



An Explosion of the Uses of Immersive Learning Environments: A Mapping of Reviews Update

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Abstract. Since the publication of the 2020 paper, “Finding the Gaps About Uses of Immersive Learning Environments: A Survey of Surveys,” the landscape of immersive learning environments (ILEs) has continued to evolve rapidly. This update aims to revisit the gaps identified in that previous research and explore emerging trends. We conducted an extensive review of new surveys published after that paper’s cut date. Our findings reveal a significant amount of new published reviews ($n = 64$), more than doubling the original corpus ($n = 47$). The results highlighted novel themes of usage of immersive environments, helping bridge some 2020 research gaps. This paper discusses those developments and presents a consolidated perspective on the uses of immersive learning environments.

Keywords: Immersive Learning · Metaverse · Augmented Reality · Virtual Reality · Extended Reality · Mixed Reality · XR · AR · VR

1 Introduction

In past work, we mapped the uses of immersive learning environments accounted for in the literature, by conducting a survey of surveys [1]. Despite high expectations from initial adoption of immersive technologies in educational contexts, impact studies are often conflicting, revealing the necessity to consider not only the technology itself but its broader context. One way to accomplish this is through an approach posited by information systems research [2], which acknowledges the observer effect [3] and the complex cause-effect relationships inherent in evaluating technology’s impact on learning [4]. Our analysis emphasized the importance of understanding actual uses of immersive learning environments [1].

Further, we argued that the impact of learning technology extends beyond traditional metrics like academic or skill performance, influencing systemic dynamics and potentially altering learning practices and expectations. Evaluating technology solely based on impacts can be shortsighted, missing out on more transformative potentials [2]. Thus, research on immersive learning environments should encompass both evaluation and design & development dimensions, addressing practical and complex problems [5]. By scoping current empirical research and identifying gaps, we aimed to inform future efforts and set new goals for the research community.

2 Background

2.1 Immersion

The word “immersion” has come to mean many things to different scholars. Computing literature often ignores all other possible definitions and explains it as an objective characteristic of the technical system features and affordances: the physical ability to look around and experience an alternative virtual world, as if one is part of it [6]. Others have deemed it the psychological feeling of being present in that virtual world [7], albeit this feeling is now commonly deemed to be a different concept: Presence [11]. However, other fields of knowledge, such as literature or game studies, have long explored immersion as a phenomenon, revealing the importance of other aspects for it, such as the diegetic narrative [8] or player agency [9]. Even studies centered on technical aspects of immersion have demonstrated that interpreting their impacts requires considerations that go beyond providing synthetic virtual representations. Slater has pointed out the importance of plausibility for this phenomenon to arise, based on the narrative circumstances and participants’ considerations on their levels of possible agency [10].

In the last decade, panoramic reviews of the topic exposed the nature of this phenomenon, particularly the works of Nilsson et al. [11] & Agrawal et al. [12]. They have collected and contrasted multiple perspectives to provide a theoretical framework towards a more holistic understanding of immersion. The latter explained immersion as:

“a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes (with or without sensory stimulation) cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world” [12].

Nilsson et al. had previously reached a similar understanding, while not making an assertive definition statement, by showing how the multifaceted views on immersion could be combined under three dimensions (system, narrative, and challenges). They also provided helpful clarification by visualizing this phenomenon conceptually, using each dimension as coordinates of a cube. The relationship of Immersion as a phenomenon with Presence as a sensation is also clarified by several authors synthesized by Nilsson et al., detailing how the abstractness of a challenge could lead to immersion and absence, rather than presence, and as a reader’s role or absence in a story could likewise have related effects. Later works renamed the “challenge” dimension as “agency”, due to it including operational interventions and tactical and strategic considerations on possible actions [13, 14]. In this work we have followed this terminology.

2.2 Uses, Practices, and Strategies in Immersive Learning Environments

Under the above definition of “immersion”, we define “immersive learning” as the application of that theoretical lens to the phenomenon of learning. Hence, when wishing to interpret, describe or plan educational interventions using immersive learning, one must identify its personal view and guiding theories on learning. Immersive learning by itself is agnostic regarding learning, acknowledging the existence of diversified and sometimes conflicting perspectives on the phenomenon.

Thus, to identify educational accounts of uses of immersive environments we sought to distinguish between aspects that have explicit pedagogical rationales from those that do not. As we collected the original data for the survey of surveys [1], we inductively derived thematic categories to distinguish different level of scope, from operational “uses”, tactical “practices”, and “strategies”, defining a three-tiers framework for classifying educational activities [15]. The latter two categories have explicit pedagogic rationales and are not relevant for this paper. We defined an “account of use” as: “... Meaning the literature plainly reports 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.” [1]. Others have since used this approach for specific areas of interest [14, 16] or to conduct reviews of the field and describe it [17]. Since the publication of the original survey, Pedrosa et al. [14] also discovered two additional use themes, which we adapted as “Mobility” and “Learning Management”.

3 Methods

To perform this update to the previous work, we followed the same goal, “to assemble a panorama of accounts of use of immersive learning environments,” using the same definition of ‘Account of Use’: a case where “*the literature plainly reports an actual learning activity [without] (...) its pedagogical-educational rationale, or when that rational is limited to an intent, without specifying the means to achieve it.*” [1]. We also employed the previous work’s scope and methods for literature search on Google Scholar, including keywords, search strings, inclusion and exclusion criteria, and data extraction methods [1], only updating the date range. As in that previous study, we did not check which original papers of publication were aligned with each account of use. This means that a single original account may be reported on multiple surveys, potentially biasing the prevalence results for each use, but not their diversity. Analyses of the coverage of diverse research domains by various indexing services indicate that Google Scholar encompasses the majority of sources indexed by alternative platforms [18].

