Describing and Interpreting an Immersive Learning Case with the Immersion Cube and the Immersive Learning Brain

Dennis Beck[1][0000-1111-2222-3333] and Leonel Morgado[2,3][1111-2222-3333-4444]

[1] University of Arkansas, Fayetteville, AR, USA
[2] Universidade Aberta, Coimbra Delegation, Portugal (CIAC, LE@D & CEG)
[3] INESC TEC, Porto, Portugal
debeck@uark.edu, Leonel.Morgado@uab.pt

Abstract. Current descriptions of immersive learning cases are often difficult or impossible to compare. This is due to a myriad of different options on what details to include, which aspects are relevant, and on the descriptive approaches employed. Also, these aspects often combine very specific details with more general guidelines or indicate intents and rationales without clarifying their implementation. In this paper we provide a method to describe immersive learning cases that is structured to enable comparisons, yet flexible enough to allow researchers and practitioners to decide which aspects to include. This method leverages a taxonomy that classifies educational aspects at three levels (uses, practices, and strategies) and then utilizes two frameworks, the Immersive Learning Brain and the Immersion Cube, to enable a structured description and interpretation of immersive learning cases. The method is then demonstrated on a published immersive learning case on training for wind turbine maintenance using virtual reality. Applying the method results in a structured artifact, the Immersive Learning Case Sheet, that tags the case with its proximal uses, practices, and strategies, and refines the free text case description to ensure that matching details are included. This contribution is thus a case description method in support of future comparative research of immersive learning cases. We then discuss how the resulting description and interpretation can be leveraged to change immersion learning cases, by enriching them (considering low-effort changes or additions) or innovating (exploring more challenging avenues of transformation). The method holds significant promise to support better-grounded research in immersive learning.

Keywords: Immersive Learning, Case Descriptions, Immersion.

1 Introduction

A common problem in the field of immersive learning is the evaluation of outcomes without the means to determine if the instructional approaches and contexts are comparable. This is clear from both the emphasis on systematic literature reviews that focus on outcomes as well as the paucity of those that examine instructional approaches [1].

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

This absence of research on comparing instructional approaches used in immersive learning is also connected to the more general, but still considerable, gap between theory and practice found in education in general.

A related problem arises in the practice of immersive learning: teachers/trainers struggle to identify methods enabling them to utilize immersive learning in their instructional approaches [2]. Lesson planning requires teachers to locate appropriate instructional elements with which to support their instruction, as well as to develop an activity plan that combines their educational approaches and philosophies with the characteristics and potentials of immersive learning environments. Implementation and assessment bring further challenges by requiring coordination of the ever-changing nature of technological skills and the lack of situational awareness of ongoing events [3]. Eventually, teachers often give up and choose to use educational approaches with which they are more familiar. The theory-practice gap is also present here, with the lack of comparability of outcomes and cases hindering teachers' ability to successfully select and implement immersive learning approaches in their instruction.

These problems of research and practice led to efforts to develop descriptive frameworks for understanding and interpreting uses and pedagogical interventions in immersive learning environments, using the Immersion Cube [4] and Immersive Learning Brain [1]. However, a method for employing these frameworks does not currently exist, and examples of how to use them for research and practical purposes are non-existent. Therefore, our purpose here is to present a method for employing these frameworks and to provide a rich description of how to utilize them in the context of researcher and practitioner needs. Our research problem is thus how to employ the Immersion Cube and the Immersive Learning Brain frameworks to describe and interpret educational approaches, and then leverage that to enrich and innovate educational approaches.

This paper tackles this problem by first providing a background on immersive learning and the analysis of educational activities and summarizing the Immersion Cube and Immersive Learning Brain frameworks. It then provides a sample case on wind turbines maintenance procedures training in a virtual reality environment, which will be used to demonstrate the feasibility of the method. The method is presented, in two stages, for different levels of description and interpretation: using the Immersive Learning Brain for strategies and practices and then the Immersion Cube for uses. Then we demonstrate the method on the sample case, yielding as an artifact its Immersive Learning Case Sheet (Fig. 5). We conclude by leveraging that interpretation to enrich and innovate immersive learning cases, explaining the overall rationale it enables and the concrete application to the sample case, and then exposing limitations and extracting conclusions.

2 Background

2.1 Immersive Learning

Deceptively intuitive, immersive learning can mean multiple things. According to recent results of a survey of researchers and practitioners working in this area, there is agreement that "The perspective of the field of 'immersive learning research' status is

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

muddled/fragmented, the current knowledge partially disjointed, specifically among different disciplines" [5]. While a common understanding of immersive learning sees it almost as synonymous with the use of virtual reality in education, this technocentric perspective is giving way to a more holistic, theory-grounded perspective that combines two complex phenomena: *Immersion* and *Learning* [6].

The phenomenon of immersion is seen by recent literature reviews, notably Nilsson et al.'s [7] as a "deep mental involvement" [8], to the point that an individual's attention and awareness shift away from its physical world surroundings. The phenomenon of learning is also seen as being more encompassing than what occurs at the level of individuals, from neurological to cognitive aspects, where it is already "non-linear, adaptive, and constructive" [9]: current research on learning considers also social and sociological aspects, such as culture, school and professional practice, institutional concerns and the diversity of factors that shape it [6]. Combined, the field of immersive learning research is seen as addressing the phenomenon of learning seen and influenced through the lens of immersion [6].

