Electronic, didactic and innovative platform for learning based on multimedia assets

e-DIPLOMA

Funded by the European Union

Guidelines and best practices extracted from Piloting monitorization

HISTORY OF CHANGES			
Version*	**Publication date**	**Beneficiaries**	**Changes**
V1.0	11.09.2025	TU	▪ Initial version of Deliverable Owner
V1.2	20.09.2025	TU	▪ Version including suggestions of WP Contributors
V1.3	22.09.2025	UPV, UJI	▪ Pre-final version reviewed by Internal Reviewers
V1.4	06.10.2025	TU	▪ Final version approved by Project Coordinator

(*) According to the section “Review and Submission of Deliverables” of the Project Handbook

1. Technical References

Project Number	101061424
Project Acronym	e-DIPLOMA
Project Title	Electronic, Didactic and Innovative Platform for Learning based On Multimedia Assets
Granting Authority	European Research Executive Agency (REA)
Call	HORIZON-CL2-2021-TRANSFORMATIONS-01
Topic	HORIZON-CL2-2021-TRANSFORMATIONS-01-05
Type of the Action	HORIZON Research and Innovation Actions
Duration	1 September 2022 – 31 October 2025 (38 months)
Entry into force of the Grant	1 September 2022
Project Coordinator	Inmaculada Remolar Quintana

Deliverable No.	D3.1: Guidelines and best practices extracted from Piloting monitorization
Work Package	WP3: Piloting and testing of Innovation procedures and technology enhancement
Task	T3.1: Coordinating the codesign
Dissemination level*	PU- Public
Type of license:	CC-BY
Lead beneficiary	Universitat Jaume I (UJI)
PIC of the Lead beneficiary	999882985
Contributing beneficiary/ies	Choose among the following ones: ▪ **Tallinn University (TLU) Contributors: Kai Pata, Terje Väljataga**
PIC of the Contributing beneficiary/ies	Choose among the following ones: ▪ **TLU: 999421653**

Due date of deliverable	30th September 2025
Actual submission date	06th October 2025

1. Executive summary

This report D3.1 Guidelines and best practices extracted from Piloting monitorization provides guidelines for designing practice based e-learning with immersive technologies emerged from the e-DIPLOMA three e-DIPLOMA learning prototypes - Block programming, Social entrepreneurship and VR learning (a detailed description of the prototypes can be found in e-DIPLOMA report D4.3 Course prototypes). The report introduces the important elements of the application of the experiential learning practices using immersive learning spaces. We also use the descriptions of the e-DIPLOMA learning modules to illustrate the guidelines with specific cases from e-DIPLOMA. In the e-DIPLOMA project report D3.5 we have previously formatively evaluated learning issues during e-DIPLOMA piloting of the three prototypes. In this report 3.1 we will use these formatively described problem issues and try to offer possible design solutions. These solutions are supported by the literature review findings we made in the research paper (Pata & Väljataga, 2024) and in the e-DIPLOMA report D2.2 Review of e-learning ecosystems. The current report also complements e-DIPLOMA report D2.1 Best practices report, which focuses on demonstrating how effectively the e-DIPLOMA incorporated pedagogical paradigms into 3 prototypes' modules. While the D2.1 validates the prototypes in regards to the cognitive complexity elements and the achieved knowledge gain as well as describes the learning effects with immersive technologies, the report D3.1 concentrates on outlining problems and solutions together with design guidelines in practice-based e-learning with immersive technologies from an instructional design perspective.

2. Introduction

Emerging learning technologies provide new ways of affording learning within the practice-based e-learning situations. We view in this report the emerging learning technologies generally: immersive learning technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR) and extended reality (XR), and the adaptive AI tools for learning. Virtual reality (VR) is the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a headset with a screen inside or gloves fitted with sensors. VR creates a completely synthetic virtual world which can be used through devices like a headset. VR may be presented within different devices as a smartphone, computer, web based platform, or with headset in physical spaces. Virtual reality (VR) is conceptually a technological system that can precisely substitute a person's sensory input and transform the meaning of their motor outputs with reference to an exactly knowable alternate reality ("knowable" to distinguish from dreams or hallucinogenic experiences). In this view motor actions and sensory input are not separable. VR produces an illusion of reality and profits from exploitation of the brain to produce illusions of perception and action (Slater, 2014). Virtual simulations are worlds that let students engage with representations of real-world events and phenomena (Plass & Schwartz, 2014) providing opportunities for active learning (Mayer, Mautone & Prothero, 2002) and affording exploration (Rieber, 2005). The user can alter several parameters inside a specific simulation, and an underlying computer model reacts by presenting the outcomes of the user's input (Plass, Homer & Hayward, 2009). Augmented reality (AR) is the real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects. It is this "real world" element that differentiates AR from virtual reality. AR allows its users to supply digital overlays of data, creative content, or holographic images, animations, text, and documents. Augmented reality can be viewed through AR goggles that combine a view of the immediate surroundings with computer graphics, or on a smartphone display that does the same thing using the phone's camera to see and manipulate the world in front of the viewer. Mixed Reality (MR) lies somewhere at the intersection of VR and AR. This technology blends real and virtual worlds to create complex environments where physical and digital elements interact in real time. Extended reality or cross reality (XR) is a cover concept that summarises a group of technologies (VR, AR) or Mixed Reality (MR) environments in a way that lets you interact with different technologies simultaneously to create an entirely virtual immersive experience for users. All XR technology takes the human-to-PC screen interface and modifies it, either by 1) immersing you in the virtual environment (VR), 2) adds to, or augments, the user's surroundings (AR), or 3) both of those (MR). XR may be multisensory integrating the five traditional senses, including sight, hearing, smell, taste and touch or even more senses. The UNESCO report "AI in Education: Change at the Speed of Learning" (Duggan & Knyazev, 2020) predicts that immersive learning technologies can revolutionise education, making learning immersive and more engaging, and free learners from the classroom.

AI tools for learning may be categorised as bots or software robots that use automated scripts to autonomous agents that execute actions when conditions are met (Santhanam, Hecking, Schreiber & Wagner,2022). Bots operate with digital assistants that consist of a wide range of systems from mobile apps to virtual characters in augmented reality. They may operate autonomously or would require interaction with text or speech or gesture input. Bots may have rule based or retrieval based conversational capabilities with text or speech recognition using natural language processing, they can recommend, run automated tests, validate options, check for errors and repair the errors, document the processes, manage with information (e.g. outdated information, requests), monitor and enhance the productivity, they can nudge the users' actions in specific direction or trigger the events using deep learning and machine learning methods (Santhanam et al., 2022). Bots may have personas - the characteristics given to them for a smoother social interaction in specific task roles (e.g. collaborator, antagonist, authority figure, dependent, clown, social organiser, storyteller). The future moves towards the Theory of Mind (ToM) type of AI bots (Cuzzolin, Morelli, Cirstea & Sahakian, 2020) that can possess humans like empathy, can attribute mental states to the other, can consider emotional states in thinking, may have their own feelings, have self-consciousness and may regard specific values and can make moral or ethical decisions. Duggan & Knyazeva (2020) foresee this type of technology to advance personalised learning through cognitive services tailored to students' individualised learning needs and pathways (e.g. supervised, reinforcement and unsupervised learning) and enabling the teachers and learners and educational systems to be more efficient and speed up learning.

The problem solving guidance with immersive technologies and adaptive AI support creates the medium and object for practice where cognitive, metacognitive, affective and psychomotor and embodied learning effects may be differently experienced and facilitated.

3. Experiential learning practices in immersive environments

To discuss how emerging technologies mediate or change the problem based 'practice', we first define the components of 'practice' and in next sections associate it with the e-DIPLOMA examples and lessons that we learnt in piloting.

In the middle of 'practice' is

- the individual, collaborative or collective 'problem situation' (Jonassen, 2000) that is mediating the 'shared and situated problem space' (Newell & Simon, 1972) (WHAT?);
- in which 'individual learners' alone or with 'facilitators' or with 'teams' or with 'artificial agents' or 'systems empowered by collective knowledge' (WHO?)
- do search through the problem space using different 'reasoning practices' (deductive, inductive, abductive, embodied) (Lavoie, 1999; Thagard & Shelley, 1997) and experimentation with different 'physical or intellectual mediating tools' (Vygotsky, 1978) (HOW?);
- that transform certain 'knowledge artefact or physical artefact' experientially (Kolb, 1984; Paavole, Engström, Hakkarainen, 2012) and surrounding 'situations' (Greeno, 1998; Hughes, Prinz, Rodden, Schmidt & Robertson, 1997), in which individual transformation (Mezirow, 1997) and 'learning' happens for individuals, groups, and at collective cultural level (which may be an artificial intelligence) and at ecosystems (WHY?).

The problem space according to (Newell & Simon, 1972) incorporates

- physical and mental representations of the problem,
- generative physical and mental representations of the set of possible solutions and actions to be taken to solve that problem,
- and the goals to be accomplished as a problem solution (Ohlsson, 2012).

According to Kolb (1984) holistic model experiential learning in practice situations goes through four phases where problem space is experienced concretely and inductively, next, the space is reflectively analyzed that may presume deductive reasoning, then knowledge would be generalized and abstracted theoretically creating conceptual coherence between what was observed and the theoretical concepts, and finally this abstract conceptualization is deductively tested again to validate the theory. The reasoning process about the problem space and knowledge artefacts that guide the problem solving requires validation through self-reflections, discussions or physical interaction with the space. The practice requires activating cognitive, affective, metacognitive, psychomotor, and embodied learning such as described in the taxonomies of cognitive (Bloom, 1956), affective (Krathwohl & Bloom, 1964), metacognitive (Dave, 1970), psychomotor (Ferris & Aziz, 2005) and embodied actions' (Hughes et al., 1997) domains.