The previous work had mapped literature reviews up until the end of 2019, and we began this updating in March 2022, when the search was conducted. This resulted in $n = 64$ new articles found for extracting, meaning the updated results comprised a mapping of $n = 111$ reviews. The laborious qualitative process was finished in October 2024. As a result, this update does not include any surveys published after March 2022 (Fig. 1).

After data extraction, we initiated qualitative thematic content analysis, employing the Vaismoradi et al. [19] process for coding each extracted account of use of immersive environments. Our approach to inter-rater coding attempted to improve both the quality and efficiency of the coding process. Training and employing additional human expert coders is a lengthy process, risking the timeliness of this updated review. Hence, we created QUAL-E, an artificial intelligence custom GPT, as a co-intelligent parallel coder [20]. Training QUAL-E took about the same amount of time as a human junior researcher, but the coding process was faster and could be repeated as often as necessary, while achieving accuracy comparable to our own, as reported earlier [20]. In short, each researcher individually coded each account of use, and then we compared our codes with

those coded by QUAL-E. When codes differed between human coders and QUAL-E, we reconciled them by referring to the specific definition of an account of use of an immersive environment and checked if the codes aligned to that definition. Any human or QUAL-E codes unaligned to that definition were eliminated. For codes that did follow the definition, regardless of whether they originated from a human coder or QUAL-E, the human coders discussed their adequacy until a consensus was reached. The number of codes per account was determined by saturation, not a preset limit.

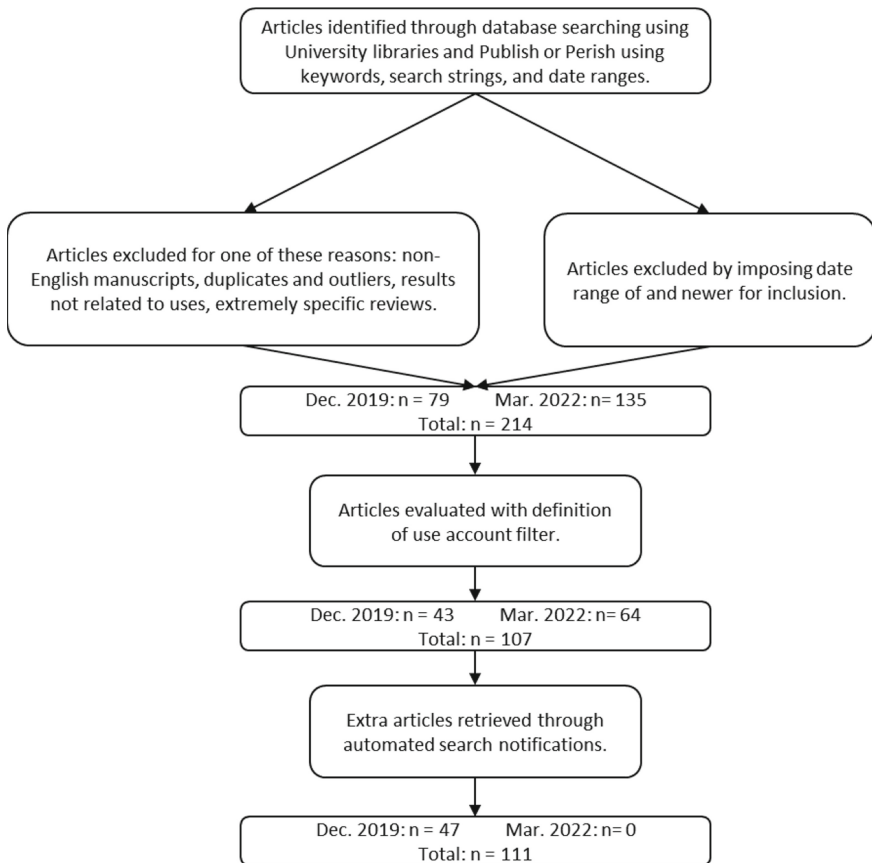


Fig. 1. Overall systematic survey search process, combining the previous one and this update.

We also followed the Vaismoradi et al. process for theme construction, which involved classifying, comparing, and labeling. As described in the Background section above, the previous survey had identified 16 themes [1] and a later work [21] had pointed out the relevance of two new themes, so 18 themes in all, with their definitions, already existed and were considered in this process. Many of the codes were classified into those 18 existing themes, but also four new themes were synthesized and defined, taking into consideration the definitions of existing themes.

In the previous survey, we had deemed the code “games” as referring to a setting and not to an activity, and thus that code was not part of the results. In retrospect, the current analysis consensually deemed that decision to be inadequate, so a new theme, Games, was created to account for those accounts of use of immersive environments. Another new theme, Storytelling, emerged from this process. In the 2019 codes, three were impacted by the emergence of this new theme, and thus moved into it from the Augmented Context theme. The resulting themes and their definitions are presented in Sects. 5, and their prevalence in Sect. 6 (Table 2 and Fig. 4).