2.2 Analysis and Planning of Educational Activities

To better understand the activities that occurred in immersive learning environments, it became important to understand the kinds of activities which occurred therein. The taxonomy proposed by Beck et al. [1, 4] was proposed to interpret these activities at three levels: Uses, Practices, and Strategies. A *Use* of immersive learning was defined as, "an actual learning activity, rather than its pedagogical-educational rationale, or when that rationale is limited to an intent, without specifying the means to achieve it" [4]. Thus, a Use is strictly operational, focusing on the activity that occurs or will occur, void of any explicit pedagogical reasoning or justification. At a tactical level, *Practices* are localized educational activities that have a pedagogical rationale [1], which may emerge inductively from beliefs, traditions, actions, and choices of educators, or be pragmatic operationalizations of overarching goals, philosophies, or plans. Here the emphasis is on having a pedagogical rationale at a localized level, with limited impact on the overall learning goals and activities over time. Finally, *Strategies* deal with the strategic level, i.e., defined as rationales that go beyond localized activities. They are the overarching goals, philosophies or plans that influence practices or emerge from their structuring. Strategies range from holistic viewpoints to pragmatic patterns which guide decisions and practices towards goals [1].

2.3 Immersion Cube

The Immersion Cube was originally conceived by Nilsson et al. [7] as a means for organizing and visualizing immersion along three dimensions: System, narrative, and challenge-based immersion. Subsequently, the cube was qualitatively operationalized and used to identify gaps in uses of immersive learning environments [4]. The resulting gaps pointed toward the need for:

1. More immersive learning environments research on physical spaces with system immersion.
2. Revisiting the use of traditional immersive environments like games, books, and traditional role-playing games.
3. The creation of high-narrative, high-challenge, high-system environments.
4. More research on leveraging data collection, both by users and from users, and on interactive exploration, both for the visible and the invisible.

Beck et al. [4] also suggested (but did not demonstrate) that the Immersion Cube could be used to interpret current use cases of immersive learning, as well as to enrich and innovate use cases.

2.4 Immersive Learning Brain

There are abundant lists of educational practices and strategies available in multiple websites and publications. Although these lists can be beneficial to browse through, the reader can become easily lost in the lists and unaware of relevant practices and strategies they may wish to utilize in their situation. Absent from these resources was a method for intuitively connecting educational practices and strategies to provide a better way of navigating among these long alphabetical lists that are currently available on many websites and publications. One solution to this problem was the creation of the Immersive Learning Brain (ILB), a mapping of practices to strategies by Beck et al. [1], which resulted in the Engagement and scaffolding, Real and virtual multimedia learning, Active learning, Collaboration, Presence, and Traditional practices clusters of connections. We called the visualization of these clusters the ILB because the layout resembled that of a human brain. We then overlaid our map of practices and strategies onto a traditional image of a brain to emphasize this metaphor. Beck et al. [1] also suggested (but did not demonstrate) that the ILB could be used to interpret the practices and strategies used in current cases of immersive learning, as well as to enrich and innovate those cases.

2.5 Sample Case: Training of Wind Turbines Maintenance Procedures

In the following sections of this paper, we are presenting a method for interpreting immersive learning cases using the two instruments presented above: the immersion cube and the immersive learning brain. Those methods will then be exemplified by applying them to a sample case. This subsection presents that case in brief.

This case was reported in the literature and is an immersive training environment for a major wind turbine manufacturer [10], as shown in Fig. 1.

Cassola et al. [10] described the case as a short course in several stages. First, two expert trainers selected the course content from a technical procedures' manual (Fig. 1, left), and recorded their own execution of the technical procedures in the immersive environment (Fig. 1, center). Then there were independent training sessions with the trainees using virtual reality headsets, with the following structure: a) a visual demonstration of the environment and its affordances; b) a free interaction period for

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

adaptation; c) execution of the procedures by the trainees within the immersive environment, using as references both the manual in-world (Fig. 1, left) and the prerecorded trainer demonstrations, and then interacting directly with the three-dimensional models (Fig. 1, center); d) a certification test, where participants executed the trained tasks upon a physical wind turbine (Fig. 1, right).

Fig. 1. The sample immersive learning case described by Cassola et al. [10]: guidance (left), demonstration and execution (center), certification (right). Pictures from the same source.

The execution of the procedures was done individually by the trainees, and the system would only allow correct actions to be taken. Other than consulting the documentation and watching the pre-recorded actions demonstrated by the expert trainers, no coaching or other support took place.

3 Interpreting Cases with the Immersive Learning Brain

3.1 The Method to Interpret/Describe a Case

The Immersive Learning Brain [1] (as described in the background section) is made up of six main clusters: Engagement and scaffolding, Real and virtual multimedia learning, Active learning, Collaboration, Presence, and Traditional practices. These comprise 21 different practices and 45 strategies (66 items in total), linked together, each inductively derived from the research literature with a definition, description, and example.
We used the Immersive Learning Brain as an interpretive and descriptive tool to tag and annotate cases with specific practices and strategies, indicating if they were present. However, given that we have 66 such tags, conducting this in a plain sequence would be potentially overwhelming and clearly fastidious, and hence at high risk of becoming incoherent. For instance, anyone tagging a specific case in this manner would risk making different decisions depending on where they began in the list of practices and strategies. Suppose one would start with the practices: 22 items later, when going through the strategies, there could be the risk of neglecting judgments employed when considering the first practices. Even within the practices or the strategies themselves, similar situations might arise.
Our response to this problem was to organize those 66 items into theoretical affinity clusters. This allowed one to look at each cluster as a subset of practices and strategies

