

Immersive Learning Environments for Self-Regulation of Learning: A Literature Review

Daniela Pedrosa¹[0000-0001-9536-4234], Leonel Morgado²[0000-0001-5517-644X] and Dennis Beck³[0000-0003-1771-3237]

¹ Department of Education and Psychology, Universidade de Aveiro, Laboratory of Didactics of science and technology, Research Centre on Didactics and Technology in the Education of Trainers (CIDTFF), Aveiro, Portugal

² Universidade Aberta & INESC TEC, Coimbra, Portugal

³ University of Arkansas, Fayetteville, AR, USA

dpedrosa@ua.pt

leonel.morgado@uab.pt

debeck@uark.edu

Abstract. Self-regulation of learning (SRL) plays a decisive role in learning success but characterizing learning environments that facilitate development of SRL skills constitutes a great challenge. Given the growing interest in Immersive Learning Environments (ILE), we sought to understand how ILE are built with attention to SRL, via a literature review of pedagogical uses, practices and strategies with ILE that have an explicit focus on SRL. From a final corpus of 25 papers, we collected 134 extracts attesting use of ILE for SRL. We classified and mapped them using the Beck, Morgado & O'Shea framework and its three dimensions of the immersion phenomenon: system, narrative and challenge. There is a predominance of uses of ILE for SRL aligned with Challenge-based immersion: Skill Training, Collaboration, Engagement, and Interactive Manipulation and Exploration. In contrast, uses aligned with System-based immersion (Emphasis, Accessibility, Seeing the Invisible) were not identified. There were few cases of use of Narrative-based immersion. Uses combining the three dimensions of immersive had residual prevalence. We concluded that there is greater tendency in studies of SRL in ILE to enact active roles (aligned with the Challenge dimension of immersion). The low prevalence of Narrative immersion and System immersion evidence gaps in the diversity of pedagogical uses of ILE to develop SRL, which indicate opportunities for research and creation of innovative educational practices.

Keywords: Immersion, Self-Regulated Learning, Educational Uses, Educational Practices, Educational Strategies.

1 Introduction

Self-Regulated Learning (SRL) skills are a key element for successful learning [1], enabling learners to be independent, caring about what and how to learn [2]. Develop-

ing SRL skills requires learning environments that help students align their actions towards their learning process and goals [3].

There are opportunities and challenges for educators to support development of SRL skills using Immersive Learning Environments (ILE), since they are characterized by being highly engaging [4], [5]. However, their pedagogical integration requires instructional design suited to educational goals and results [6]. Thus, research is needed on how to combine ILE with SRL [7]: ILE involve high cognitive agency, which can adversely affect SRL, if immersive classes do not offer an opportunity for reflection [4].

Environments that present high levels of interaction can affect the student's ability to monitor and adapt their metacognitive, cognitive, motivational, and affective processes, an effect that can be minimized if the instructional design is well structured [8], [9]. The instructional designer can facilitate SRL by considering challenges and reflection activities that enable learners to activate their metacognitive processes.

To support instructional design that employs ILE in developing SRL skills, we conducted a systematic literature review, which identified actual accounts of educational use, practices, and strategies with ILE to develop SRL skills. We classified and mapped these per in thematic analysis, using the Beck et al. framework [10]. The outcome provides an understanding of how ILE are being used to support SRL, in the conceptual space of immersion theory. It also enabled the identification of gaps of low or null application of ILE use methods towards SRL skills development in that conceptual space, identifying areas for future research and development of innovative practices.

2 Related work

2.1 Immersion and Immersive Learning Environments

Immersive learning has been an area of increasing interest [4]. Recent research explores immersive learning as processes [11] from three perspectives [12]: a) educational outcomes; b) internal processes of active construction and ability to adapt cognitive, affective, and psychomotor models; and c) educational methods for ILE as learning tools.