The practice situations also presume that an integrated cognitive, metacognitive, affective and embodied problem space will be individually or jointly conceptualised, co-constructed, understood and enacted. In solving the problem the hybrid third space is created, which is a cultural learning inspired concept coined in human-computer interaction research (Muller, Froggett & Bennett, 2020). This is an “in-between” region, or “third space,” in which learners can combine diverse knowledge with new insights and plans for action, to inform the needs of their organisations, institutions, products, and services (ibid). The emergence of hybrid third spaces is promoted with the transformation of the physical and intellectual artefacts and representations of the cognitive, metacognitive, affective and embodied problem spaces.

Practice requires different reasoning approaches for solving problems that promote cognition and interpersonal, situated and ecological cognition. Most common is the deductive inquiry that starts from a hypothesis and its testing with different methodologies. Critical thinking and data-evidence-based deductive reasoning processes are practised to find the solutions. The second approach is inductive inquiry in which hypothetic-predictive reasoning (Lavoie, 1999) processes and observations would lead to formulating an empirical based hypothesis in the end. Third type of abductive inquiry associates with abductive reasoning processes (Thagard & Shelley, 1997) that are very common in model-based learning. The abductive reasoning process uses models as metaphors in making inferences about the phenomena. Finally, ecological (Greeno, 1998) and embodied cognition describes the learning that is directly induced by ecological cues in the problem space in which internal processing of representations and reasoning are bypassed.

Practice-based learning may also be viewed through the actor’s point of view, in terms of how self-directed and engaged the learners are in the problem-solving process. This raises the metacognitive and affective lenses of practice. According to Knowles (1975) self-directed learning is a process in which individuals take initiative with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating outcomes. For example, if the learners are leading the discovery, they need to process what is the role of other actors who support the process, what promotes them to stay motivated in learning and have agency.

Below we will use the model of practice described above to analyze how immersive technology and AI mediates practice based learning situations and disrupts learning:

I. The individual or collaborative situations and the shared problem space (WHAT)
Situations in immersive VR, XR should change dynamically as the problem solving space should be moving to the new state. This requires adaptive AI supported simulations.
In immersive technologies the situations have become multilayered (AR), multisensorial (XR), the search area is immersive surrounding (VR, XR) that opens up different spatial and 3-dimensional perspectives of the problem space and requires spatial reasoning to be used. The psychomotor and embodied cognition aspects of learning will need to be designed and related with cognitive learning goals. The ability of AI learning technologies to analyse whole situations in problem space without linguistic input is limited, particularly the cognitive, affective, metacognitive, psychomotor and embodied states of thinking the actors have cannot be yet detected by AI.

II. The individual learners alone or with facilitators or with teams (WHO)
The immersive or AI supported learning situations are currently more individual, there are difficulties in sharing interpersonally the perspectives of the problem space. The experience is often shared through another representation that is in a different (screen view) mode than the mode directly experienced with the immersive glasses in teams. The AI is more used in linguistic mode, recommending knowledge and guiding the problem

solving process rather than guiding the metacognition, affective states and psychomotor and embodied learning.

III. The conceptual and physical tools that transform certain knowledge artefact or physical artefact and situations (HOW)
The immersion in AR, XR is still not so touch friendly, manipulation of the VR, AR artefacts, tools with joystick or through the avatar hands is not training the same psychomotor skills as real actions would. Work with knowledge artefacts in AR, VR, XR to transform knowledge into different representational forms is hindered.

IV. The shared cognitive, metacognitive, affective and embodied problem space should be jointly conceptualised, co-constructed, understood and enacted as the hybrid third space. The process of design practice in hybrid space is usually incorporating several iterative events, that require seeding and reseeding the problem solutions to the situations and back, that may be supported with AI-empowered simulations. In immersive environments the wearables hinder the formation of the shared awareness in the problem space as the third space. The reasoning processes would require more spatial reasoning, inductive reasoning and may hinder deductive and abductive reasoning. (WHY)

4. Guidelines for designing practice-based learning in immersive environments. What we learnt from e-DIPLOMA pilots?

4.1. Learning goals and competencies

4.1.1. Goal of the learning activity

Every practice-based learning activity has learning goals related to domain knowledge and a set of desired competences (cognitive, affective, psychomotor) a learner is expected to acquire. In our report the learning goals and competences are related to the e-DIPLOMA prototypes such as block programming and computational thinking, social entrepreneurial concepts and strategies, learning theories and principles' applicability, etc. Here we introduce only the cognitive competences that were mostly regarded in e-DIPLOMA prototypes. However, the metacognitive, affective and psychomotor competences should also be considered as learning goals.

4.1.2. Cognitive competences

Based on Bloom's taxonomy six cognitive levels from lower-order to higher-order thinking were designed in three e-DIPLOMA prototypes: *Remember* involves recalling knowledge (e.g., reciting Newton's laws), while *Understand* requires explaining concepts in one's own words. *Apply* focuses on using knowledge in new contexts (e.g., calculating kinetic energy), and *Analyze* entails breaking concepts into parts to compare or interpret (e.g., differentiating potential and kinetic energy). At higher levels, learners *Evaluate* by making judgments and justifying choices (e.g., deciding between conservation of energy or momentum), and finally *Create* by synthesizing knowledge into new structures or products (e.g., designing an original physics problem).

4.2. Problem space elements

4.2.1. The problem and the task

At learning activities, the problem-solving practice is guided by the type of the problem and task.

4.2.1.1 Problem typology

Complex problem solving requires structured strategies, such as formulas, rules, or step-by-step procedures. To work effectively, learners must also use suitable tools—ranging from augmented reality applications to physical instruments or measurement devices—depending on the problem's context. Solutions can be straightforward with clear answers or open-ended, encouraging creativity and multiple valid outcomes. Jonassen (2000) described problem types along a continuum from well-structured to ill-structured: *Logical Problems* (abstract reasoning puzzles), *Algorithmic Problems* (repeated procedures or formulas), *Story Problems* (narratives with embedded formulas), *Rule-Using Problems* (goal-oriented but flexible in method), *Decision-Making Problems* (choosing among alternatives using criteria), *Troubleshooting Problems* (diagnosing faults), *Strategic Performance* (real-time responses to competing needs), *Case Analysis* (complex systems with ill-defined goals), *Design Problems* (vague goals with few constraints), and *Dilemmas* (conflicting positions).

In e-DIPLOMA modules, the task was not always clearly provided. The problems in e-DIPLOMA modules were rule-based simple problems or complex strategic performance problems.

Example 1. A rule-based problem in VR

Prototype 3 - Module 3. The activity was presented as a mini game with several stages, in which a user acts as a shepherd and needs to navigate a virtual environment to bring sheep to predefined locations (Figure 1). The difficulty arises from the fact that the sheep cannot be directly impacted but are indirectly affected by the user. Whenever the user is close enough to a sheep, it will move away in the opposite direction. In consequence, the user builds up the necessary skills to navigate the environment.

Figure 1. A screenshot of a rule-using problem in VR (Prototype 3 Module 3).

The game consists of several levels, each making use of different typical navigation metaphors, smooth motion, teleporting, minimap, or flying.

In simple, rule-using types of problems, the tasks were often predefined by the educators.

Guideline 1. Understanding the task in immersive environment

Problem:

It was difficult to **grasp learning objectives only from the VR headset information**. (Prototype 3)
In Prototype 1 learning merits were easy to grasp, **inexperienced programmers struggled to understand how to apply the concepts in practice.** (Prototype 1)
Solution:

- **Use the virtual environment to anchor and help encode learning (Baceviciute, Terkildsen & Makransky, 2021).**

In complex problem solving practice, the task could be self-created by learners. For example design problems were present in the Prototype 3 Module 5.

Example 2. A sandbox type of problem solving environment where learners create their own tasks

Prototype 3 - Module 4. This element focuses on the fact that virtual scenes are recreated with 3D graphics required to define light sources and materials. These have a huge impact on the appearance of the environment. For example, a light source placed at the position of the observer will eliminate most of the surface cues (Figure 2). The module starts with a short lecture explaining the basics of lighting and object appearance. This is followed by an interactive experience. Here, a user will first position, then illuminate a car and play with different lighting settings. Further, they can explore some non-realistic depiction. This implementation was used as a basis for exploring visualization style on the effectiveness of recognition and memorization tasks.