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

that are related to one another. Thus, the similar concepts and concerns are regularly involved, and the likelihood of inconsistent decisions will likely diminish.
The method we are proposing here is to select the cluster most related to a case first, then the next most related cluster, etc., and only consider the practices and strategies within one cluster at a time. This process will help to develop a list of proximal practices and strategies which are associated with the case. Depending on the purpose for the analysis, we may recommend going through all the clusters systematically, or stopping after the most relevant clusters are analyzed (e.g., you want to decide what to look for, not catalog every aspect). Thus, we developed the following step-by-step method to interpret a case:

1. Develop a full description of your case. This description should include as much information as possible about how immersive learning was employed and not just outcomes.
2. Ask which ILB cluster seems the most relevant to your case. If, for example, the case involves significant collaboration, then it would be likely to look first at the Collaboration cluster for relevant practices and strategies.
3. Using the definitions from the Themes and Categories derived from the review of Practices and Strategies found in Tables I & II of Beck et al. [1], compare each practice and strategy listed in the cluster to the case description and determine whether it applies to the case.
4. Continue to the next most relevant cluster and repeat the process. This process should result in the list of strategies and practices used in your case.
5. Finally, rewrite your initial case description, making sure that you provide enough information to account for the presence of those strategies and practices in case you neglected to provide that in the first draft.

This method should result in a well-described immersive learning case that focuses on how immersive learning was employed, alongside a list of tags of its relevant practices and strategies, for others to access and compare. This can then be used by researchers to compare different cases, including their outcomes, or doing meta-analyses, using this method to acknowledge similarities and differences between cases. It can also be used by practitioners to identify examples for implementation in their instruction, in accordance with their personal or institutional pedagogic choices. Both researchers and practitioners can also use this method to decide on how to expand/extend a case to explore new insights.

3.2 Applying the Method to the Sample Case

For Step 1, we are providing a short description of the case above, but the full description with details can be found in its original publication [10].

For Step 2, we asked which ILB clusters seemed the most relevant to our case. Given that trainers and trainees in our case are quite active in the spatial context and are leveraging their presence alongside turbines and their procedures, we found relevance to our case in the Active Context and Presence clusters. We also find relevance in the Real

and Virtual Multimedia Learning cluster because the case description mentions rich visual content and physical interaction with machines.

Regarding the "Engagement and Scaffolding" cluster, at this level of analysis we don't see obvious engagement activities, and there is explicit mention that there is no support or feedback, so we don't find relevance for this cluster. Activities are done in isolation, so we also did not see relevance in the Collaboration cluster, and there were no lectures or typical instruction, so we also did not see relevance in the Traditional Practices cluster. Of these 3 clusters with some relevance, the case clearly focuses on meaningful actions in the context of their application, so we deemed Active Context to be the foremost cluster of interest, and thus the one from which we would proceed with this analysis.

For Step 3, we reflected on each of the practices and strategies listed under the *Active Context* cluster, on Table IV of the ILB paper [1], using the definitions from Tables I (practices) and II (strategies) of the same paper. We compared our case description to each practice and strategy listed in the cluster and determined whether it applied to the case. For example, we took the definition of the first item, *Authentic Practice and Assessment* (Table I, [1]), "Practices which aimed to make connections between real-world problems, tasks, and outcomes, as well as assessments based on those practices", and asked ourselves if our case description clearly and specifically mentioned aspects of this Practice. Our case focused on learning how to maintain a wind turbine, which is a real-world problem, and then followed it up with a certification test where students performed the same procedures in the physical world that they accomplished in VR, so it clearly matched this Practice. Then we took the definition of the first listed strategy on that cluster, *Active Learning Theories*: "Learning or educational theories related to active learning. This included active learning theory proper." The case involves students actively interacting and completing technical procedures on a VR wind turbine, with freedom to explore beforehand and later applying this to a physical turbine, so it clearly matched this Strategy. We proceeded similarly with the remaining practices and strategies in these clusters, not all of which matched. For instance, the second listed practice (Table IV, [1]), *Enriching student storytelling & roleplay*, is defined as "Practices involving immersion to enrich student activities in storytelling and character roleplaying" and it is not a match because our case does not involve student roleplaying or storytelling, as we discuss later in section 4.2 regarding narrative aspects of this case.

By completing this process for the remaining practices and strategies of the *Active Context* cluster, we attained this list of relevant practices and strategies:

Practices: Authentic practice and assessment, Exploration and experimentation of concepts/processes
Strategies: Active learning theories, Authentic learning, Contextual theories

In Step 4, we continued to the next most relevant cluster and repeated the process. For our case, this was the Presence cluster, and the process was identical to the one described in the previous step, so it will not be provided in detail here. It resulted in the following list of strategies and practices from our case:

Practices: Embodied Interactions
Strategies: Interactive visualization; Presence

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

We also identified the Real and Virtual Multimedia Learning cluster as potentially relevant to our case, and similarly went through its items, identifying the following:

Practices: Information visualization and inference; Learning design for multimodal information
Strategies: (none)