4 Corpus

Table 1 presents the list of 64 new survey papers used for extraction; the original 47 papers are listed in the original review [1].

Table 1. Dataset of new survey papers resulting from the updated search.

ID/Year	Authors/Title
P48/2020	Tilhou et al./3D virtual reality in K-12 education: A thematic systematic review
P49/2021	Pathania et al./A Chronological Lit. Rev. of Diff. Aug. Real. Appr. in Education
P50/2021	Dahl/A Preliminary Scoping Review of Immersive Virtual Soft Skills Learning and Training of Employees
P51/2022	Godoy Jr/A Rev. of Aug. Real. Apps for an AR-Based STEM Ed. Framework
P52/2021	Koscielniak/A review of immersive learning technologies featured at EDUCAUSE annual conferences: Evolution since 2016
P53/2019	Ziden et al./A Review of Research of Augmented Reality: Learning Approach and The Potential in Education
P54/2021	Wulandari et al./A Rev. of Res. on The Use of Aug. Reality in Physics Learning
P55/2020	di Lanzo et al./A review of the uses of virtual reality in engineering education
P56/2021	Jaiswal et al./A Review on Augmented Reality in Education
P57/2021	Sukirman et al./A Strategy of Learning Computational Thinking through Game Based in Virtual Reality: Systematic Review and Conceptual Framework
P58/2021	Lau et al./A Syst. Lit. Review of Augmented Reality Used in Language Learning
P59/2021	Alper et al./A Systematic Literature Review towards the Research of Game-Based Learning with Augmented Reality
P60/2021	Mystakidis et al./A systematic mapping review of augmented reality applications to support STEM learning in higher education

(continued)

Table 1. (continued)

ID/Year	Authors/Title
P61/2021	Majid et al./A Syst. Rev. of Aug. Reality Applications in Language Learning
P62/2022	Mazzuco et al./A systematic review of augmented reality in chemistry education
P63/2021	Rodríguez-Abad et al./A Systematic Review of Augmented Reality in Health Sciences: A Guide to Decision-Making in Higher Education
P64/2020	Radianti et al./A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda
P65/2021	Gómez Rios/Using Aug. Real. in programming learning: A syst. Mapping study
P66/2022	Lai et al./Adoption of Virt. And Aug. Real. For Math. Ed.n: A Scoping Review
P67/2022	Özçelik et al./Aug. Real. (AR) in Lang. Learn.: A Principled Rev. of 2017–2021
P68/2021	Theodoropoulos et al./Aug. Real. And programming ed.: A systematic review
P69/2021	Gutiérrez et al./Aug. Real. For Distance Education: A Syst. Literature Review
P70/2020	Fan et al./Aug. Real. For early lang. Learning: A systematic review of augmented reality application design, instructional strategies, and evaluation outcomes
P71/2021	Godoy Jr/Augmented Reality for Education: A Review
P72/2020	Ahmad et al./Aug. Reality for learning mathematics: A syst. Literature review
P73/2020	Parmaxi et al./Aug. Real. in language learn.: A state-of-the-art rev. of 2014–2019
P74/2020	Sırakaya et al./Augmented reality in STEM education: A systematic review
P75/2022	Tolba et al./Augmented Reality in Technology-Enhanced Learning: Systematic Review 2011–2021
P76/2021	Sari et al./Aug. Real. Tech. as a tool to support chemistry learn.: a scoping review
P77/2020	Alzahrani/Augmented reality: A systematic review of its benefits and challenges in e-learning contexts
P78/2020	Nassar et al./Computer simulation and virtual reality in undergraduate operative and restorative dental education: A critical review
P79/2021	Mystakidis et al./Deep and meaningful e-learning with social virtual reality environments in higher education: a systematic literature review
P80/2021	Karacan et al./Educational Augmented Reality Technology for Language Learning and Teaching: A Comprehensive Review
P81/2021	Cai et al./Exploring Aug. Reality Games in Accessible Learning: A Syst. Rev
P82/2020	Weber/Exploring the potential of virt. Real. For learning—a syst. Literature review
P83/2021	Blair et al./Imm. 360° videos in health and social care ed.: a scoping review
P84/2021	Hamilton et al./Imm. Virt. Real. as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design
P85/2021	Peixoto et al./Imm. Virt. Real. For foreign lang. ed.: A Prisma systematic review

(continued)

Table 1. (continued)