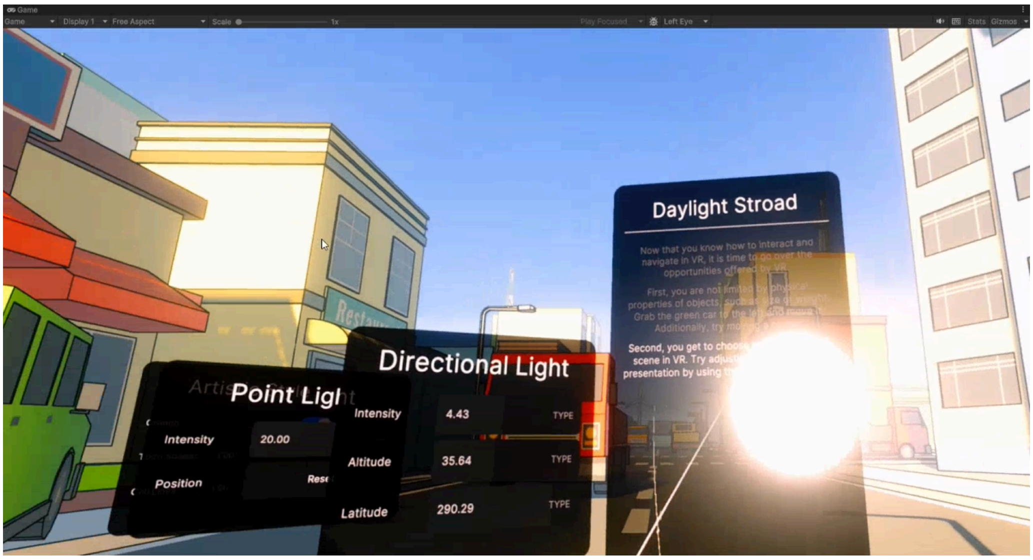

Figure 2. A screenshot of Module 4 in Prototype 3.

Example 3. A design problem for free explorations

Prototype 3 - Module 6 enables users to design their own 3D VR environment. They can define a floor plan, place walls or barriers, as well as paint and color the environment. Next, they can place objects and light sources to complete their designs. Afterwards, they define navigation metaphors. For example, allow teleporting to certain locations (e.g., a point of interest in front of an exhibited object) or to enable the possibility to fly in certain locations (e.g., to examine a large statue). The user can iterate between the different stages if needed. The design takes place at a scale in which the user is much enlarged. This enables them to obtain an overview of the entire environment. The actual museum visit takes place in the game mode, where the user is seamlessly shrunk to the scale of the actual museum and can then test the walkthrough. In particular, it is possible to place interactive highlighting elements that are triggered, when the user passes over certain areas. The resulting museum design can be shared with other users. It also means that users can save their work and continue at a latter point to further refine their designs. Such a concept of a virtual museum can be an interesting element to grow a potential e-DIPLOMA community around in the future.

Guideline 2. Free exploration as a task

Problem:
Some learners felt **reluctant to complete tasks in free exploration** and finished quickly (Prototype 3)
Solution:

- A **sandbox type experience where the most interested participants can feel comfortable with the technology would enhance spending additional time** with situated VR **experimenting** (Prototype 3).
- **Promote learner agency, feeling of control** (DeWitt, Chan, Loban, 2022) with active exploration (Argyriou, Economou & Bouki, 2020) and making their own choices (Buijs-Spanjers, Harmsen & Hegge, 2020).

Guideline 3. The size of learning tasks

Problem:
The Prototype 3 was very didactic, **taking the learners through steps**. More experienced participants progressed much faster, **while less experienced learners required the full scaffolding**. The sense of **being immersed** in an unmediated reality may impact negatively on **cognitive load** (Baceviciute et al., 2021; Di Natale, Repetto, Riva & Villani, 2020; Bahari, 2022; Rizzetto, Rantas, Vezzulli, Cassin, Aseni & Vertemati, 2023) and **concentration on task** (Arayaphan, Sirasakmol, Nadee & Puritat, 2022; Buyego, Katwesigye, Kebirungi, et al., 2022; Ebadi & Ebadijalal, 2022).

Solution:

- Provide **short tasks** to keep participants motivated and **sustain their attention. Concentration may be held by shorter tasks.** (Prototype 1).
- **Make use of the repeated practice (Chen, 2021).**

Guideline 4. Sequential model of progressive tasks (Prototype 1, Prototype 3) versus Puzzle model (Prototype 2)

Problem:
Learning tasks often fail to progress from lower to higher cognitive levels, which limits the presence of experiential learning phases needed to support learners' understanding in both situated and abstract contexts.
Solution:

- Activate learners' prior knowledge (Asad, Naz, Churi & Tahanzadeh, 2021).

4.3. The problem solving in the problem space: Understanding WHAT, WHO, HOW and WHY?

4.3.1. Presentation of the problem situation

Sensory channels. Emerging technology provides multiple sensorial media making possible the inclusion of layered sensory stimulation and interaction through multiple sensory channels (Ghinea et al., 2014). Immersive technology can bring in other sensory channels besides visual and auditory - tactile (processing touch information from the body), vestibular (sense of head movement, orientation and balance in the space), proprioceptive (sensations from muscles and joints of body, senses of the position, location, orientation, and movement of the body muscles and joints, sense of the relative position of neighbouring parts of the body and effort used to move body parts), gustatory (sensations from tastes), olfactory (sensations from smells).

Multimedia types and modes. Emerging learning technologies provide new ways of affording learning within the practice based learning situations. The problem solving guidance with different digital content forms (multimedia, mulsemedia) supplied by immersive technologies and adaptive AI support creates the medium and object for practice where cognitive, metacognitive, affective and psychomotor and embodied learning effects may be differently experienced and facilitated. In immersive technologies the practice based learning situations have become multilayered (AR), multisensorial (XR), the search area is immersive surrounding (VR, XR) that opens up different spatial and 3-dimensional perspectives of the problem space. In e-DIPLOMA prototypes a list of immersive technologies such as VR, AI chatbot, AR, XR, virtual games, TEAMS chat were implemented to mediate learning experiences. Immersive technologies incorporate multiple modes such as image, text, sound, video, heuristic, model avatar, diagram.

4.3.2. Pedagogical approaches and problem solving

Different pedagogical approaches consider differently how the problem solving could take place. In e-DIPLOMA prototypes, the following approaches were present.

4.3.2.1. Information processing approach and knowledge acquisition

According to the **information processing approach** (Atkinson & Shiffrin, 1968) the problem solving requires mapping and sensemaking between textual, audio and visual information of objects and processes that the learner experiences, and associating these with the conceptual abstract knowledge. In immersive environments such a semantic process is less supported because providing abstract information adds cognitive load into the learning space because:

- the textual and visual processing channels may be overloaded, and it is important to consider dual channel processing rather than processing information at the same channel;
- the links are not formed across visual and textual information, so it is better to associate them with direct short labels, arrows to make visual associations;
- the textual explanations are often overlooked in the dynamic tasks due to cognitive overload.

Example 4. Mapping concepts with virtual objects

Prototype 1 - Module 1 - introduces theoretical concepts via audiovisual content on general programming topics. The learners are individually expected to understand and learn three different concepts related to general programming (Figure 3).

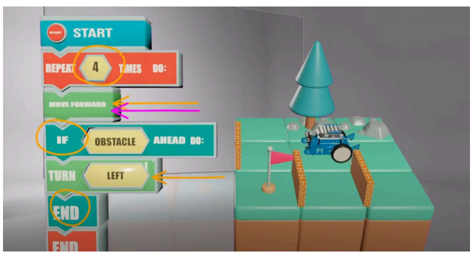

Figure 3. A screenshot of the activity in Module 1 (Prototype 1).

Example 5. Audiovisual concept learning

Prototype 1 - Module 3 - presents theoretical concepts via audiovisual content on the basics of electronics: the Arduino board, sensors, actuators, and how they are assembled. The learners are expected to understand the concepts through watching videos individually (Figure 4).

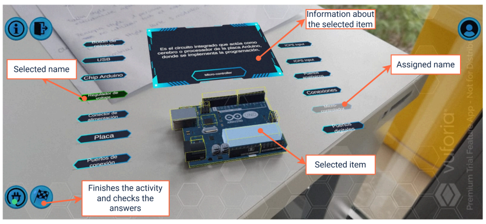

Figure 4. A screenshot of the activity in Module 3 (Prototype 1).

Example 6. Augmented reality overlays for concept learning

Prototype 1 - Module 4 - uses augmented reality (AR) to identify the various devices covered in the course, display key information about them, and allow students to complete exercises related to their connections and communication, the learners are individually expected to understand and actively experiment with the concept (Figure 5).

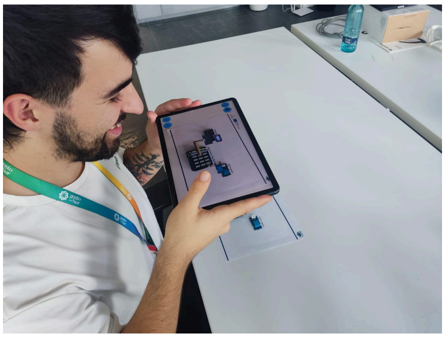

Figure 5. A screenshot of the activity in Module 4 (Prototype 1).

Guideline 5. Make associations between objects in immersive environment and abstract concepts

Problem:

The participants had difficulties **to associate visually modelled and electronic connections**. (Prototype 1)

Solution:

- The **AR overlay text was considered helpful for problem solving with electronics.** (Prototype 1)
- **Give the learners control over their body and movement** (Eiris, Jain, Gheisari & Wehle, 2020; Ahn, Nowak & Bailenson, 2022) and **allow learners to use their body, mediated limbs with controllers and skin sensors** to promote an understanding of abstract concepts (Di Natale et al., 2020; Chen, 2021; Rey-Becerra, Barrero, Ellegast & Kluge, 2021; Johnson-Glenberg, Bartolomea & Kalina, 2021).

Guideline 6. Learners' cognitive diversity influences them in immersive spaces

Problem:
Some participants tried to speed up videos, people felt bored and fatigued. (Prototype 1)

The participants were overwhelmed by too many concepts. (Prototype 1)

The reading speed may be lower in immersive reality (Bahari, 2022), learning from auditory information may be lower than learning from visual information (Di Natale et al., 2020), and learning specific facts, names, dates may be hindered (Ebadi & Ebadijalal, 2022).