"Cassola et al. [1] described the case as a short course in several stages. First, two expert trainers selected the course content from a technical procedures' manual (Fig. 1, left), and recorded their own execution of the technical procedures in the immersive environment (Fig. 1, center), designing the activity to provide both aspects (Learning design for multimodal information). The content and procedures reflected the context of an actual maintenance shop in which a physical wind turbine would be worked on (Authentic learning, Contextual theories). Then there were independent training sessions with the trainees using virtual reality headsets, with the following structure: a) a visual demonstration of the environment and its affordances; b) a free interaction period for adaptation, where trainees were allowed to explore and experiment (Exploration and experimentation of concepts/processes), actively interpreting the VR model and environment in its context (Information visualization and inference); c) execution of the procedures by the trainees within the immersive environment, experimenting how to perform them on the turbine (Active learning theories, Exploration and experimentation of concepts/processes), using as references both the manual in-world (Fig. 1, left) and the prerecorded trainer demonstrations, therefore an information-diverse experience (Learning design for multimodal information). After this, trainees interacted directly with the three-dimensional models (Fig. 1, center), using their own hand movements, and walking around (Embodied Interactions), present in this technology-based environment (Presence); d) a certification test, where participants executed the trained tasks upon a physical wind turbine in a real-world environment (Authentic learning, Authentic practice and assessment) (Fig. 1, right).
The execution of the procedures was done individually by the trainees (Active Learning theories), and the system would only allow correct actions to be taken. Other than consulting the documentation and watching the pre-recorded actions demonstrated by the expert trainers, no coaching or other support took place."

Fig. 2. The resulting case description, after applying step 5 of the process. Red text denotes edits, blue text within parentheses are simply tags to explain the practices and strategies involved, it is not part of the case description.

This process would continue with the *Real and Virtual Multimedia Learning* cluster and all other clusters, until all clusters are analyzed, particularly if the goal of this interpretation and description is for research purposes. For professional practice purposes, however, it may be deemed sufficient to analyze only the clusters most immediately relatable to the case. The full list of practices and strategies resulting from the process would be a list of tags associated with the case.

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

Finally for Step 5, we rewrote our initial case description from section 2.5, augmenting our initial text to account for the presence of the above listed strategies and practices. Figure 2 shows the outcome, we included the textual additions and edits as red text and added tags for the Practices and Strategies in blue text (within parentheses) for the reader's reference - it isn't needed for the actual case description.

4 Interpreting Cases with the Immersion Cube

4.1 The Method to Interpret/Describe a Case

The Immersion Cube (as described in the background section) structures the phenomenon of immersion along three conceptual dimensions: system, narrative, and agency. The effort that produced the ILB of practices and strategies also analyzed the uses of immersive learning environments, and placed them on that conceptual space, resulting in six clusters of 16 different uses [4].

The Immersion Cube serves as an instrument to identify the non-pedagogical uses of the case. Uses, as explained in the background section, differ from practices by being plain statements of something that happens, without an explicit pedagogical rationale. The pedagogical approaches were identified with the ILB (previous section). The method we are proposing here follows the criterion used in the mapping effort, identifying the level of dependence of the plain aspects of the case regarding each dimension of immersion: system, narrative, and agency. Thus, we developed the following step-by-step method to interpret a case with the Immersion Cube:

1. Develop a full description of your case that involves individuals feeling present amidst its setting (system immersion); the story, diegetic space, and characters (narrative immersion); and intervention possibilities (agency immersion). This description should focus on aspects that are deemed essential to reflect the nature of the case.
2. Evaluate, considering the aspects identified in step 1, how much the case relies on each immersion dimension (on a scale of 0 to 1, or 0% to 100%, 0 has no evidence of that type of immersion, and 1 has evidence of being fully immersed in that kind of immersion.
3. Map the case into the conceptual space of the Immersion Cube, by assigning the coordinates established in step 2.
4. Identify which of the 16 known uses mapped in the cube are proximal to it, by measuring the Euclidean distance to them in the cube.
5. Check if your case matches any of the proximal uses. If not, this process is complete. But if so, rewrite your initial case description, making sure that you provide enough information to account for the occurrence of those uses, in case you neglected to provide that in the first draft.

This method should result in a well-described immersive learning case that focuses on the Uses of immersive learning, alongside a list of tags of its relevant Uses for others to access and compare. This can then be used by researchers to compare different cases,

including their outcomes, or doing meta-analyses, using this method to acknowledge similarities and differences between cases. It can also be used by practitioners to identify examples of Uses in their instruction, in accordance with their personal or institutional pedagogical choices. Both researchers and practitioners can also use this method to decide on how to expand/extend a case to explore new insights.

4.2 Applying the Method to the Sample Case

For Step 1, we provided a short description of the case above, and the full, detailed description is available in its original publication [10]. Recall that the case is about a training course for a major wind turbine manufacturer in a virtual reality environment.

For Step 2, let's first consider how much it relies on system immersion. The entire process requires feeling present in the virtual environment: to analyze the instructions, to freely explore the virtual environment, to watch the recorded procedure in that environment and to replicate it there. Feeling present is also required in the physical certification afterwards in the physical space with the wind turbine. So, we consider this complete dependence on feeling present in the virtual environment for this dimension of immersion as being equal to 1 (100%).