The core concept of ILE is Immersion. It is a phenomenon reflecting a psychological deep state of mental involvement affecting cognitive and sensory processes [10-11, 13], used as a lens for analyzing, interpreting, and adjusting the learning context [10]. Immersion contributes to learning by removing peripheral aspects, controlling variables, and providing student feedback [14] and emerges from three dimensions, which can be affected by technologies or other mediating elements, such as human intervention [10], [13]:

- 1) Challenge, immersion from agency, occurring when one experiences and actively engages in tasks and initiatives involving cognitive and physical processes, and application of competences. This dimension is the one that most requires the subject to exert agency, being active and interacting.

- 2) Narrative, immersion from intensely focusing on a story, on meanings, or on interpretations of elements such as characters, spatiotemporal contexts, objects, sounds, etc. (and interactions between these elements). It most involves identifying meaning and context from the experience.
- 3) System, immersion from feeling subjectively surrounded or present within an environment. Commonly associated with technology (e.g., virtual reality, pervasive technology), but also with the physical environment that envelops us and other surrounding systems: organizational, political, economic, and socio-cultural aspects.

In immersive environments, the phenomenon is experienced, arising from one or more of these dimensions. ILE are such immersive environments where the learning phenomenon is manifested [15]. They can be simulated/augmented environments built using digital technologies (e.g., head-mounted monitors, tactile devices, mobile devices) [16–20], but also entirely physical environments [15] or atypical environments, independent of location [21].

2.2 Self-Regulation of Learning

SRL is a complex process that depends on several factors, and enables the construction of meanings, objectives, and strategies from the information available in the physical and psychological environment [22]. Is considered as a meta-process [23] that requires active participation of students in the control and regulation of their metacognitive, cognitive, behavioral, emotional, and motivational and environmental processes. It requires skills for selection and use of strategies for personal learning processes, with the purpose of achieving the outlined goals and stimulate self-knowledge, self-awareness and self-efficacy [23–25].

3 Methodology

3.1 Planning: purpose, goals, and research question

This systematic literature review focus on providing an overview of studies that use ILEs for development of SRL skills, identifying and mapping their educational uses, practices, and strategies. We understand these as: 1) a ‘use’ is when the educational action is clear but without an explicit pedagogical rationale; 2) a ‘practice’ is when the educational action is clear and provided with an explicit pedagogic rationale; 3) a ‘strategy’ is either an overarching goal (or inspiring philosophy) for an educational approach, or an explicit pragmatic pattern guiding decision-making and practices towards pedagogic goals [26].

The specific goals are: 1) Identify studies in which ILE are used for SRL providing an overview in terms of year, field, and educational context; 2) Provide a mapping on how ILE are used for SRL; 3) Identify areas for research development in this topic.

Given that the phenomenon of immersion can emerge from three conceptual dimensions [13], our research question to fulfil these goals is “What is the panorama of educational approaches for developing SRL with ILE in the conceptual space of immersion?”

3.2 Work process

This review searched for papers that focus on ILEs for promoting SRL, regardless of technology use, and explicitly contain the terms "self-regulation of learning" and "immersion". The work process along five phases [27]: Literature Search; Screen for inclusion; Extraction; Analysis; Systematization and final discussion (Fig. 1).