Solution:
- Do not increase cognitive complexity beyond what learners can and operate.
- Learners with different cognitive processing abilities may need different time for task completion in immersive tasks.
- Limit the number of concepts per task.
- Grow the number of concepts across the sequential tasks. (Prototype 1)
- Embed meaningful textual information but be cautious to create need to scroll, press buttons etc. (Hayes, Dhimolea, Meng & Tesh, 2021).

4.3.2.2. The social constructive approach

The social constructivism approach focuses on discussions and grounding the concepts through peer-learning that helps to better understand the meanings in situated learning (Dehghanzadeh, Fardanesh, Hatami, Talaee & Noroozi, 2021; Li, Fang & Jiang, 2022; Yang, Chang, Hwang & Zou, 2020). The approach is still hindered in immersive learning environments with VR headsets, and hand devices to coordinate movement. Effective grounding in the problem space requires that learners feel immersed and freely moving in the joint space, where they can without delays act, point to the things, talk about them so that they move nearer to the shared problem space perception. Developing shared problem representations in this process has been considered helpful to reduce the cognitive load the team members experience, because such shared space can visualise their shared understanding.

Example 7. Pair collaboration with VR

Prototype 1 - Module 5 - In the task *Saving the Earth* done in pairs, within an immersive virtual reality VR environment using HMD, students collaborated to achieve a common objective by applying the knowledge they have gained in electronics and programming (Figure 6). The students could see the shared problem representation on the screen, they talked and grounded their actions and meanings via the headset. This adds complexity because they need to decide the actions as well as the meanings of their actions.

Figure 6. A screenshot of the activity in Module 5 (Prototype 1).

Example 8. Collaboration between VR player and the external class members

Prototype 2 - Module 3. The activity was designed for the participation of 4 students in VR and a moderator who also acts as the experimental session controller (Figure 7). The learning room was created by the integration of Moodle and AWS virtual machines running Brainstorm Edison Software where the Business model canvas project was running. The students were invited by the moderator in turns to carry out the completion of the business model canvas areas during a determined time duration. Within the Teams conferencing tool the students could query and consult four AI Personas developed for the prototype. The personas' knowledge was focused on social entrepreneurship and the students were supported on this topic while they were completing the business model canvas exercise. The students were asked to communicate within the group in the MS Teams conferencing tool room to discuss the items that were to be added at every canvas area.

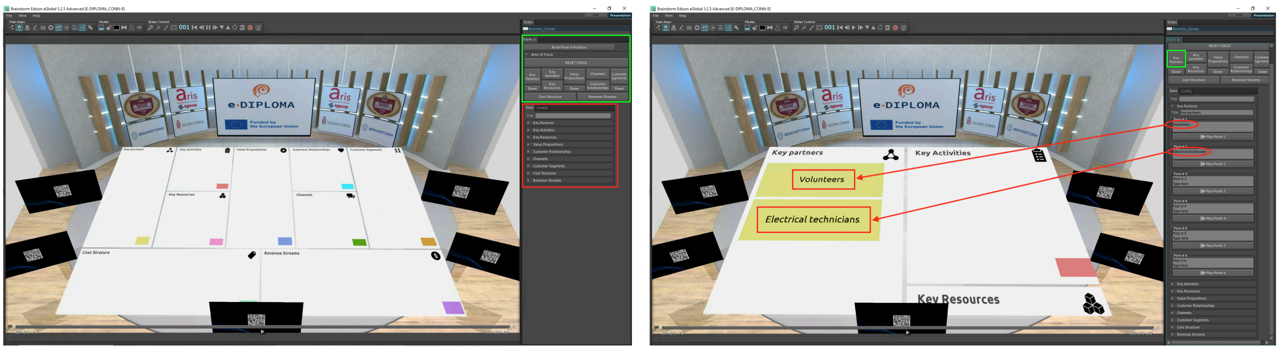

Figure 7. A screenshot of the activities in Module 3 (Prototype 2).

Guideline 7. How to enhance collaboration on the task in immersive spaces

Problems:
The collaborative virtual problem solving did not work as well as expected at Prototype 1 Module 5, and ended up working more individually. (Prototype 1)
In Prototype 2 Module 5 the strategies were discussed and proactive attitudes taken only if the **game rules** and **motor motion** were understood well. (Prototype 2)
In Prototype 2 students **discussed strategies external from the VR settings** extensively. (Prototype 2)
In Prototype 2 Module 3 the **technological setup was too complex,** teams and Edison platform combination was not intuitive, and **technology hindered the collaborative activity.** (Prototype 2)
Solutions:

- Provide **clear rules** of the game for learners
- Provide **problem-solving strategies** for the teams working in immersive spaces
- Provide **a shared visual of the problem representation** that can be **jointly manipulated**
- Enable **external from immersive space discussions during collaboration** in immersive space
- Enable **hearing others using the headset**
- **Collaborative task situations and tasks require less complexity** than individual tasks

Guideline 8. Social motivation enhances learning

Problem:
Solving complex and dynamic problems **alone is too much cognitively demanding** in a short time by a single person.

Solutions:

- Provide in an immersive space motivation **management to hold the interest with gamification elements, avatars, in-depth details (DeWitt et al., 2022), perceived authenticity** (Yang & Goh, 2022), **interactivity that involves personally** (Cummings, Tsay-Vogel, Cahill, & Zhang, 2022), and **develop positive emotions - fun, enjoyment** (Dubovi, 2022), happiness, excitement (Dhimolea, Kaplan-Rakowski & Lin, 2022).
- Provide interaction with learners or avatars to improve understanding (Yang & Goh, 2022; Chen, 2021; Dhimolea et al., 2022) or add the narrators (Argyriou, Economou & Bouki, 2020).
- Provide **interaction with AI virtual avatars**.(Prototype 2)
- Virtual characters' **body language may help to guess the meaning** (Akgün & Atici, 2022).

Also the immersive learning environment requires different approaches on how to give guidance to the learners.

Learning is highly embedded in social interaction. In addition to interacting individually with the content and technology, interaction with the facilitator, peers or AI chatbots in collaborative groups introduces an interpersonal element to conceptual knowledge adding an extra level of complexity as different social interactions introduce a range of perspectives, communication styles, and interpersonal dynamics. When learners collaborate, negotiate, or engage in discussions, they must not only focus on the content but also navigate social cues, group roles, and varying levels of understanding among peers. It's important to develop mutual understanding of the content being learned, foster group cognition, and recognize how learning is co-driven by the group. Thus, different types of social interactions from individual, pair with facilitator, group with facilitator, peer-to-peer to AI partnered were detected. Scaffolding, a concept derived from Vygotsky's "zone of proximal development" (Vygotsky, 1978), involves using various strategies to help students complete tasks they would not be able to achieve on their own. As an instructional approach, scaffolding offers learners guidance, feedback, and support, which can be effectively delivered through well-designed technological tools. Scaffolding types refer to what type of support (scaffolding) is provided by humans or with technology. Hill and Hannafin (2001) identified four types of scaffolding—conceptual, metacognitive, procedural, and strategic—while Steinert, Marin, and Roeser (2022) added affective scaffolding. *Conceptual scaffolding* helps learners reason through complex problems and address misconceptions (e.g., hints, coaching, feedback). *Metacognitive scaffolding* supports reflection and self-regulation by prompting learners to analyze their thinking, recall prior experiences, or identify weaknesses. *Procedural scaffolding* emphasizes effective use of tools and resources, with teachers guiding learners on system functions and capabilities. *Strategic scaffolding* directs learners in tackling tasks by highlighting alternative methods and useful resources. Finally, *affective scaffolding* supports learners' emotions and motivation through environmental and emotional resources.

Guideline 9. How to embed support and guidance to immersive situations

Problems:
Guidance provision on immersive space in textual mode does not work well (Prototype 1)
Participants **did not read the guidance information** as was supposed, but used **trial and error method**. (Prototype 1)

Despite the **guidance texts in VR, learners did not read them and needed additional guidance from human supporters.** (Prototype 3)
.
Solution:

- Use **video or textual instruction before the task** in an immersive environment starts.

Guideline 10. Scaffolding by a human facilitator

Problems:
There was often a **need for the support person** to guide students about theoretical and learning scenario rules-related aspects in the modules. (Prototype 1)
Prototype 3 was considered challenging in the current form, because it required additional guidance and it would need larger user autonomy.
Solutions:

- Scaffold the learners (Buijs-Spanjers et al., 2020; Chen, Chang, Hwang & Zou, 2021).
- Provide an informal learning environment with the atmosphere of mutual trust and empathy (Li et al., 2022).
- Human facilitators beyond immersive space might help the learners **to understand what they need to do (the rules of the activity)**, and explain the concepts.

Example 9. Scaffolding by AI avatars

Prototype 2 - Module 1 Lodestars – The Social Entrepreneur has a complex problem space representation that requires many sensory channels to be used. It is an immersive VR game, where the players need to talk in the microphone to AI chatbots representing social entrepreneurs and other characters like criminals, regular social workers, plain old school for-profit businesses, and customers (Figure 8). They can discuss their experiences, ambitions and may learn about other characters in the city to whom players can teleport using hand controllers. The game itself is played by multiple people, each taking turns venturing into the virtual world, after which they return to their groups to discuss the conversations they just had for social learning. The problem-solving situation uses some procedural scaffolding. The problem itself is vaguely presented. Rule-based problem solving is to be used where learner interactivity is low and at concrete experience level - learners manipulate controllers, microphone, ask questions, but cannot analyze collected information during their game turn, but need to remember what they learnt for later discussions.