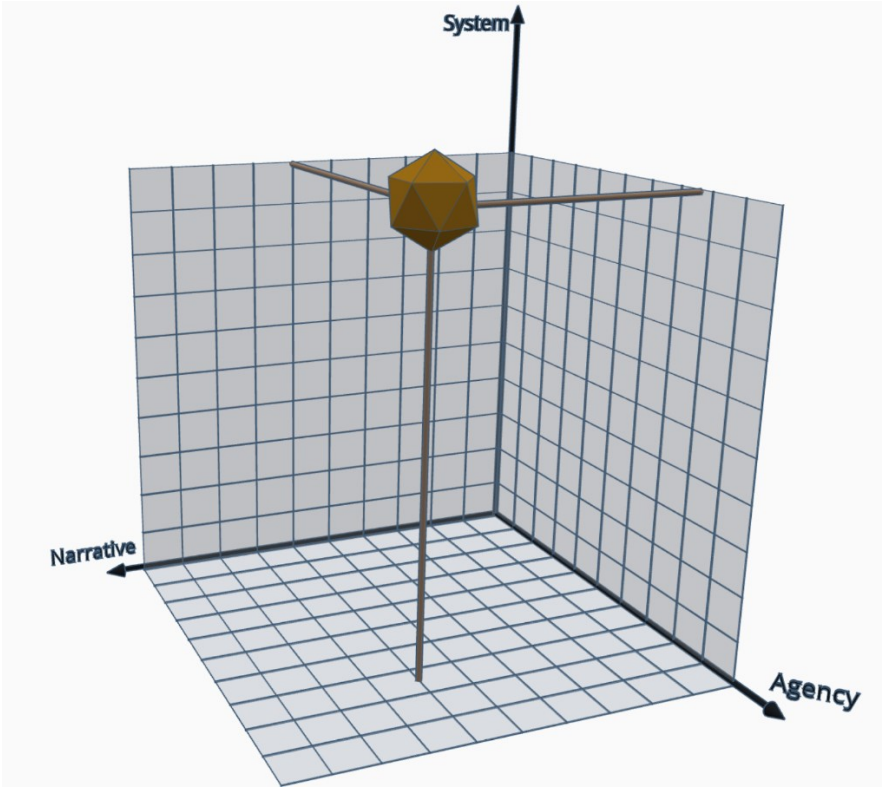

Fig. 3. Placement of the case at coordinates (1,0.6,0.75) in the immersion cube conceptual space.

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

Next, we consider narrative immersion. Narrative immersion involves the spatial, temporal, and emotional aspects of the narrative. Spatially, we have the visual setting providing the context of a maintenance shop and a wind turbine. From the description of the activity, if only the turbine remained and the maintenance shop around it disappeared, the activity would remain the same, and likewise for the physical certification part. Temporally, participants are required to follow an explicit sequence of actions in the instructions sheet and experience them both in recorded demonstration and as one proceeds to execute them. Also, the model of the wind turbine changes visually in response to participants' interactions with them. Emotionally, the instructions have explicit purpose and goals, which provides a plot of sorts. However, there are no other indications of emotional narrative immersion aspects: there is no explicit narrative role being played by the student or the expert trainers, nor an overall storyline under which the procedure is serving a purpose or moving the plot forward, no interest in the outcome beyond its correct execution. Thus, while there is some dependance of the spatial and temporal aspects of the narrative, there is very limited dependance of the emotional aspects, and we consider this as slightly above halfway on the scale: Narrative = 0.6 (60%).

Finally, we consider agency immersion. From the background, we need to consider the strategic and tactical levels, i.e., aspects requiring or expecting participants to plan, to have awareness of their possibilities to intervene, and the operational level, actual expected interventions. At the strategic/tactical level, one only expects the trainees to realize they can check the instructions, that they can explore the settings and their perspective, rather than standing still at their initial position (i.e., their "spawning location"). Even trainers' agency in this regard is extremely limited to selecting the next procedure in order, and not other aspects of the educational activity. At the operational level, there is almost complete dependence of actual interventions upon the environment by both trainers and trainees. So we consider this as highly dependent on agency immersion, although not completely, due to the lack of strategic/tactical aspects: Agency = 0.75 (75%).

For Step 3, we simply place the case in the (system, narrative, agency) coordinates (1,0.6,0.75), as shown in Fig. 3.

For Step 4, we measure the Euclidian distance between coordinates (1,0.6,0.75) for this case, and the coordinates of the 16 known uses, as published by Beck et al. [4]. This is the straight-line distance between the case and the center of each ball in Fig. 5 of Beck et al. [4]. If one wants to be rigorous, it can be calculated using Equation 1, where use_i refers to each of those 16 uses (i going from 1 to 16).

$$Euclidean\ distance\ (case, use_i) = \sqrt{(System_{case} - System_i)^2 + (Narrative_{case} - Narrative_i)^2 + (Agency_{case} - Agency_i)^2} \quad (1)$$

Applying this formula to all 16 uses, we get the results in Table 1, which shows that there is clear proximity to uses in cluster 2, "Simulating", and as the farthest uses "Emotional and cultural experiences" and "Engagement", with the remaining uses in between, as shown in Fig. 4. Given this distribution, we consider as proximal only those two closest cases, since all others are clearly distant, from a visual analysis of the figure.

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

Table 1. Euclidean distances from the case to the 16 uses of immersive learning environments.