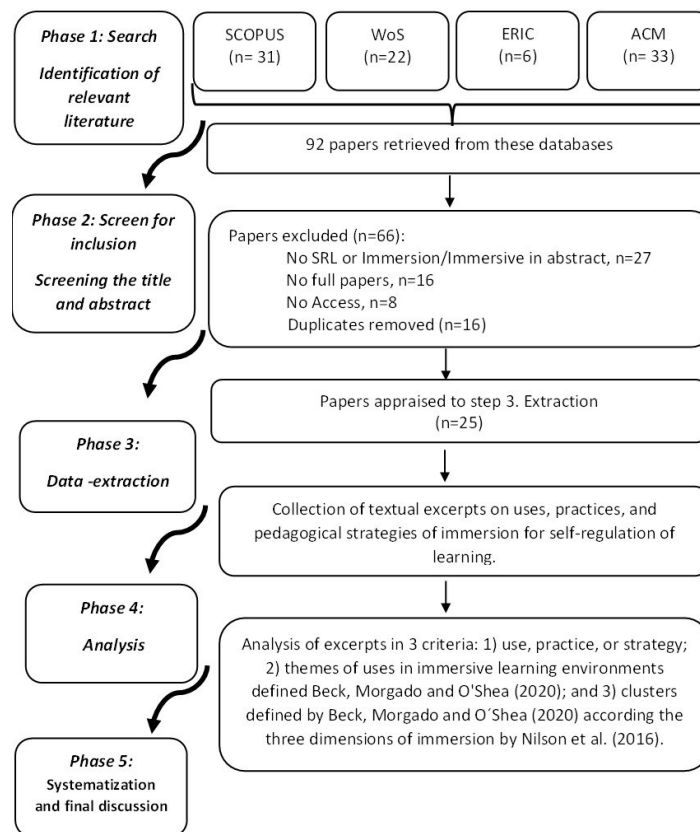


Fig. 1. Work process.

In phase 1, we searched for relevant literature on bibliographic databases: SCOPUS, WoS, ACM, and ERIC. From the research goals and question, we defined the search string: (“Self-Regulated learning” OR “Self-Regulation of Learning”) AND (“Immersion” OR “Immersive”), without delimiting publication date and only

considering peer-reviewed papers in these languages: English, Portuguese, or Spanish. In this phase, 92 papers were identified as potentially relevant (SCOPUS, n=31; WoS, n=22; ERIC, n=6; ACM, n=33).

In phase 2, we screened papers for inclusion, beginning by analyzing their titles and abstracts. We followed these inclusion criteria: a) written in English, Portuguese, or Spanish languages; b) explicitly including in the abstract: “self-regulated learning” or “self-regulation learning”, and “immersion” or “immersive” to make the study more focused. We considered all educational contexts and research designs. We eliminated papers to which we did not have access or were found to be duplicated. This excluded 66 papers: a) 27 without both terms in their abstracts; b) 16 papers without full text; c) 8 papers we could not access, and d) 16 duplicates. After this process, 25 papers constituted the corpus (see Table 1). Also, we provide the list of papers as an open dataset companion [28].

Table 1. Dataset of final papers

ID	Authors	Year	Title
P1	Zheng et al.	2009	Nurture Motivated, Confident, and Strategic Learners in Engineering through Cognitive and Psychological Instructions for an Entry-Level Course
P2	Shih et al.	2010	Integrating Self-Regulated Learning Instruction in a Digital Logic Course
P3	Rahayu & Jacobson	2012	Speaking self-efficacy and English as a foreign language: learning processes in a multi-user
P4	Mikroyannidis et al.	2016	Applying a methodology for the design, delivery and evaluation of learning resources for remote experimentation
P5	Cho et al.	2017	Medical student changes in self-regulated learning during the transition to the clinical environment
P6	Pellerin	2018	Affordances of New Mobile Technologies: Promoting Learner Agency, Autonomy, and Self-regulated Learning
P7	Cárdenas-Robledo & Peña-Ayala	2019	A holistic self-regulated learning model: A proposal and application in ubiquitous learning
P8	Nurieva	2019	E-learning as Part of Self-Regulated Foreign Languages Acquisition (A Case Study of Bauman Moscow State Technical University)
P9	Sakdavong et al.	2019	Virtual Reality in Self-regulated Learning: Example in Art Domain
P10	Chen & Hsu	2020	Self-regulated mobile game-based English learning in a virtual reality environment
P11	Wan et al.	2021	Self-regulatory school climate, group regulation and individual regulatory ability: towards a model integrating three domains of self-regulated learning
P12	Talamantes	2021	A Critical Classroom Study of Language Oppression: Manuel and Malena’s Testimonios, “Sentía como que yo no valía nada . . . Se reían de mí
P13	Nachtigall et al.	2022	Fostering cognitive strategies for learning with 360° videos in history education contexts
P14	del Moral Pérez et al.	2022	Producción de narraciones orales con una app en educación infantil: análisis del engagement y la competencia narrativa