ID/Year	Authors/Title
P86/2021	Pellas et al./Immersive Virtual Reality in K-12 and Higher Education: A systematic review of the last decade scientific literature
P87/2020	Di Natale et al./Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research
P88/2021	Ummihusna et al./Investigating immersive learning technology intervention in architecture education: A systematic literature review
P89/2021	Lehikko/Measuring Self-Efficacy in Immersive Virtual Learning Environments: A Systematic Literature Review
P90/2021	McBain et al./Scoping review: The use of augmented reality in clinical anatomical education and its assessment tools
P91/2021	Ratchiffe et al./Sensorimotor learning in imm. Virt. Real.: a scop. Literature review
P92/2021	Pirker et al./The potential of 360-degree virtual reality videos and real VR for education-A literature review
P93/2022	Urlings et al./The role and effectiveness of augmented reality in patient education: a systematic review of the literature
P94/2022	García et al./The Use of Aug. Real. in Latin-American Eng. Ed.: A Scop. Rev
P95/2019	Rappa et al./The use of eye tracking technology to explore learning and performance within virtual reality and mixed reality settings: a scoping review
P96/2021	van der Linde-van den Bor et al./The use of virtual reality in patient education related to medical somatic treatment: a scoping review
P97/2019	Diao et al./Trends and research issues of augmented reality studies in architectural and civil engineering education—A review of academic journal publications
P98/2021	Alizkan et al./Trends of Aug. Real. in Science Learning: A Rev. of the Literature
P99/2021	Redep et al./Use of Aug. Reality with Game Elements in Education—Lit. Rev
P100/2021	Jones et al./Use of virtual and augmented reality-based interventions in health education to improve dementia knowledge and attitudes: an integrative review
P101/2021	Christian et al./Virt. Real. (VR) in Sup. Ed. Distance Learn.: A Syst. Lit. Rev
P102/2021	Scavarelli et al./Virt. Real. And aug. Real. in social learning spaces: a lit. Rev
P103/2022	Kruk et al./Virt. Real. as a patient education tool in healthcare: A scoping review
P104/2021	Asad et al./Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review
P105/2020	Pirker et al./Virtual reality in computer science education: A systematic review
P106/2021	Luo et al./Virtual reality in K-12 and higher education: A systematic review of the literature from 2000 to 2019
P107/2022	Jiang et al./Virtual Reality in Medical Students' Education: Scoping Review

(continued)

Table 1. (continued)

ID/Year	Authors/Title
P108/2021	Mahajan et al./Virtual reality in presurgical patient education: A scoping review and recommended trial design guidelines
P109/2021	Huang et al./Virtual Reality in Teacher Education From 2010 to 2020: A Review of Program Implementation, Intended Outcomes, and Effectiveness Measures
P110/2021	Plotzky et al./Virt. Real. Sims. in nurse education: A systematic mapping review
P111/2022	Krassmann et al./What is the relationship between the sense of presence and learning in virtual reality? A 24 years systematic literature review

5 Results

5.1 Overview

As described in the methods section, the thematic analysis process analyzed the new 64 reviews, identifying accounts of educational use of immersive environments. This resulted in 555 new accounts. Together with the 156 accounts of the previous mapping survey, this comprises a total of 711 use accounts. The new accounts were coded, yielding 820 new codes. Since there were 477 codes in the previous survey, the total number of codes underlying these results are 1,297. The yearly distribution is shown in Fig. 2. Please note that an educational use account found in a survey paper in year ‘x’ was originally published in a paper in a previous year, referenced by that survey.

By performing qualitative theme development on those codes, we assigned new codes to the existing themes (the 16 themes by Beck et al. [1] and the two themes identified since by Pedrosa et al. [21]). We also identified and defined four new educational use themes: “Observation”, “Personification”, “Storytelling”, and “Student authoring”. As mentioned earlier, we dissented from the earlier mapping and reckoned that “Games” should not be deemed a setting, but a use, with the codes assigned to it in the previous review (57) and the new codes found in this update (13). The definitions for the Games theme and the new themes are provided below in Sect. 5.2. The list of all themes and their prevalence is presented in Table 2, and Fig. 4 illustrates the relative occurrence of uses. Figure 5 illustrates the updated representation of themes in the Immersive Learning Cube, by applying the mapping of the new themes and the new prevalences of Table 2.

5.2 Definitions of New Themes

As mentioned earlier, since the original survey [1], two new low-immersion themes were identified: Mobility and Learning Management. In this update, accounts within those two themes were also found, and four new themes emerged: Observation, Personification, Storytelling, and Student Authoring. Following the thematic content analysis process [18], we provide below the definition of each theme, with examples.

Mobility: accounts of use of immersive environments for learning activities supporting student mobility outside of traditional classroom contexts. For example:

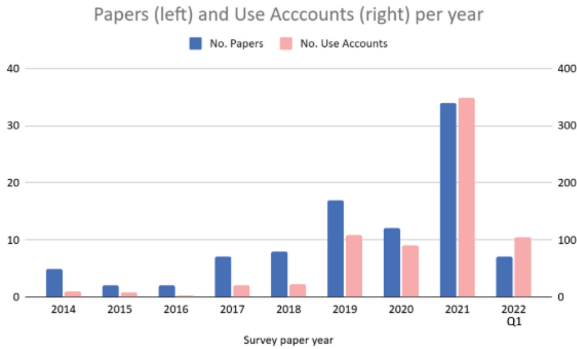


Fig. 2. Survey papers found, per year of publication, and use accounts extracted from them.

- “an AR-based mobile learning system” (cf. Paper 99), coded only as mobile learning.
- “mobile surgical training platform” (cf. Paper 107).

Learning Management: accounts of activities to support and structure the learning processes, regardless of the actual activity. For example:

- “a MOOC entitled (...) the immersive learning content is delivered for distant learners” (cf. Paper 92)

It also includes uses of immersive environments to support and structure the learning processes, regardless of the actual activity, e.g.:

- “Role management [design element framework] The VR application offers different functionalities for different roles. A distinction is made between the role of a student and the role of a teacher. For a teacher, the VR application offers extended functionalities, such as assigning and evaluating learning tasks or viewing the learning progress of students.” (cf. Paper 64)

Games: accounts of use of immersive environments that report employing games but without an explicit pedagogic rationale for their use. This includes a wide variety of game types, content and technologies, both digital and physical.