Use	Cluster of the Use	Distance to Case
Logistics	2 - Simulating	0.15
Simulate the physical world	2 - Simulating	0.27
Interactive manipulation and exploration	3 - Exploring	0.65
Accessibility	6 - Accessing	0.76
Augmented context	5 - Experiencing	0.80
Data collection	3 - Exploring	0.82
Emphasis	1 - Complementing	0.83
Perspective switching	6 - Accessing	0.85
Complement/Combine contexts, media or items	1 - Complementing	0.86
Seeing the invisible	6 - Accessing	0.91
Multimodal interaction	1 - Complementing	0.96
Changing human behavior	5 - Experiencing	1.04
Collaboration	4 - Engaging	1.04
Skill training	4 - Engaging	1.04
Emotional and cultural experiences	5 - Experiencing	1.19
Engagement	4 – Engaging	1.19

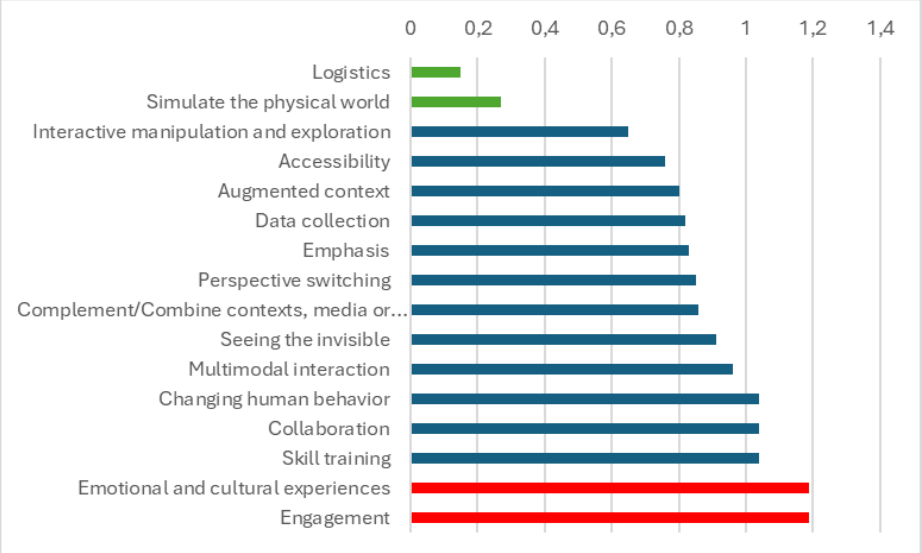

Fig. 4. Euclidean distances between the case and the 16 uses of immersive environments in the conceptual space of immersion. The colors denote three distinct groups of distances.

For Step 5, we compared the descriptions of those proximal Uses from Table 1 (*Logistics* and *Simulate the Physical World*). From the list of definitions found in Table 3 of Beck et al. [4], we see (p. 1057) that "The theme Logistics represents accounts of use of immersive learning environments for learning activities to coordinate situations involving multiple types of resources or their scarcity (time, equipment, personnel, funding)." In our case, both in our summary in section 2.5 and in its original source [10], there is no mention of coordinating resources or their scarcity, just plain statements of what was done. Therefore, there is no match to this use, and no need to change the description.

The next proximal Use, *Simulate the Physical World*, focuses on "(...) use of immersive environments for learning activities that imitate or mirror aspects of the physical world. This includes spaces and processes, as well as specific concerns about the fidelity of the environment or process being simulated." In our case, in our summary in section 2.5 there is no specific concern that the virtual reality wind turbine matches the physical wind turbine, at least enough so that students can replicate the same procedures for certification of training, and there are no statements in the case description about the level of fidelity. However, this information is provided in its original source [10], which refers that they used "CAD-based data for visual accuracy" and that the model configuration would "limit the number of possible interaction alternatives for trainees and likewise restrict the trainer's available interactions for procedure demonstration", hence having very high fidelity visually but not entirely mirroring all possible processes. So, in this step, we would edit the description in section 2.5 to clarify the concern for environmental fidelity of the wind turbine and the limits on the mirroring of processes.

5 Discussion

5.1 From Interpretation to Intervention

The completion of the method presented in the previous section, using the ILB and the Immersion Cube, resulted in a structured description of a case, leading not only to the clarification of its original description, but also to tagging in it the relevance of specific practices and strategies, to its positioning in the conceptual space of immersion, and to the identification of proximal uses. This set of information, which can be organized as an "Immersive Learning Case Sheet" (we exemplify a layout in Fig. 5) constitutes a common framework for researchers and practitioners to interpret cases, and thus supporting their comparison and informed discussion.

Beyond interpreting and describing cases, this method's output (the case sheet) also serves as a starting point for researchers who wish to experiment with variations on their cases and for practitioners who desire to try out new ways of implementing their cases in the wild. Specifically, one can "enrich" the case, by considering aspects that are closely related to it, and reflecting on whether there would be better alternatives or additions to serve the overall goals of the case or induce other small-scale adaptations. One could also "innovate" with the case, by considering seemingly unrelated aspects, and reflecting on their potential to explore entirely different goals or approaches, thus

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

supporting transformative educational activities using the case as a steppingstone. Both enrichment and innovation interventions should account for the educational goals and for the contextual constraints of the intended setting, content, and participants, using learning design frameworks and guidelines, such as the criteria for use of immersive learning environments previously published in iLRN proceedings [2]. Sections 5.2 and 5.3 below will detail how we envision these methods with our sample case.

Fig. 5. Sample layout of the Immersive Learning Case Sheet

5.2 Enrich/Innovate a Case with the Immersive Learning Brain

Using the ILB to enrich a case, one examines a cluster where that case is already active and considers applying other strategies & practices in that cluster either alongside current ones, or instead of them. To innovate in that case (also in the sense of section 5.1), one considers a different cluster, where the case is not currently active or barely so.