P15	Spiliotopoulos et al.	2019	A Mixed-reality Interaction-driven Game-based Learning Framework
P16	Boomgaard et al.	2022	A Novel Immersive Anatomy Education System (Anat_Hub): Redefining Blended Learning for the Musculoskeletal System
P17	Hayashida et al.	2020	Virtually Alone- How Facilitated Aloneness Affect Self-Study in IVE -
P18	Wan et al.	2021	Examining Flow Antecedents in Game-Based Learning to promote Self-Regulated Learning and Acceptance
P19	Li	2017	Design of Multimedia Teaching Platform for Chinese Folk Art Performance Based on Virtual Reality Technology
P20	Heaysman & Kramarski	2021	Supporting Teachers' SRL Beliefs and Practices with Immersive Learning Environments: Evidence from a Unique Simulations-Based Program
P21	Nietfeld et al.	2014	Self-Regulation and Gender Within a Game-Based Learning Environment
P22	Cheng & Tsai	2020	Students' motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A partial least squares analysis
P23	Pedrosa et al.	2016	Self-regulated Learning in Computer Programming: Strategies Students Adopted During an Assignment
P24	Berthold et al.	2012	An Initial Evaluation of Metacognitive Scaffolding for Experiential Training Simulators
P25	Perera & Allison	2015	Self-Regulated Learning in Virtual Worlds – An Exploratory Study in OpenSim

In phase 3, text excerpts were collected from these 25 papers, for the following aspects: 1) Field, and Pedagogical context towards the first research goal; 2) Accounts of uses, practices or pedagogical strategies for SRL in ILE, towards the second and third goals. The text excerpts were collected by a researcher (first author) through a complete reading of the papers, collecting the original texts excerpts and put them into a database in excel format, according to the protocol (aspects) defined by the research team (authors these paper). A total of 134 accounts were extracted.

In phase 4, we conducted descriptive statistical analysis of the studies (goal 1). For the 134 accounts extracts (goals 2 and 3) we performed thematic content analysis [29]. Firstly, we labelled accounts as uses, practices, or strategies [26]. Then we analyzed and classified them under themes according to the Beck et al. framework of uses of ILE [10, 28]. Then descriptive statistical analysis was conducted to identify their prevalence in SRL studies. Finally, the themes were situated in the “immersion cube” conceptual space [13] to identify opportunities for research development and practice innovation. In this phase, the reliability of the researchers was guaranteed through inter-rating voting.

In phase 5, for systematization and final discussion of results, we present the results in the next section where we discuss and reflect on the status and research opportunities for employing ILE for developing SRL skills.

4 Results

4.1 Overview of studies about ILE for SRL

Studies on ILE for SRL emerged recently: the first paper is from 13 years ago (2009). The last 4 years saw sudden growth in publications, revealing it is a current topic of interest. Regarding subject areas there are account across a large variety of disciplines, ‘general’ (unspecific) and ‘languages’ being the most common, followed by engineering, health, art, and technology (Fig. 2).

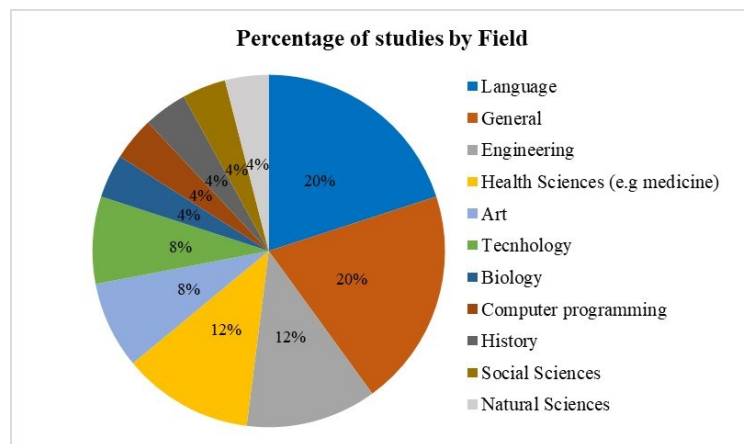


Fig. 2. Percentages of studies by field.

Regarding educational contexts, higher education is predominant, with preschool education being the least common (Fig. 3).