- “Mobile game using multiple interaction forms (touch-screen interaction, accelerometer) and a combination of AR with non-AR mini-games.” (cf. Paper 6).

Most games were AR-focused interacting with physical materials, for instance:

- “AR offers the opportunity to participate in games using real-world learning objects (e.g., maps, books, and tools)” (cf. Paper 6).

Also, sometimes games were mentioned with a pedagogic intent, but not the rationale of how that intent would be pursued. For example:

- “utilized (...) a popular AR-infused game, to improve vocabularies regarding characteristics and appearance” (cf. Paper 25).

Observation: accounts of use of immersive environments involving a learner’s attentive focus, from its own perspective, on other participants (e.g., their behaviors, emotions, or actions), or the environments (e.g. objects, setting). This includes activities taking observational notes or detecting something in that process, and regardless of the synchronous or asynchronous nature of the context. This does not include situations where the observation is intended to change the learner’s perspective. For example:

- “[in VR] students were immersed in music performance [observation] of different genres, such as classical, country, jazz, and swing, navigating inside several musical rooms” (c.f. paper 86)
- “observe objects, such as numerous art exhibitions or artistic design works” (cf. Paper 65)
- “after each participant had observed the virtual bystanders’ positive attitude towards their virtual peers in the English class” (cf. Paper 89)
- “Parents were able to watch via a computer what the child was watching in real time” (cf. Paper 96)

Personification: accounts of use of immersive environments for learning activities that leverage the presence of synthetic beings. One aspect of this is the use of those beings (a living being or animistic object) to represent an abstract quality or concept, e.g.:

- “animated-virtual actors” (Flat, Cartoon, and Lifelike-3D)” (cf. Paper 86)

This includes supporting users’ representation as avatars:

- “the integration of avatars in the learning materials” (cf. Paper 85)

It also includes the use of avatars as chatbots or non-player characters (NPCs):

- “In the paediatric setting, an animation character was used to explain the preoperative procedure in detail” (cf. Paper 96)
- “an Optical Head-mounted display (OHMD) learning assistant” (cf. Paper 102).

Storytelling: accounts of use of immersive environments for learning activities centered on a story, by any means such as words, actions and/or contexts, for example:

- “using narrative across both virtual and physical museum contexts” (cf. Paper 102).
- “students listened to pre-recorded narratives about the causes, processes, and effects of ocean acidification on their HMD headphones while exploring a virtual coral reef.” (cf. Paper 106)

Some of the accounts focused on the visualization aspect of the stories being told:

- “VR (...) visualization and simulation of narratives and true-to-life scenarios via its 3D virtual environment in (...) a biodiversity topic, objects such as flowers, trees, rivers, hills, birds, butterflies, for science course topics” (cf. Paper 86)

Student Authoring: accounts of use of immersive environments for activities leveraging students’ creativity, providing them with autonomy in authoring processes, e.g.:

- “Assembling objects [design element framework] Students can select virtual objects and put them together, including the creation of new objects by assembling several individual objects” (cf. Paper 64)

A particular form of authoring is the customization of virtual characters:

- “Online multiplayer game in which users can create their own actress and interact with other users through text messaging in a 3D environment.” (cf. Paper 109)

This theme also includes non-modelling authoring, like apps, or 360-degree video:

- “students created 360-degree resources using (...) cameras and the (...) editing studio.” (cf. Paper 52)

It also includes authoring of computer programs and other automations, for instance:

- “(...) an AR authoring environment designed for children [to learn programming]” (cf. Paper 68)
- “Learners can draw finite state machines and navigate between states [visually in VR]” (cf. Paper 105)

6 Discussion: Themes Per Immersion Definition

We detailed how there was a large increase in reviews in our corpus, particularly since 2021, with this year more than doubling the number of reviews of 2019, and the first quarter of 2022 seeing half as many as in the full year of 2019 (Fig. 2). We employed Google Trends to help determine what might have caused this increase. There was a spike in the use of the term “metaverse” in late 2021, but although that may explain the increase in the corpus after that point, it does not explain the increase before that date.

This significant number of new literature surveys also yielded a high number of new codes for accounts of use of immersive environments, most for existing themes, but also for new themes, as reported in the results. The two main types remain, as shown in Fig. 3, but “Simulate the physical world” is now the most common use, overtaking “Augmented context”. “Augmented context” reduced in prevalence from 22% to 13.7%, most likely due to the introduction of the “games” theme, which included quite a few augmented reality games. However, there were also significant growth in several other common themes, such as “Complement/Combine contexts, media or items” (that is now the third-most common theme), “Collaboration”, “Games”, “Interactive manipulation and exploration”, “Perspective switching”, “Seeing the invisible”, and “Logistics”, which all doubled or more the number of found codes, as seen in Fig. 4 (Fig. 3).