As an example, we considered the Active Context cluster, where our case was foremost active and applied other strategies and practices in that cluster. For example, we considered the *After-action review strategy*, which refers to reviewing the practices that were applied, to reflect upon them, learn and then improve upon them. An *After-action review* strategy could be helpful for trainees in our case to develop insights on their performance and the overall procedures and might be readily implemented by providing them with something that is already described in the case. The case reports that trainer actions can be viewed by the trainees, so clearly the system can record actions. Hence, it would be a simple matter of creating a step in the educational activity where trainees would review the recording of their own actions and subsequently reflect upon them.

Additionally, we considered implementing the Practice of *Enriching student storytelling & roleplay*, from that same cluster. It may be helpful for students to place themselves in a role in which they face the need to apply the actual procedure in which they have received training, better realizing the purpose of their actions. This could be readily introduced in the case by including a preliminary narrative to situate them in the proper context and role upon initiating the procedure, and possibly a concluding narrative leading to possible consequences of their maintenance of the turbine. Cut scenes could also be included at significant points to show progress and reward success.

To innovate in our case, we considered using a different cluster, where our case was not currently active. In this instance, we considered applying the Collaboration cluster, and looked upon the *Collaborative learning* Strategy, which prompted us to include the goal of "developing 'joint intellectual effort' (...) involving students, teachers, or other participants." This involved significant adaptations, since the current case was planned for individual execution by each trainee, and the expert trainers were involved only in the learning design and content recording. Thus, it involved different scheduling of people involved, more hardware (multiple headsets, while now a single headset suffices), software changes (because the software may not have multi-user affordances) and a replanning of the learning activity to include collaboration, discussion, and debate. This said, these are not insurmountable hurdles and rather unveil enticing new educational possibilities based upon the current scenario.

5.3 Enrich/Innovate a Case with the Immersion Cube

Using the Immersion Cube to enrich a case, one would examine the proximal uses of that case, and consider including them either alongside what is already occurring in the case, or instead of it. To innovate in that case, one would consider more distant uses, possibly even the most distant ones. Conversely, one could also innovate by imagining what the current case might look like if its position in the cube changed, i.e., if it were to rely more (or less) on each dimension of immersion.

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

Using the Immersion Cube to enrich our case involved identifying its position on that conceptual space and finding out which uses were the closest to it. In our case, as shown in Section 4.2, we realized the top two uses were much closer than any others (Table 1 & Figure 4). These were *Logistics* and *Simulate the Physical World*. We then looked up their definitions in Table 3 of Beck et al. [4]. For example, Logistics, "represents accounts of use of immersive learning environments for learning activities to coordinate situations involving multiple types of resources or their scarcity (time, equipment, personnel, funding)" (p. 1057). Although resource coordination or scarcity are not mentioned in the case description, one can readily imagine that demonstrating and practicing technical interventions on a wind turbine, involving physical space, materials, and tools, as well as human experts to account for safety, are multiple types of resources. Of course, some of these are not always available on demand or the needed equipment is not available for every student. Thus, the addition of this use to our case could be implemented readily and help provide anytime, anywhere access to scarce resources as well as multiple opportunities to interact with expert training that are not always available in the physical world. This would also make the case helpful for administrators responsible for the allocation and coordination of scarce resources.

We also used the Immersion Cube to innovate in our case. This involved considering if more distant uses were adequate for one's goals and resources. For instance, one of the most distant was *Emotional and cultural experiences*, whose definition focuses on, "... learning activities where non-physical concepts are experienced within context. This includes social, societal and historical situations, but also metacognitive awareness such as one's emotional responses or dangerous situations." One might consider this to enable trainees to experience undesirable outcomes resulting from maintenance malpractice, including from seemingly irrelevant (but crucial) practices, or to realize how not following due procedures may result in physical harm or even fatality. E.g., one could imagine our case implemented with feedback, reporting that electrocution or mechanical failure would occur. That feedback could even be haptic, resulting in an unpleasant tactile sensation or a narrative cutscene, such as a disciplinary meeting with a supervisor. Applying such a use would require significant investment in transforming the case, both to enable new technical features and content, and to reorganize the learning design to account for it. However, just as in the innovative examples using the ILB, it is not an unreasonable goal, and opens avenues for transformational use of this case.

Finally, we innovated the case using the Immersion Cube by keeping its Uses as they are, but varying its levels of reliance on system, narrative, or agency immersion, for experimental and practical effect. If we wanted to increase the amount of agency in our case (currently, at 75%) we might permit students to execute the maintenance procedures on the wind turbine using their own sequence, or different tools, or even to include unplanned actions. This could open opportunities to identify hidden misinterpretations or misconceptions of students, and hence address them during after-action review or evaluation. As another example, if we considered less system immersion, we might consider an augmented reality smartphone application that provides the wind turbine model and access to its intervention from the technical manual page, but not in the context of the virtual space of a maintenance shop. Since this would occur without headsets, it might enable physical collaboration between peers or with the trainer. In

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

both examples, these considerations provide reasonable avenues for alternative learning approaches from this case, albeit requiring significant effort or changes to the technical and human resources or learning design.