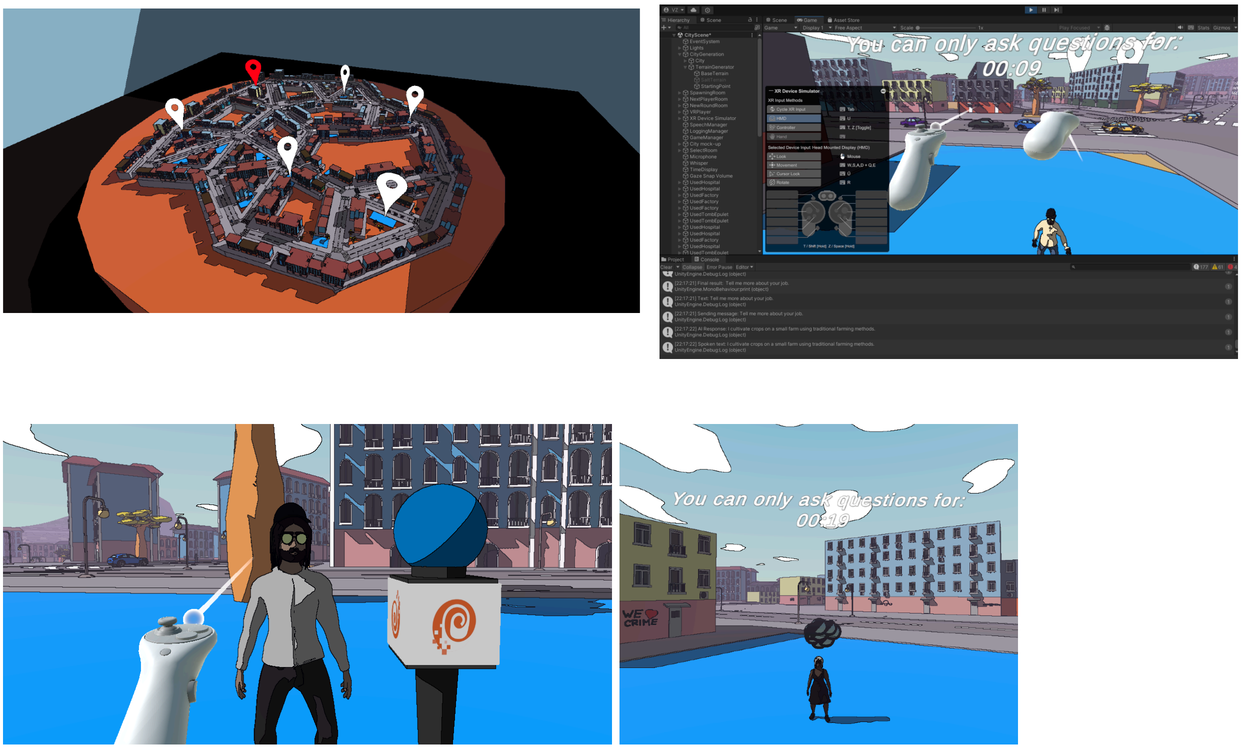

Figure 8. Screenshots of Module 1 tasks in Prototype 2.

Example 10. Scaffolding by AI chatbot

Prototype 2 - Module 4 – Social Human Resources and Team Management. Allies is a single-player dynamic decision-making game, where the player must recruit and manage an efficient team as a social entrepreneur to sell used goods. The recruitment and managing must be done simultaneously. In interviews the player talks with applicants roleplayed by a Large Language Model (LLM) to discover their personality traits and negotiates the wage. In the managing part the hired team members must be assigned to roles in the company, monitoring their performance and behavior and reacting accordingly. The dashboards must be monitored to see how well the company is doing. There is a limited time to play, and performance of the player is measured based on the final team performance accompanied by the growth, income and impact of the company. The game requires multitasking as time is not stopped during an interview. On the contrary, new tasks and problems can arise dynamically and must be handled swiftly (Figure 9).

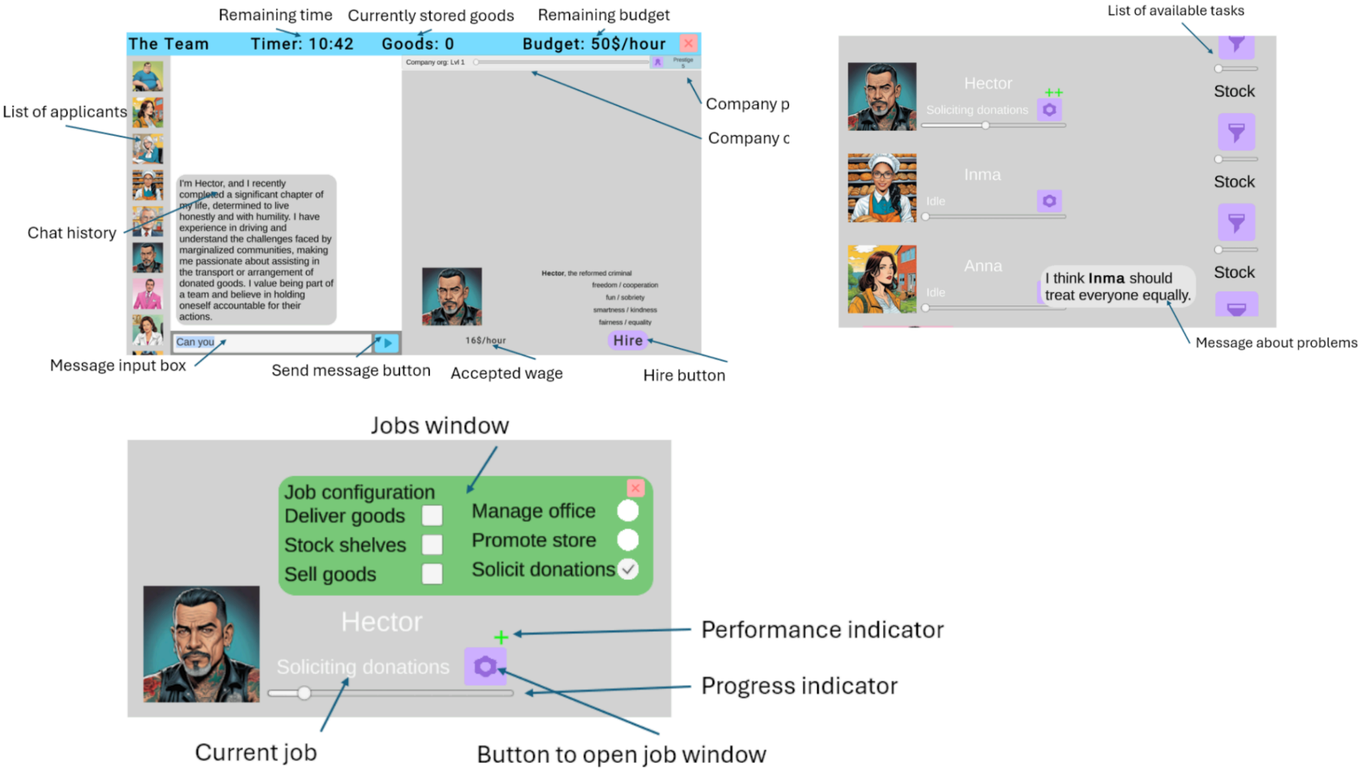

Figure 9. Screenshots of Module 4 activities in Prototype 2.

Example 11. Ghost instructor in VR

Prototype 3 - Module 5. In VR, users are not necessarily located in the same physical space. Interaction is therefore more difficult to achieve. The lecture first talks about problems of co-locating people in the form of avatars together in virtual environments and gives an overview of some of the techniques to guide attention (Figure 10).

After this passive part, the user can then experience examples of related techniques. The first asks users to imitate a given motion by a virtual avatar and to remember the motion that is initiated. Such "ghost instructor" solutions have shown to be very effective for motion/action learning . The task is repeated a few times and the accuracy of the user is measured. Upon this basis, we also explored novel schemes, to see if it can generate a benefit for the learning of the motion, which was prepared as a research paper. In another experience, the user is able to perceive the impact of comfort zones in VR. In the real world, we keep a natural distance from others, and it translates to VR. The user can explore this effect with a virtual avatar using different facial expressions and facial animations in VR, which are important for VR, but can cause discomfort when the face appears uncanny to a user. To investigate the latter point, also different rendering styles are explored. As an alternative to avatar-based interaction, a highlighting scheme is shown in the last example that illustrates how to guide users and their gaze in VR.

Figure 10. Screenshots of the task in Module 5 (Prototype 3).

4.3.2.3. Ecological learning and embodied cognition approach

In ecological learning (Cooper, Forino, Kanjanabootra & von Meding, 2020) and embodied cognition approaches (Galeote, F. D., & Hamari, 2021) the immersive learning environments provide the stimuli in the problem solving process that can be dynamically collected using the emerging patterns and cues in the environment that become evident in interaction with it, also the psycho-motor and affective aspects would the enhance the cognition. The knowledge is immersive and embodied and is not easily transferable back and forth between situated knowledge and abstracted concepts, rules and formulas.