In the original survey [1], a visual analysis classified use themes according to the conceptual dimensions of immersion of Nilsson et al. [11]. Following the rationale described in the background, we are naming these dimensions “System”, “Narrative”, and “Agency”, and we replicated the inter-rater process described in that original survey paper. Two researchers independently classified each theme on the scale 0–1, based on their reliance on system, narrative, and agency immersion, with ratings assigned in 0.25 intervals. They then discussed their classifications to reach consensus, resulting in the classifications presented in Table 2. The only previous theme where we disagreed with

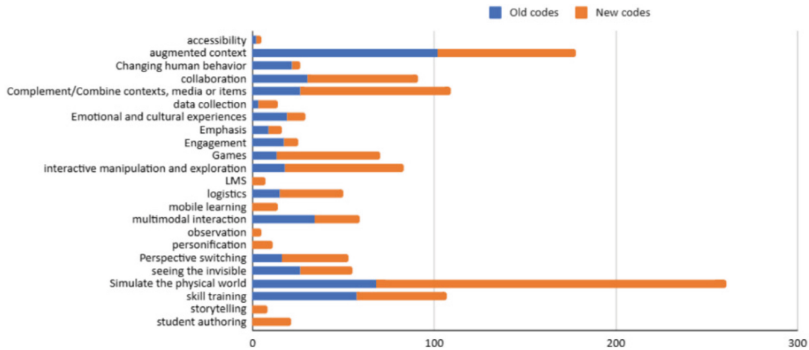


Fig. 3. Educational uses of immersive environments, combining old and newly found codes.

the prior classification was Multimodal Interaction, previously classified as (System, Narrative, Agency) = (1, 0, 0), and now as (1, 0, 0.5).

As an example of the consensual rating, the theme “Observation” represents accounts of use of immersive environments involving a learner’s attentive focus, from its own perspective, on other participants (e.g., their behaviors, emotions, or actions), or the environments (e.g. objects, panorama, setting). This includes activities taking notes of what is being observed or detecting something in that process, and regardless of the synchronous or asynchronous nature of the context. This does not include situations where the observation is intended to change the learner’s perspective (see Table 2). The researchers’ bilateral judgment from this description was that it was relatively reliant on System immersion (rating 0.5), since the ability to observe phenomena depends to a certain extent on the technological capabilities of the environment but does not require full spatial envelopment by that environment (for instance, some cases involved observing using desktop screens). Also, it had minimal emphasis on narrative and agency immersion, but not null (rating 0.25 for both), since observation requires little in the way of story or the ability to interact with the environment, but there is the need for interpreting meaning (narrative) and have both the action of observing and the tactical/strategic considerations and initiative of how to direct one’s attention.

The themes from this study are presented in Fig. 4, based on Nilsson et al.’s proposed representation of the conceptual dimensions as a cube. The new themes are presented in violet color, for easier location amidst previously existing themes.

The visual representation enabled identification of clusters, determining which themes were closer to one another than to any of the others. We named each cluster as a mnemonic. The clusters of the former survey remained, with the new themes being found to be part of one of them or emerging as new clusters by themselves, as detailed below. The notable exception was that the emergence of “Observation” and its positioning near “Data collection” led to the formation of a new cluster, the latter thus being removed from its previous membership of the “Exploring” cluster. Also, new coordinates for “Multimodal interaction” led to its reallocation to the “Exploring” cluster.

The resulting cluster list and their membership follows, and is shown in Fig. 5:

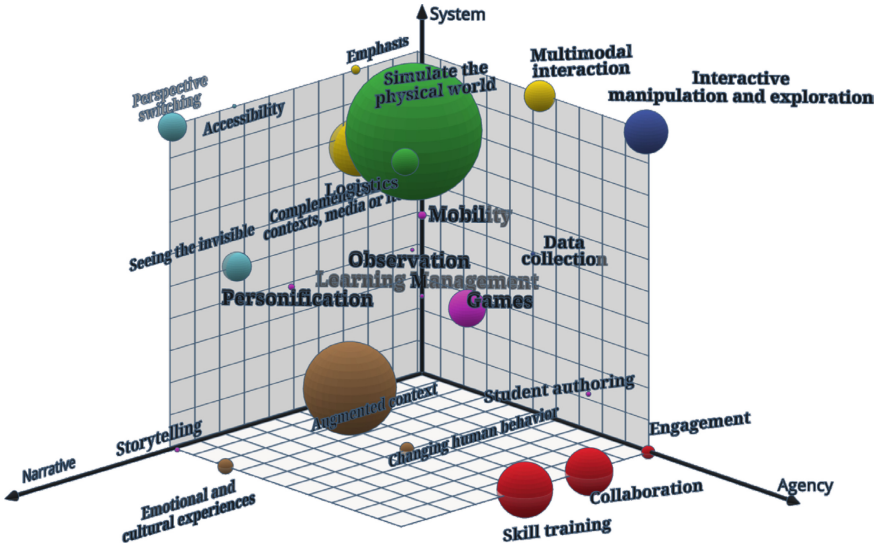


Fig. 4. Updated immersive learning cube with the new themes in violet and new relative sizes.