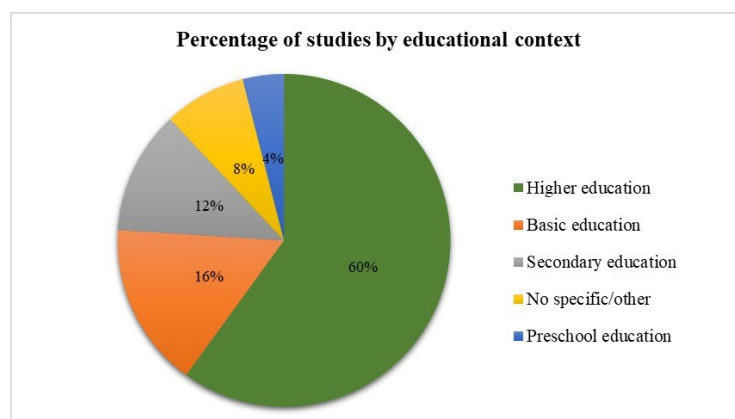


Fig. 3. Percentages of studies by educational context.

Regarding educational uses, practices, and strategies, roughly half of the 134 extracts (54%) were uses, with practices (24%) and strategies (22%) having similar prevalence (Fig. 4). This indicates that most accounts of ILE use for SRL do not provide an explicit pedagogic rationale.

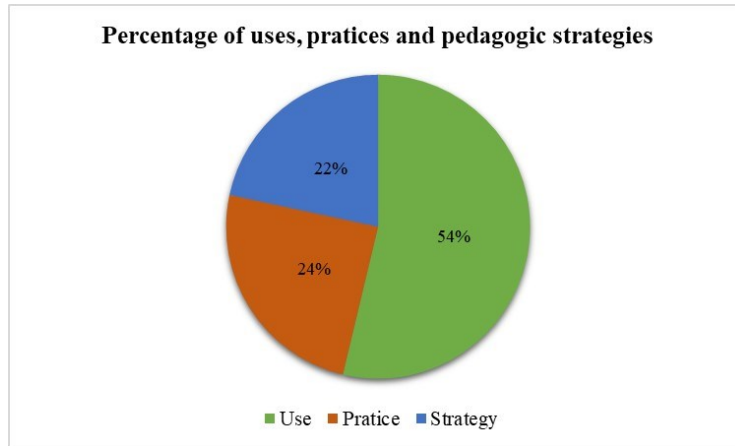


Fig. 4. Percentages of uses, practices and pedagogic strategies.

4.2 Themes of uses, practices, and strategies of ILE for SRL

Table I presents how the 134 accounts (uses, practices, and strategies) were associated with the 18 themes of ILE for SRL. These include 13 of the 16 themes from Beck et al.'s framework, and 2 new themes. 3 of the framework themes have no matching accounts using ILE for SRL. The two new themes, which were not present in the interpretative framework, are: "Mobile Learning" and "LMS".

The theme "Mobile learning" involved activities labelled as ILE but lacking further description beyond the mere use of mobile devices. Sample extracts: "(...) learners were asked to use an iPod to make a video recording of their co-construction of knowledge." P6; "the digital content [was] delivered by the U-LMS through ubiquitous devices." P7. The theme "LMS" similarly involved activities labelled as ILE but lacking further description beyond the use of a Learning Management System. Example: "(...) Moodle LMS as the on-line environment." P23.

Table 2. Themes of ILE for SRL.

Immersion Themes	No. of accounts	Prevalence accounts (n=134)	No. of papers	Prevalence papers (n=25)
Skill training	42	31,3%	17	68%
Collaboration	16	11,9%	11	44%
Engagement	14	10,4%	10	40%

Interactive manipulation and exploration	13	9,7%	9	36%
Complement/Combine contexts, media or items	8	6%	8	32%
(new) Mobile Learning	8	6%	5	20%
Logistics	8	6%	5	20%
Changing human behavior	6	5%	5	20%
Simulate the physical world	5	3,7%	3	12%
Augmented context	4	3%	3	12%
Multimodal interaction	3	2,2%	3	12%
(new) LMS	2	1,5%	2	8%
Data collection	2	1,5%	2	8%
Perspective switching	2	1,5%	2	8%
Emotional and cultural experiences	1	0,7%	1	4%
Emphasis	0	0%	0	0%
Accessibility	0	0%	0	0%
Seeing the invisible	0	0%	0	0%

The theme with highest prevalence in ILE for SRL is “Skill training” (31%), found in most papers (68%). E.g.: “SRL training that fostered students’ acquisition of cognitive strategies for processing history-related 360° videos” P13 (Practice).