Example 12. VR based problemsolving

Prototype 1 - Module 2 - Interactive activity with practical block-based programming exercises in an immersive virtual environment (VR) using a Head-Mounted Display (HMD). The learners were individually expected to actively experiment in a VR environment to solve simple problems with the goal to implement previously acquired three programming related concepts (Figure 11).

Figure 11. A screenshot of the activity in Module 2 (Prototype 1).

Example 13. VR reality coordination and information gathering from AI chatbot

Prototype 2 - Module 1. Learners manipulate controllers, microphone, ask questions, but cannot analyze collected information during their game turn, but need to remember what they learnt for later discussions (Figure 12).

Figure 12. A screenshot of the activity in Module 1 (Prototype 2).

Guideline 11. Learners prior competences influence how they learn in immersive spaces

Problems:

In Prototype 1 learners without **prior experiences faced difficulties to understand how to use the technology**, they **lacked enough time and could not focus on learning.**
In Prototype 2 the participants **lacked time to** focus deeply on engaging with the prototypes, **understanding the game rules.**
In Prototype 2 Several learners **could not handle the controllers and the situations technically quick enough and did not gras**p what they could do in the activities.
In Prototype 3 the VR **motor skills were to be learnt first, the lack of these hindered interaction** with the
prototype.
Many participants **did not learn these motor skills during the pilot at sufficient level to proceed well.** (Prototype 2)
Players **with lower coordination in VR struggle** to reach the strategy level of the game, limiting their ability to cooperate effectively in a dynamic, situated environment. (Prototype 2)
The knowledge of **motor skills in earlier modules were not transferred to the next modules.** (Prototype 3)
In Prototype 2 - Module 5 the **strategies were discussed and proactive attitudes taken** only if the **game rules** and **motor motion** were understood well.

Solutions:

- Provide time to learn how to interact (incl. Bodily interaction) with the new learning space first
- Provide more time for the beginners
- Motor skills require longer time to be developed in immersive environments

Guideline 12. Situated immersion helps understanding and application of knowledge

Problem:

In Prototype 2 the participants had **difficulties in connecting theoretical knowledge with the dynamic decision-making actions.**

Solution:

- Develop authentic situations with immersive storytelling (Rizvic, Boskovic, Bruno, Petriaggi, Sljivo, & Cozza, 2019) for better understanding (Baceviciute et al., 2021; Eiris et al., 2020; Li et al., 2022), stimulation of imagination (Barrett, Pack & Quaid, 2021), improvement of knowledge and skill transfer with multisensory opportunities that can help to relate interdisciplinary domains and understand the complexity (Erdogmus, Ryherd, Diefes-Dux & Armwood-Gordon, 2021; Bahari, 2022; Cooper et al., 2020, but consider that they may also cause integration difficulties (Bahari, 2022).

- Use VR and AR to support players in better understanding social enterprise tasks and contexts, while fostering a stronger sense of responsibility as social entrepreneurs.. (Prototype 2)
- Leverage users' prior knowledge, that enables them to recognize the potential usefulness of the VR module, especially when adapted to specific teaching content.(Prototype 3)
- Provide an interactive environment to represent physical phenomena, which enables users to explore different configurations and **better assimilate the educational content**. (Prototype 3)

Guideline 13. Immersion that provides visual feedback

Problem:
In Prototype 2 the games would have needed **better immediate decision-making feedback to see the results of dynamic actions.** (Prototype 2)
Solutions:

- The **animated car and movement was appreciated and enhanced immersion** while providing a strong visual feedback. (Prototype 1)
- Create an assessment integrated into teaching.

Guideline 14. The complexity of rules in gamified immersive learning

Problem:
In Prototype 2 Module 5 **the game rules were perceived as overly complex.**

Solution:

- **Make game rules that fit to the beginners increase for the expert level players**
- **Provide game rules in advance**
- **Develop feedback from correct behaviours if rules are followed**

Example 14. Complex gamified learning with dashboards to follow the knowledge gain

Prototype 2 Module 5. Angels – Social Product Management and Marketing. Angels is an online board game played by four players featuring an underlying market simulation. It teaches financing options, market research, product positioning, and marketing in a learning-by-doing manner (Figure 13). The game is played in a fictitious city, with four districts, represented by textured discs. Every district has 36 representative citizens, represented by pawns. All citizens can be categorized into six groups along seven social statistics. While playing the game is a group activity, it is a competitive game simulating market dynamics, where outcompeting rivals or following leaders could be fruitful strategies. The game consists of rounds and phases. The first round has a single, starting phase where players cannot perform any action, but they can navigate the play area, hover the mouse over game elements, and read corresponding tooltips. They learn about the basics of the game in this phase. Later rounds all consist of three phases: Carousel phase: a set of cards rotates slowly over the game area. Players can pick cards that are in the quarter of the carousel closest to them, as long as they have enough picks. Cards represent business development opportunities, and the number of picks depends on the financing and sales the player has. The choice between several cards is the main mechanism in the game. Making this choice can be based on the knowledge displayed on the cards in the form of imagery, short catchphrases, but also slightly more detailed tooltip explanations. Picked cards move to the player's hand. Planning phase: players can, independently, play any number of cards from their hands. These actions are not revealed to the other players. Sales phase: the results of the actions are evaluated and displayed to all players. Sales are performed and tallied.

Figure 13. Screenshots of Module 5 tasks in Prototype 2.

Guideline 15. Scores as gamification elements give feeling of the success that motivates

Problem:
In Prototype 3, not all users were able to complete the activities, limiting their ability to experience the enjoyment reported by those who did.
Solution:

- Add scores that give immediate feedback
- Consider that monitoring scores in action would not cause cognitive overload

Guideline 16. Immersive spaces may have negative effects on learners that influences cognitively their task completion

Problems:
Some **dizziness** was experienced. (Prototype 1)
In Prototype 2 **nausea** was often felt in the last part of the activity, also **learners experienced fatigue and**
frustration.
Vast majority of users experienced **nausea and dizziness, motion sickness especially in flying, some felt**
disoriented and did not remember learning objectives. (Prototype 3)
Solutions:

- Consider learners' sensory (Galeote & Hamari, 2021; Elzie & Shaia, 2021), cognitive and motor impairments (e.g. BCI-illiteracy) and negative psycho-physical effects like fear at heights, anxiety, cybersickness, stress, risk-taking, headache, dizziness, nausea, disorientation, blurred and double vision, eyestrain, focusing difficulty, heart rate, difficulty at breathing/speaking (Di Natale et al., 2020; Bahari, 2022; DeWitt et al., 2022; Elzie & Shaia, 2021; Rey-Becerra et al., 2021; Chang & Hwang, 2021; Radianti, Majchrzak, Fromm & Wohlgenannt, 2020; Coban, Bolat & Goksu, 2022) and learning distractions (Drigas, Mitsea & Skianis, 2022; Buyego et al., 2022).

- Use **actual rather than teleported movement** (Dreger & Ticknor, 2022)

- Consider **graphic quality** - object realism level (Li et al., 2022), image quality (Eiris et al., 2020; Bahari, 2022; Galeote & Hamari, 2021), rendering speed, visibility issues (DeWitt et al., 2022; Buyego et al., 2022), noise and sound level, speech quality (Dalim, Sunar, Dey & Billinghurst, 2020).

- Immersive environments **cannot be used intensively and with long period of time**

- **Some learners cannot use the environment** due to their specific sensory experiences

Guideline 17. Immersive situations cause danger

Problem:
Learners had issues in pumping to the cables when being in VR headset and needed a supporter to guide them from dangers in the room. (Prototype 3)
Solutions:

- Provide a **physically comfortable** (Yang & Goh, 2022; Bahari, 2022; Arayaphan et al., 2022), adjusted to persons' eyes (Akgün & Atici, 2022) and a safe environment. The position of the **learner in situations could be central, being the main character** (Cummings et al., 2022) as having an **egocentric point of view** may improve skills transfer to real world situations (Barrett, Pack & Quaid, 2021).
- See that the **virtual space would not outsize available physical space** (Clack, Hirt, Kunz & Sax, 2021).

4.4 Interaction in the problem space

4.4.1 Learner engagement

According to Kolb (1984) effective learning occurs through a continuous cycle of experience, reflection, conceptualization, and experimentation. Learner engagement in the activity in experiential learning phases follows Kolb's experiential learning cycle:

- Concrete Experience – The learner goes through a direct experience, which could be something entirely new or a fresh take on a past event based on new perspectives or ideas.
- Reflective Observation – The learner thinks deeply about the experience, comparing it to what they already know. They focus especially on any gaps or contradictions between what they expected and what actually happened.
- Abstract Conceptualization – From this reflection, the learner forms new ideas or updates existing theories. This stage represents the actual learning, where insights begin to take shape.
- Active Experimentation – The learner tests their new ideas in real-life situations, applying what they've learned to see the results and refine their understanding.

In e-DIPLOMA prototypes the reflective observation tasks were not provided. This may be difficult because the immersive environments are more action centred.

4.4.2. Learner interactivity

Based on Väljataga et al. (2015), the following category was taken as a basis for understanding learners' interaction with disruptive technologies and content in the e-DIPLOMA prototypes:

- Consume - This is the most basic form of interaction with technology and content. Learners passively engage by watching, listening, or reading. The content remains unchanged and unaltered.
- Annotate - Users add personal or social meaning to existing content through actions like highlighting, liking, tagging, rating, or commenting. These annotations typically affect only the metadata and may be shared in online environments.