- **Cluster 1: High System, Low Narrative, Low Agency, “Complementing”** (Combined prevalence: 9.6%: ↓↓ from 14.8%)
 Emphasis, Complement/Combine contexts, media or items (**REMOVED: “multimodal interaction”**)
- **Cluster 2: High System, Mid-High Narrative, Mid-High Agency, “Simulating”** (Combined prevalence: 24%: ↑ from 17.9%)
 Simulate the physical world, Logistics
- **Cluster 3: High System, Low Narrative, Mid-High Agency, “Exploring”** (Combined prevalence: 10.9: ↑↑ from 4.5%)
 Interactive manipulation and exploration, Multimodal interaction (**moved**) (**REMOVED: “data collection”**)
- **Cluster 4: Low System, Mid-Low Narrative, High Agency, “Engaging”** (Combined prevalence: 18.7%: ↓ from 22.5%)
 Skill training, Engagement, Collaboration, **Student authoring (new)**
- **Cluster 5: Low System, Mid-High Narrative, Mid Agency, “Experiencing”** (Combined prevalence: 18.5%: ↓↓ from 30.8%)
 Augmented context, Emotional and cultural experiences, Changing human behavior, **Storytelling (new)**
- **Cluster 6: Mid-High System, High Narrative, Low Agency, “Accessing”** (Combined prevalence: 9.4%: = unchanged)
 Perspective switching, Accessibility, Seeing the invisible, **Personification (new)**
- **Cluster 7: Mid System, Mid Narrative, Mid-High Agency, “Gaming”** (Prevalence: 5.4%: new.) **Games**
- **Cluster 8: Mid System, Low Narrative, Low-Mid Agency, “Inquiring”** (Combined prevalence: 1.5%: new.)
 Observation (new), Data collection (moved)

Table 2. Educational uses of immersive environments, and immersion cube categories.

Educational use theme	Codes	Prevalence	System	Narrative	Agency
Accessibility	5	0,4%	1	0.75	0
Augmented context	178	13,7%	0.25	0.75	0.5
Changing human behavior	26	2,0%	0	0.5	0.5
Collaboration	91	7,0%	0	0.25	1
Compl./Combine contexts, media, items	109	8,4%	0.75	0.25	0
Data collection	14	1,1%	0.5	0	0.5
Emotional and cultural experiences	29	2,2%	0	1	0.25
Emphasis	16	1,2%	1	0.25	0
Engagement	25	1,9%	0	0	1
Games	70	5,4%	0.50	0.50	0.75
Interactive manipulation and exploration	83	6,4%	1	0	1
Learning Management	7	0,5%	0.25	0	0
Logistics	50	3,9%	1	0.75	0.75
Mobility	14	1,1%	0.50	0	0
Multimodal interaction	59	4,5%	1	0	0.5
Observation	5	0,4%	0.50	0.25	0.25
Personification	11	0,8%	0.50	0.75	0.25
Perspective switching	53	4,1%	1	1	0
Seeing the invisible	55	4,2%	0.5	0.75	0
Simulate the physical world	261	20,1%	1	0.5	0.5
Skill training	107	8,2%	0	0.5	1
Storytelling	8	0,6%	0	1	0
Student authoring	21	1,6%	0.25	0.25	1

- **Cluster 9: Low-Mid System, Low Narrative, Low Agency, “Implementing”**
(Combined prevalence: 1.6%: new.)
Mobility (new), Learning Management (new)

These clusters represent updated main trends of educational use of immersive environments. Opportunities for least-explored research directions are represented by the least-explored clusters. Researchers should consider these as fertile ground for their future research. Areas where there are no clusters at all represent a complete absence of empirical data, or what we call a “Void” (see Fig. 6):

- **Void 0: Low System, Low Narrative, and Low Agency.** Research has now differentiated themes more, identifying Learning Management and Mobility as part of the new “Implementation” cluster, which resulted in the overall reduction of this void.

- Void 1: Mid-Low Narrative, Mid System and the full span of Agency. Research has now differentiated themes more, identifying “Games”, “Observation”, and “Student Authoring” as new themes that resulted in the overall reduction of this void.
- Void 2: The full span of System and High Narrative, High Agency. This void combines 2 & 3, contiguous in the original survey. It has not seen any new developments.

7 Conclusions

We can see the trajectory of uses in immersive learning environments changed significantly since the original study. “Observation”, “Personification”, “Storytelling”, and “Student Authoring” are new themes, Mobility and Learning Management were adopted [20]. Major themes from the original study remained strong in the literature, although some waned. The most interesting of these is that “simulate the physical world” increased to 20.1% while the previous strongest theme decreased to 13.7% of the use codes, most likely due to the simultaneous introduction of the “games” theme and the increase in more readily available VR simulation environments for practitioners. “Student Authoring” was the most prevalent of the new themes, also emphasizing the increase in more readily available VR authoring environments for practitioners.

We should also note that Void 0 and Void 1 both reduced in size due to the introduction of new use themes to the corpus. Void 0 (Low System, Low Narrative, and Low Agency) was reduced due to more literature reviews included in the corpus surrounding the “Implementing” cluster. This cluster contained the themes “Mobility” and “Learning Management” which focused on the implementation of mobile and immersive learning environments but lacked further description of the use beyond the technology itself, and thus partially addressed the Low System, Low Narrative, and Low Agency of Void 0. Also, Void 1 (Mid-Low Narrative, Mid System and the full span of Agency) was reduced due to more use accounts included in the corpus surrounding the “Gaming” use theme, which formed its own cluster. This focused on the use of immersive environments that report employing any of a wide variety of game types, content and technologies, including digital and physical games, and thus partially addressed Void 1. This void was also reduced due to more use themes included in the corpus surrounding the “Inquiring” cluster. This cluster contained the themes “Observation” and “Data collection” which focused on the use of immersive environments that collect data from the users whether for the express intent of collecting data, or for some other purpose. As a result, the “Inquiry” cluster partially addressed other areas of Void 1. The voids point to the need to consider new keywords to find out what is happening in immersive learning in those areas that we may be missing. For example, our criteria need to consider keywords that capture non-VR forms of immersive learning better.

