics	Electricity and circuits; force; energy transformations; motion
Chemistry	Chemical bonding and molecular structure; stoichiometry; conservation of matter
Biology	Photosynthesis; cellular respiration; genetics; inheritance
Earth & Environmental Science	Climate systems; carbon cycle; plate tectonics

STEM area	Priority topics identified
Mathematics	Variables and functional relationships; spatial visualisation; rate of change and accumulation; proportional reasoning; proof and deductive reasoning; limits and continuity
Technology/Engineering	Logic and debugging; optimisation and system interdependence; abstraction and algorithm design; representational transfer and systems integration
Integrated STEM	Climate change; energy policy; biotechnology; systems modelling

These priorities are directly supported by the review's synthesis. In physics, **electricity and circuits** emerged most frequently (n=15), followed by force and energy transformations (n=9 each) and motion (n=8). Chemistry difficulties centred particularly on chemical bonding and molecular structure. Biology showed especially pronounced difficulties with photosynthesis, followed by cellular respiration and genetics. Earth and environmental science difficulties included climate systems, the carbon cycle and plate tectonics.

Mathematics presented difficulties in variables and functional relationships and spatial visualisation (n=11 each), followed by rate of change and accumulation, proportional reasoning, proof and deductive reasoning, and limits and continuity. Technology and engineering difficulties included logic and debugging, optimisation and system interdependence, abstraction and algorithm design.

Integrated STEM contexts also revealed significant challenges, particularly **climate change (n=15), energy policy (n=5), biotechnology (n=3), and interdisciplinary projects and systems modelling (n=6)**. These areas are especially interesting because they are cognitively demanding but can support integrated understanding when appropriate scaffolding is provided.

• 7. From Identified Difficulties to AR/VR Educational Resources

The purpose of identifying difficult STEM topics is not simply to compile a catalogue of misconceptions. The findings will inform the **selection and pedagogical design of AR/VR educational resources in WP3**.

Priority should therefore be given to topics that satisfy several criteria simultaneously: they emerge as problematic in the literature; teachers identify them as difficult to teach; learners identify them as difficult to understand or remember; and their characteristics make them particularly suitable for immersive representation.

The systematic review provides a strong theoretical justification for this approach. Many of the most difficult topics require learners to integrate abstract representations with mechanisms that are **invisible, dynamic or systemic**. Examples include molecular

interactions, electricity, forces, energy transformations, cellular processes and complex Earth systems.

This is precisely where AR/VR may offer particular educational value. For example, an AR/VR resource could allow learners to visualise molecular bonding at different scales, manipulate forces and observe resulting motion, enter a three-dimensional cell to explore cellular respiration, visualise energy transformations dynamically, explore plate interactions, or manipulate components of the carbon cycle and observe systemic consequences.

Thus, the final selection should not simply be:

“Which topics are difficult?”

but rather:

“Which difficult STEM concepts could become more comprehensible through spatial, interactive, dynamic or immersive representation?”

This distinction provides a direct and defensible link between **WP2 needs analysis and WP3 resource development**.

- **8. Retention Assessment**

The retention component represents an important added value of the STEM-IT Learning Experience Assessment.

The systematic review demonstrates a substantial research gap: only four of the 204 studies explicitly examined retention. The limited available evidence nevertheless suggests an important pattern. **Procedural knowledge may persist while conceptual understanding deteriorates when learners are not given opportunities for structured reflection and re-engagement.** *A_Systematic_Review_of_the_Comp...*

For example, evidence reviewed in physics indicated that procedural ability relating to force and energy could persist while explanatory reasoning deteriorated without structured review. In mathematics, iterative and reflective learning was associated with stronger performance on a delayed four-week assessment. *A_Systematic_Review_of_the_Comp...*

The STEM-IT retention assessment should therefore go beyond factual recall. Wherever possible, it should distinguish between:

Procedural retention — “Can the learner still do it?”

and

Conceptual retention — “Can the learner still explain why it happens?”

This distinction would substantially strengthen the evaluation of the AR/VR resources because a successful immersive learning experience should ideally contribute not only to engagement and immediate performance but also to **durable conceptual understanding**.

• 9. Integration of Quantitative and Qualitative Findings

The final Learning Experience Assessment should integrate the different sources of evidence rather than reporting them independently.

For example, a STEM topic may receive a high priority when several findings converge: teachers report that students struggle to understand it; learners identify it as difficult; literature identifies persistent misconceptions; retention scores are low; and participants indicate that visualisation or interactive manipulation would support their understanding.

Conversely, a topic that is difficult but primarily requires repetitive procedural practice may be a lower priority for immersive development than a concept involving **three-dimensional structures, dynamic processes, invisible mechanisms, spatial relationships or complex systems**.

A final **Priority Matrix for WP3** could therefore be produced:

Topic	Literature evidence	Survey evidence	Interview evidence	Retention difficulty	AR/VR suitability	Priority
Electricity & circuits	High	To be assessed	To be assessed	To be assessed	High	TBD
Energy transformations	High	To be assessed	To be assessed	To be assessed	High	TBD
Chemical bonding	High	To be assessed	To be assessed	To be assessed	Very high	TBD
Photosynthesis	High	To be assessed	To be assessed	To be assessed	High	TBD
Cellular respiration	High	To be assessed	To be assessed	To be assessed	Very high	TBD
Spatial visualisation	High	To be assessed	To be assessed	To be assessed	Very high	TBD
Climate systems	High	To be assessed	To be assessed	To be assessed	Very high	TBD
Carbon cycle	High	To be assessed	To be assessed	To be assessed	Very high	TBD
Plate tectonics	High	To be assessed	To be assessed	To be assessed	Very high	TBD

The **“To be assessed” entries are important at this stage**. The uploaded document provides the literature evidence, but it does not contain the STEM-IT questionnaire, interview or retention-test results. Those columns should therefore not be populated until actual participant data are available.

- **10. Expected Outcomes and Recommendations**

The Learning Experience Assessment will provide an evidence-based foundation for the development of the STEM-IT AR/VR educational resources. By combining technology acceptance, motivation, task interest, qualitative user experience, conceptual difficulty and retention, the assessment moves beyond a simple evaluation of whether participants “liked” immersive technology.

The findings will allow the consortium to identify **which STEM topics should be prioritised, why learners experience difficulty with them, and which characteristics of AR/VR could be used pedagogically to address those difficulties**.

The systematic review already indicates that the central educational challenge is not primarily students' ability to perform procedures, but the development of coherent, transferable and durable conceptual understanding. Students are more likely to retain knowledge that has been meaningfully integrated, whereas knowledge acquired procedurally without reflection is more vulnerable to fragmentation and decay.

Accordingly, WP3 resources should prioritise **active exploration, multiple representations, manipulation, modelling, inquiry and opportunities for reflection**, rather than using AR/VR primarily for visual attractiveness or technological novelty. The ultimate criterion for successful STEM-IT immersive resources should therefore be their capacity to move learners from **“knowing how” toward “knowing why”**, while supporting engagement, accessibility and sustained understanding.

One important methodological point: I would present the systematic review as **one evidence stream within the Learning Experience Assessment**, not as if it were the questionnaire result. This makes the deliverable much stronger: **systematic review → TAM/IMMS/TIS-based needs assessment → interviews → retention test → priority STEM topics → WP3 AR/VR development**. That gives the whole work package a very clear methodological chain.