- Manipulate – Learners interact with elements within the content (e.g., clicking, dragging, or entering data), but they cannot change or add to the core content. These interactions may provide immediate feedback but are temporary and leave the original content untouched.
- Submit – Learners actively respond to prompts, solve problems, or engage with interactive tasks, with their input submitted for teacher or peer review. Although engagement deepens, the learners' contributions are not embedded into the original content.
- Expand - Learners add small contributions to existing content—such as completing gaps, adding a caption, or combining clips—while keeping the original material largely intact and recognizable.
- Remix - Learners transform content by changing, rearranging, or merging elements to create a new version. The original may become unrecognizable, and the meaning may shift significantly, reflecting the student's own creative expression.
- Create - Learners generate entirely original content from the ground up, without relying on pre-existing material. This represents the highest level of creative engagement.

Example 15. Highly interactive immersive learning environment

Prototype 2 - Module 2 Heroes: Stakeholders and societal change was an example of a highly interactive learning environment. That was dynamically changing multisensory and gamified where learners needed to control the handheld controllers, monitor dashboards, as well as to pay attention to the changes in virtual town (Figure 14). The concepts to be learnt were of holistic nature about collaborative city planning that considers mutual benefits. Heroes is a multiplayer game teaching collective dynamic decision-making when building a city with shops, hospitals, cinemas and factories in right neighborhoods. Learners need to control and monitor money, health, pollution and energy levels visible at dashboards to keep citizens happy. This requires active experimentation with application of abstract concepts into the decision-making situations where analysis and evaluation are important. Each player could act autonomously in VR, but they could talk in the room to collaborate. The players could approve or delete each other's constructions. Players could cooperate but this was not specifically asked. They needed to act fast as there was a race against time, to expand the town to a certain size. The instructional scaffolding was given only in the beginning of the game.

Figure 14. Screenshots of activities and scaffolding in Module (Prototype 2).

5. Summary

We have embedded 17 guidelines and examples within the theoretically based structured guideline to illustrate the best practices. This report highlights some of the best practices that were collected in the e-DIPLOMA piloting monitorisation process. The guidelines can be divided into five themes: task design, cognitive diversity, social/motivational support, scaffolding and competence, and safety/health considerations.

Task Design - Immersive learning works best when tasks are short, progressively structured, and scaffolded from simple to complex. Free exploration should be balanced with sandbox-style opportunities that give learners agency. Visual anchors, AR overlays, and embodied interactions help link abstract concepts to virtual representations.

Cognitive Diversity - Learners process information differently, and VR can easily cause overload. Tasks should be paced, limited in complexity, and adapted to different learning speeds. Collaboration is effective when tasks are simplified, rules are clear, and learners share visualizations and communication channels.

Social and Motivational Support - Social dynamics enhance engagement. Avatars, gamification elements like scores, and authentic interactions foster motivation and enjoyment. VR should provide meaningful feedback, immersive storytelling, and opportunities for shared problem-solving.

Scaffolding and Learner Competence - Human facilitators are vital for guidance, encouragement, and clarification of rules. Beginners need more time to learn VR motor skills and interaction methods before focusing on learning content, while experienced users can progress faster and collaborate more strategically.

Safety, Health, and Accessibility - Immersive environments carry physical and cognitive risks, including nausea, dizziness, fatigue, and collisions with real-world objects. Designers must ensure safe setups, comfortable equipment, and alignment between physical and virtual spaces. Careful attention to visual quality, sound, movement design, and time limits is essential to keep learning accessible and sustainable.

Overall, successful immersive learning comes from balancing good task design, support for different learning needs, engaging social features, clear scaffolding, and safe, accessible setups. When these elements work together, immersive technologies can provide motivating, effective, and inclusive learning experiences.

References

1. Ahn, S. J. G., Nowak, K. L., & Bailenson, J. N.: Unintended consequences of spatial presence on learning in virtual reality. Computers & Education, 186, 104532, (2022).
2. Akgün, M., & Atici, B.: The Effects of Immersive Virtual Reality Environments on Students' Academic Achievement: A Meta-analytical and Meta-thematic Study. Participatory Educational Research, 9(3), 111-131, (2022).
3. Arayaphan, W., Sirasakmol, O., Nadee, W., & Puritat, K.: Enhancing intrinsic motivation of librarian students using Virtual reality for education in the context of culture heritage museums. TEM Journal, 11(2), (2022).
4. Argyriou, L., Economou, D., & Bouki, V.: Design methodology for 360 immersive video applications: the case study of a cultural heritage virtual tour. Personal and Ubiquitous Computing, 24, 843-859, (2020).
5. Asad, M. M., Naz, A., Churi, P., & Tahanzadeh, M. M.: Virtual reality as a pedagogical tool to enhance experiential learning: a systematic literature review. Education Research International, 1-17, (2021).
6. Atkinson, R. C., & Shiffrin, R. M.: Human memory: A proposed system and its control processes. Psychology of learning and motivation 2, 89-195 (1968).

7. Baceviciute, S., Terkildsen, T., & Makransky, G.: Remediating learning from non-immersive to immersive media: Using EEG to investigate the effects of environmental embeddedness on reading in Virtual Reality. Computers & Education, 164, 104122 (2021).
8. Bahari, A.: Affordances and challenges of teaching language skills by virtual reality: A systematic review (2010–2020). E-Learning and Digital Media, 19(2), 163-188, (2022).
9. Bloom, B., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R.: Taxonomy of Educational Objectives, the classification of educational goals, Handbook I: Cognitive Domain. David McKay Company (1956).
10. Buijs-Spanjers, K.R., Harmsen, A., Hegge, H.H. et al.: The influence of a serious game's narrative on students' attitudes and learning experiences regarding delirium: an interview study. BMC Medical Education, 20(289), (2020).
11. Chang, C-C. & Hwang, G-J.: An experiential learning-based virtual reality approach to fostering problem-resolving competence in professional training. Interactive Learning Environments, (2021).
12. Chen, C. Y., Chang, S. C., Hwang, G. J., & Zou, D.: Facilitating EFL learners' active behaviours in speaking: A progressive question prompt-based peer-tutoring approach with VR contexts. Interactive Learning Environments, 1-20, (2021).
13. Chen, C.-J.: Immersive virtual reality to train preservice teachers in managing students' challenging behaviours: A pilot study. British Journal of Educational Technology, 53, 998-1024, (2021).
14. Clack, L., Hirt, C., Kunz, A., & Sax, H.: Experiential training of hand hygiene using virtual reality. Recent Advances in Technologies for Inclusive Well-Being: Virtual Patients, Gamification and Simulation, 31-42, (2021).
15. Coban, M., Bolat, Y. I., & Goksu, I.: The potential of immersive virtual reality to enhance learning: A meta-analysis. Educational Research Review, 100452, (2022).
16. Cooper, V. A., Forino, G., Kanjanabootra, S., & von Meding, J.: Leveraging the community of inquiry framework to support web-based simulations in disaster studies. The Internet and Higher Education, 47, 100757, (2020).
17. Cummings, J. J., Tsay-Vogel, M., Cahill, T. J., & Zhang, L.: Effects of immersive storytelling on affective, cognitive, and associative empathy: The mediating role of presence. New Media & Society, 24(9), 2003-2026, (2022).
18. Cuzzolin, F., Morelli, A., Cirstea, B., & Sahakian, B. J.: Knowing me, knowing you: theory of mind in AI. Psychological medicine, vol. 50, 7, pp. 1057-1061. Cambridge University Press (2020). https://doi.org/10.1017/S0033291720000835
19. Dalim, C. S. C., Sunar, M. S., Dey, A., & Billinghurst, M.: Using augmented reality with speech input for non-native children's language learning. International Journal of Human-Computer Studies, 134, 44-64, (2020).
20. Dave, R. H.: Developing and Writing Behavioral Objectives. Educational Innovators Press (1970)
21. Dehghanzadeh, H., Fardanesh, H., Hatami, J., Talaee, E., & Noroozi, O.: Using gamification to support learning English as a second language: a systematic review. Computer Assisted Language Learning, 34(7), 934-957, (2021).
22. DeWitt, D., Chan, S. F., & Loban, R.: Virtual reality for developing intercultural communication competence in Mandarin as a Foreign language. Educational Technology Research and Development, 70(2), 615-638, (2022).
23. Dhimolea, T. K., Kaplan-Rakowski, R., & Lin, L.: A systematic review of research on high-immersion virtual reality for language learning. TechTrends, 66(5), 810-824, (2022).
24. Di Natale, A. F., Repetto, C., Riva, G., & Villani, D.: Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research. British Journal of Educational Technology, 51(6), 2006-2033, (2020).
25. Dreger, K. C., & Ticknor, B.: Situational XR: Are There More Than Absolutes? Journal of Educators Online, 19(2). https://doi.org/10.9743/JEO.2022.19.2.4, (2022).
26. Drigas, A., Mitsea, E., & Skianis, C.: Virtual reality and metacognition training techniques for learning disabilities. Sustainability, 14(16), 10170, (2022).
27. Duggan, S., & Knyazeva, S.: AI in education: change at the speed of learning: UNESCO IITE policy brief. UNESCO Institute for Information Technologies in Education, Moskow (2020).
28. Dubovi, I.: Cognitive and emotional engagement while learning with VR: The perspective of multimodal methodology. Computers & Education, 183, 104495, (2022).
29. Ebadi, S., & Ebadijalal, M.: The effect of Google Expeditions virtual reality on EFL learners' willingness to communicate and oral proficiency. Computer Assisted Language Learning, 35(8), 1975-2000, (2022).
30. Erdogmus, E., Ryherd, E., Diefes-Dux, H. A., & Armwood-Gordon, C.: Use of virtual reality to improve engagement and self-efficacy in architectural engineering disciplines. In 2021 IEEE Frontiers in Education Conference (FIE), pp. 1-7. IEEE, (2021).
31. Eiris, R., Jain, A., Gheisari, M., & Wehle, A.: Safety immersive storytelling using narrated 360-degree panoramas: A fall hazard training within the electrical trade context. Safety Science, 127, 104703, (2020).
32. Elzie, C. A., & Shaia, J.: A pilot study of the impact of virtually embodying a patient with a terminal illness. Medical Science Educator, 31, 665-675, (2021).
33. Ferris, T. L., & Aziz, S.: A psychomotor skills extension to Bloom's taxonomy of education objectives for engineering education. Doctoral dissertation, National Cheng Kung University Tainan (2005).
34. Galeote, F. D., & Hamari, J.: Game-based climate change engagement: analysing the potential of entertainment and serious games. Proceedings of the ACM on Human-Computer Interaction, 5(CHI PLAY), 1-21, (2021).
35. Ghinea, G., Timmerer, C., Lin, W., & Gulliver, S. R. (2014). Mulsemedia: State of the art, perspectives, and challenges. ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM).
36. Greeno, J. G.: The situativity of knowing, learning, and research. American psychologist, vol. 53, 1, pp. 5-26. (1998). https://doi.org/10.1037/0003-066X.53.1.5.
37. Hayes, A. T., Dhimolea, T. K., Meng, N., & Tesh, G.: Levels of immersion for language learning from 2D to highly immersive interactive VR. In Contextual Language Learning: Real Language Learning on the Continuum from Virtuality to Reality, pp. 71-89. Singapore: Springer Singapore, (2021).
38. Hill, J. R., & Hannafin, M. J. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning. Educational technology research and development, 49(3), 37-52.