6 Limitations

A significant limitation of the utilization of the ILB and Immersion Cube as interpretive and descriptive tools, and then as a starting point to enriching and innovating cases, is that the approach relies on two frameworks which have not been extensively vetted by the community. Hence the output of this method (Immersive Learning Case Sheets) may need to be revised if those frameworks change. Additionally, we have not established strict criteria for judgment calls at each step, so different researchers may classify the same case in different ways, and thus the method here needs to be empirically developed and more solidly grounded in its components. Further, we have not subjected this method to extensive application by third parties, to evaluate its feasibility to different usage profiles, or aspects which require further clarification, particularly given that judging for applicability of specific strategies and practices may demand significant knowledge of a diverse array of educational science concepts and theory. Additionally, there is a need to allow this method to compare uses, practices and strategies in the diverse academic subject areas and applications of the field of immersive learning.

7 Conclusions

We have presented a method for interpreting and describing immersive learning cases and demonstrated it with a specific case, showing its feasibility. The interpretation/description achieved, provided as a structured format that we named Immersive Learning Case Sheet, opens the possibility of comparing or contrasting immersive learning cases and thus the enticing ambition of having more solid research results on outcomes of immersive learning approaches. It is anticipated that this method can be used within the field of immersive learning to bolster the strength of future meta-analyses by considering multiple cases with common tags of Uses, Practices, and Strategies. Conversely, this may also enable researchers to be more aware of differences between cases and acknowledge them. Finally, the Immersive Learning Case Sheet enabled us to discuss potential avenues for intervention upon cases, and in doing so constitutes a new tool for learning design and educational planning of immersive learning.

A final thought is given to the wide range of scientific disciplines that seek to employ and research immersive learning, each with their diverse epistemological and ontological frameworks and viewpoints. As shown recently, the community of research and practice in Immersive Learning sees its definitions, concepts, and methods as being fragmented and needing consistency, and support the idea of the creation of a common conceptual framework, common methods, and other research instruments [5]. The Immersive Learning Research Network has authored the Immersive Learning Knowledge Tree, a systematization effort focused on the integration of both scholarly and practical knowledge, for the purpose of cultivating a robust and ever-growing knowledge base

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.

and methodological toolbox for immersive learning and promoting evidence-informed practice and guiding future research in the field, and the ILB and Immersion Cube were presented as part of it in iLRN 2023. We hope that this method based on those instruments, as presented in this paper will help further this effort.

Acknowledgments. This work is financed by National Funds through the FCT - Fundação para a Ciência e a Tecnologia, I.P. (Portuguese Foundation for Science and Technology) within the project FronTowns, with reference PTDC/HAR-HIS/3024/2020.

Disclosure of Interests. The authors board members of Immersive Learning Research Network.

References

1. Beck, D., Morgado, L., O'Shea, P.: Educational Practices and Strategies with Immersive Learning Environments: Mapping of Reviews for Using the Metaverse. IEEE Trans. Learn. Technol. 17, 319–341 (2024). https://doi.org/10.1109/TLT.2023.3243946
2. Morgado, L., Torres, M., Beck, D., Torres, F., Almeida, A., Simões, A., Ramalho, F., Coelho, A.: Recommendation Tool for Use of Immersive Learning Environments. In: 2022 8th International Conference of the Immersive Learning Research Network …. pp. 1–8 (2022)
3. De Lima, C.C., Morgado, L.C., Schlemmer, E.: Relevant Aspects To Promote Teacher Awareness in the Pedagogical Orchestration of Learning Activities Where Students Move. In Review (2021)
4. Beck, D., Morgado, L., O'Shea, P.: Finding the Gaps about Uses of Immersive Learning Environments: A Survey of Surveys. J. Univers. Comput. Sci. 26, 1043–1073 (2020)
5. Morgado, L., Beck, D., Gütl, C., Oliveira, T., Richter, J.: Immersive Learning Research from the Perspective of Its Researchers and Practitioners: Questionnaire Validation and Early Results from a Survey on a Conceptual Framework for the Field. In: Bourguet, M.-L., Krüger, J.M., Pedrosa, D., Dengel, A., Peña-Rios, A., and Richter, J. (eds.) Immersive Learning Research Network. pp. 53–69. Springer Nature Switzerland, Cham (2024)
6. Morgado, L., Beck, D.: Unifying Protocols for Conducting Systematic Scoping Reviews with Application to Immersive Learning Research. In: 2020 6th International Conference of the Immersive Learning Research Network (iLRN). pp. 155–162. IEEE, San Luis Obispo, CA, USA (2020)
7. Nilsson, N.C., Nordahl, R., Serafin, S.: Immersion Revisited: A review of existing definitions of immersion and their relation to different theories of presence. Hum. Technol. 12, 108–134 (2016). https://doi.org/10.17011/ht/urn.201611174652
8. Agrawal, S., Simon, A., Bech, S.: Defining Immersion: Literature Review and Implications for Research on Immersive Audiovisual Experiences. In: 147th AES Pro Audio International Convention. p. 14. Audio Engineering Society, New York (2019)
9. Doolittle, P. e.: Complex Constructivism: A Theoretical Model of Complexity and Cognition. Int. J. Teach. Learn. High. Educ. 26, 485–498 (2014)
10. Cassola, F., Mendes, D., Pinto, M., Morgado, L., Costa, S., Anjos, L., Marques, D., Rosa, F., Maia, A., Tavares, H., Coelho, A., Paredes, H.: Design and Evaluation of a Choreography-Based Virtual Reality Authoring Tool for Experiential Learning in Industrial Training. IEEE Trans. Learn. Technol. 15, 526–539 (2022). https://doi.org/10.1109/TLT.2022.3157065

Preprint accepted for the Immersive Learning Research Network 2024 conference, Glasgow, Scotland, UK, 1-7 July.