The resulting map of clusters and voids points towards the need for more immersive learning environments research on the area of Void 2: The full span of System and High Narrative, High Agency. In other words, we need accounts of use of immersive environments with strong interactive storylines, regardless of the technology environments. These types of immersive learning environments can be extremely challenging to create, so it is no wonder that this area experienced little change from our original study. Still, they do exist, and the continued existence of this void of research accounts points to the need for revisiting this area. For instance, traditional game books, role-playing games,

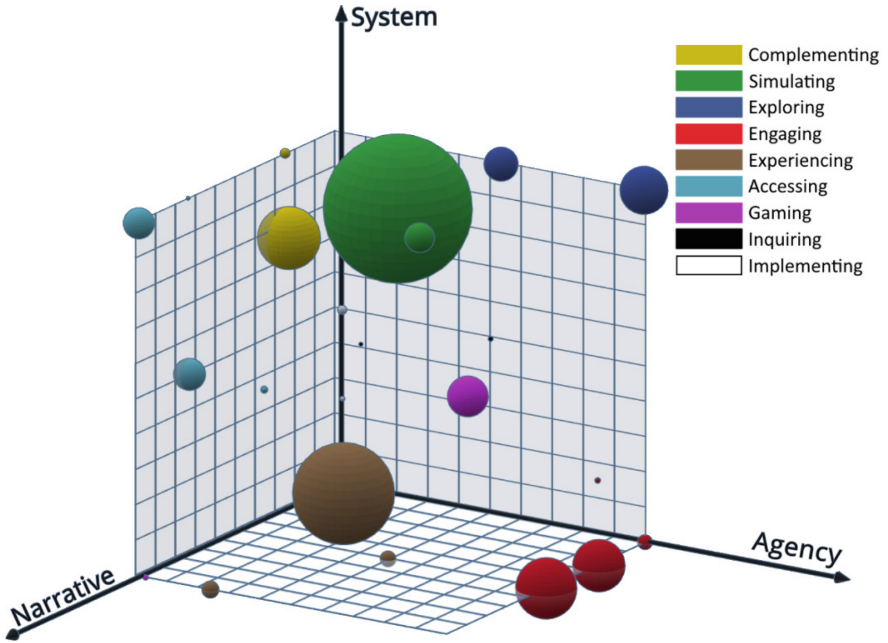


Fig. 5. Updated immersive learning cube with the new theme clusters.

and board games are part of this area, but entirely absent from our corpus. This indicates this research is not being analyzed under the lens of immersion, which poses an opportunity for novel perspectives and insights. Additionally, we need to continue to address Void 1 with more research applying immersion theory to activities with some reliance on the envelopment provided by digitally enhanced physical spaces, such with Internet of Things, Interactive Escape Rooms, Mixed Reality Arcades, smart board games and the novel developments on artificial intelligences based on natural language.

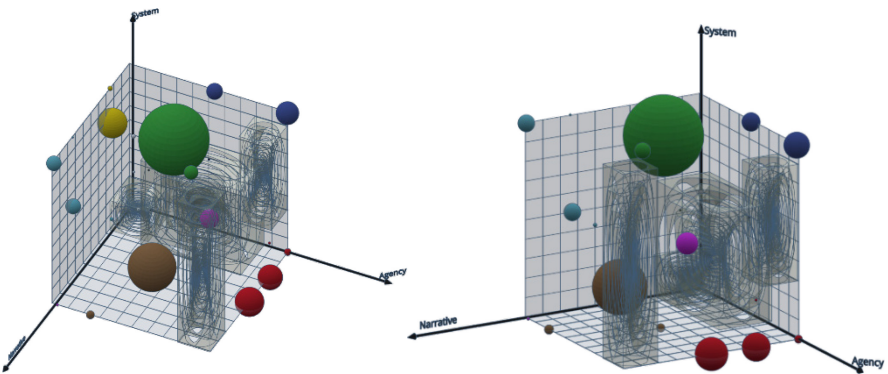


Fig. 6. Updated visualization of the voids of use (different perspectives).

8 Future Work

It is important to note that the research gaps presented in the results and conclusions focus only on accounts of use of immersive learning environments. As we stated earlier, immersive learning research needs to look at what works and how it works in specific contexts, as well as how to design and develop immersive learning experiences. As a result, we are also developing the analysis of this corpus focusing on the update to the mapping of surveys on practices and strategies in immersive learning environments published in 2024 [15]. Other research is still needed to pinpoint where specific pieces of current knowledge are located, simplify concepts, confirm the importance of criteria and dimensions used, and identify possible questions for future literature reviews, which can then provide even stronger, evidence-based overviews of current knowledge on immersive learning environments. To support further research, we will make our data publicly available, as we did with the previous review data [22].

Finally, the large number of new reviews included in our updated corpus (64) present a time-intensive and consistency challenge for a continuous mapping of the literature. Our use of QUAL-E [23] to code the uses of immersive learning environments provides a promising option for opening new avenues to standardizing qualitative criteria application among research teams, possibly enabling more regular and diversified approaches to achieving overviews of the current knowledge in the field. There are also many innovative literature research tools, such as LitMaps or Research Rabbit, which may provide new insights on how to identify relationship in the corpus and change our research voids and clusters.

Ultimately, we believe that by providing framework of the existing uses of immersive environments, in concert with higher-order descriptive frameworks of practices and strategies, the research and practice community may better compare and contrast their experiences and cases, leading to more solid conclusions for this field.

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