39. Hughes, J. A., Prinz, W., Rodden, T., Schmidt, K., & Robertson, T.: Cooperative work and lived cognition: a taxonomy of embodied actions. In: Proceedings of the Fifth European Conference on Computer Supported Cooperative Work, pp. 205-220. Springer Netherlands (1997). https://doi.org/10.1007/978-94-015-7372-6_14.
40. Johnson-Glenberg, M. C., Bartolomea, H., & Kalina, E.: Platform is not destiny: Embodied learning effects comparing 2D desktop to 3D virtual reality STEM experiences. Journal of Computer Assisted Learning, 37(5), 1263-1284, (2021).
41. Jonassen, D. H.: Toward a design theory of problem solving. Educational technology research and development, vol. 48, 4, pp. 63-85. Springer Nature Link (2000). https://doi.org/10.1007/BF02300500
42. Johnson-Glenberg, M. C., Bartolomea, H., & Kalina, E.: Platform is not destiny: Embodied learning effects comparing 2D desktop to 3D virtual reality STEM experiences. Journal of Computer Assisted Learning, 37(5), 1263-1284, (2021).
43. Knowles, M. S.: Self-directed learning: A guide for learners and teachers. Association Press GT Follett Publishing Company, Chicago (1975)
44. Kolb, D.A.: Experiential learning: Experience as the source of learning and development. FT press (1984)
45. Krathwohl, D.R., Bloom, B.S., Masia, B.B. Taxonomy of educational objectives: Handbook II: Affective domain. David McKay Company (1964)
46. Lavoie, D. R.: Effects of Emphasizing Hypothetico-Predictive Reasoning within the Science Learning Cycle on High School Student's Process Skills and Conceptual Understandings in Biology. Journal of Research in Science Teaching, vol. 36, 10, pp. 1127-1147 (1999). https://doi.org/10.1002/(SICI)1098-2736(199912)36:10<1127::AID-TEA5>3.0.CO;2-4
47. Li, P., Fang, Z., & Jiang, T.: Research into improved distance learning using VR technology. Frontiers in Education, 7, (2022).
48. Mayer, R. E., Mautone, P., & Prothero, W.: Pictorial aids for learning by doing in a multimedia geology simulation game. Journal of Educational Psychology, vol. 94, 1, pp. 171–185. (2002). https://doi.org/10.1037/0022-0663.94.1.171
49. Mezirow, J.: Transformative learning: Theory to practice. New directions for adult and continuing education, vol. 74, pp. 5-12 (1997). https://doi.org/10.1002/ace.7401
50. Muller, L., Froggett, L., & Bennett, J.: Emergent knowledge in the third space of art-science. Leonardo, col. 53, 3, pp.321-326 (2020). https://doi.org/10.1162/leon_a_01690
51. Newell, A., & Simon, H. A.: Human problem solving, vol. 104, 9. Englewood Cliffs, NJ, Prentice-hall (1972)
52. Ohlsson, S.: The problems with problem solving: Reflections on the rise, current status, and possible future of a cognitive research paradigm. The Journal of Problem Solving, vol. 5, 1, pp. 101-128 (2012). doi:10.7771/1932-6246.1144
53. Paavola, S., Engeström, R. & Hakkarainen, K.: Trialogical approach as a new form mediation. In: A.Moen, A.I. Morch, S. Paavola (eds.), Collaborative Knowledge Creation: Practices, Tools, Concepts, pp. 1-14. SensePublishers, Rotterdam (2012). https://doi.org/10.1007/978-94-6209-004-0_1
54. Pata, K., Väljataga, T.: The learning effects in immersive technologies. In: Bridging Education and Technology, pp. 98-108. 14th International Conference on Methodologies and Intelligent Systems for Technology Enhanced Learning University of Salamanca (Spain) 26th-28th June, 2024. Lecture Notes in Networks and Systems: Springer (2024). https://doi.org/10.1007/978-3-031-84170-5_9
55. Plass, J. & Schwartz, R.: Multimedia Learning with Simulations and Microworlds. In E. R. Mayer (ed.). Cambridge Handbook of Multimedia Learning, Ed. 2, pp. 729-761. Cambridge University Press (2014). https://doi.org/10.1017/CBO9781139547369.036
56. Plass, J. L., Homer, B. D., & Hayward, E. O.: Design factors for educationally effective animations and simulations. Journal of Computing in Higher Education, vol. 21, 1, pp. 31–61 (2009). https://doi.org/10.1007/s12528-009-9011-x
57. Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I.: A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & Education, 147, 103778, (2020).
58. Rey-Becerra, E., Barrero, L. H., Ellegast, R., & Kluge, A.: The effectiveness of virtual safety training in work at heights: A literature review. Applied Ergonomics, 94, 103419, (2021).
59. Rieber, L.: Multimedia learning in games, simulations, and microworlds. In R. E. Mayer (ed.), The Cambridge handbook of multimedia learning, pp. 549–567. Cambridge University Press (2005). https://doi.org/10.1017/CBO9780511816819.034
60. Rizzetto, F., Rantas, S., Vezzulli, F., Cassin, S., Aseni, P., & Vertemati, M.: New Trends in Surgical Education and Mentoring by Immersive Virtual Reality: An Innovative Tool for Patient's Safety. In The High-risk Surgical Patient (pp. 657-667). Cham: Springer International Publishing, (2023).
61. Rizvic, S., Boskovic, D., Bruno, F., Petriaggi, B. D., Sljivo, S., & Cozza, M.: Actors in VR storytelling. In 2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games) (pp. 1-8). IEEE, (2019).
62. Santhanam, S., Hecking, T., Schreiber, A., & Wagner, S.: Bots in software engineering: a systematic mapping study. PeerJ Computer Science, vol. 8 (2022). https://doi.org/10.7717/peerj-cs.866
63. Slater, M.: Grand challenges in virtual environments. Frontiers in Robotics and AI, vol.1, 3. (2014). https://doi.org/10.3389/frobt.2014.00003.
64. Steinert, S., Marin, L., & Roeser, S. (2022). Feeling and thinking on social media: emotions, affective scaffolding, and critical thinking. Inquiry (United Kingdom). https://doi.org/10.1080/0020174X.2022.2126148.
65. Thagard, P., Shelley, C..: Abductive reasoning: Logic, visual thinking, and coherence. In: Dalla Chiara, M.L., Doets, K., Mundici, D., van Benthem, J. (eds) Logic and Scientific Methods. Synthese Library, vol 259. Springer, Dordrecht (1997). https://doi.org/10.1007/978-94-017-0487-8_22
66. Vygotsky, L. S.: Mind in society: The development of higher psychological processes. Harvard University Press (1978).

67. Väljataga, T., Fiedler, S.H., Laanpere, M. (2015). Re-thinking Digital Textbooks: Students as Co-authors. In: Li, F., Klamma, R., Laanpere, M., Zhang, J., Manjón, B., Lau, R. (eds) Advances in Web-Based Learning -- ICWL 2015. ICWL 2015. Lecture Notes in Computer Science(), vol 9412. Springer, Cham. https://doi.org/10.1007/978-3-319-25515-6_13.
68. Yang, F., & Goh, Y. M.: VR and MR technology for safety management education: An authentic learning approach. Safety science, 148, 105645, (2022).
69. Yang, Q. F., Chang, S. C., Hwang, G. J., & Zou, D.: Balancing cognitive complexity and gaming level: Effects of a cognitive complexity-based competition game on EFL students' English vocabulary learning performance, anxiety and behaviours. Computers & Education, 148, 103808, (2020).

e-DIPLOMA

Funded by
the European Union