Themes “Collaboration”, “Engagement”, and “Interactive manipulation and exploration” follow in prevalence (10%-12%) and are commonly found in the papers (36%-44%). These are all themes sharing high levels of Challenge-based (agency) immersion, indicating activities that imply an active role of the learner for developing knowledge and its personal, motivational, and social skills. E.g.: “Immersion architecture is designed for mixed reality and smart learning environments, which will afford interaction with content and among learners as well as self-regulated learning”. P15 (practice – interactive manipulation and exploration).

With lower prevalence, we then found the themes “Complement/Combine contexts, media or items”, “Mobile Learning” (new theme), “Logistics”, and “Changing human behavior” (5%-6%), but still somewhat common in papers (20%-32%). E.g.: “Metacognitive Scaffolding Service (MSS), which has been integrated into an already existing and mature medical training simulator.” P24 (use – complement/combine).

With less prevalence, we found the themes “Simulate the physical world”; “Augmented context”; “Multimodal interaction”, “LMS” (new theme), “Data collection”;

“Perspective switching” and “Emotional and cultural experiences” which are uncommonly found in the papers (4%-12%). E.g.: “(...) displayed text changed automatically after every pre-determined time slot (...) short breaks at any point between task (...) reading each English text” P17, (use – Multimodal interaction). These are themes with a variety of immersion characteristics, mostly with Mid/High narrative immersion or Mid/High system immersion.

The themes “Emphasis”, “Accessibility”, “Seeing the invisible” (0%) were not identified. Their immersion characteristics share Mid/High system immersion.

5 Discussion

5.1 Overview of studies about ILE for SRL Themes of ILE for SRL per immersion dimensions

In figure 5, we see the panorama of ILE uses for SRL. The position of each bubble and their clustering (1 to 6) was given by the reference framework, but we sized them according to their prevalence in this survey. To place the bubble for the two new themes, we interpreted them as system-based immersion only, given the lack of information on narrative or challenges: Mobile learning: System 50%, Narrative 0%, Challenge 0%; LMS: System 25%, Narrative 0%, Challenge 0%. These two themes partly hit what the framework called “Voids” 0 and 1, with Low/Mid system, Low narrative, and Low challenge. Thus, we deemed them to form their own cluster, henceforth Cluster 7 (new cluster). The prevalence of ILE for SRL themes within each cluster, we get, most to least:

Cluster 4 (red bubbles): High Challenge, Low-Mid Narrative, Low System. Themes: Skill training (31,3%), Collaboration (11,9%), Engagement (10,4%). Total prevalence (TP): 53,6%

Cluster 3 (dark blue bubbles): Mid-High Challenge, Low Narrative, High System. Themes: Data collection (1,5%), Interactive exploration and manipulation (9,7%). TP: 11,2%

Cluster 2 (green bubbles): Mid-High Challenge, Mid-High Narrative, High System. Themes: Simulate the physical world (3,7%), Logistics (6%). TP: 9,7%

Cluster 5 (brown bubbles): Mid Challenge, Mid-High Narrative, Low System. Themes: Augmented context (3%), Emotional and cultural experiences (0,7%), Changing human behavior (5%). TP: 8,7%.

Cluster 1 (yellow bubbles): Low Challenge, Low Narrative, High System. Themes: Complement/Combine (6%), Emphasis (0%), Multimodal Interaction (2,2%). TP: 8,2%

Cluster 7 (new) (orange bubbles): Low Challenge, Mid-Low System, Low Narrative. Themes: LMS (1,5%), Mobile Learning (6%). TP: 7,5%.

Cluster 6 (light blue bubbles): Low Challenge, High Narrative, Mid-High System. Themes: Perspective switching (1,5%), Accessibility (0%), Seeing the invisible (0%). TP: 1,5 %.

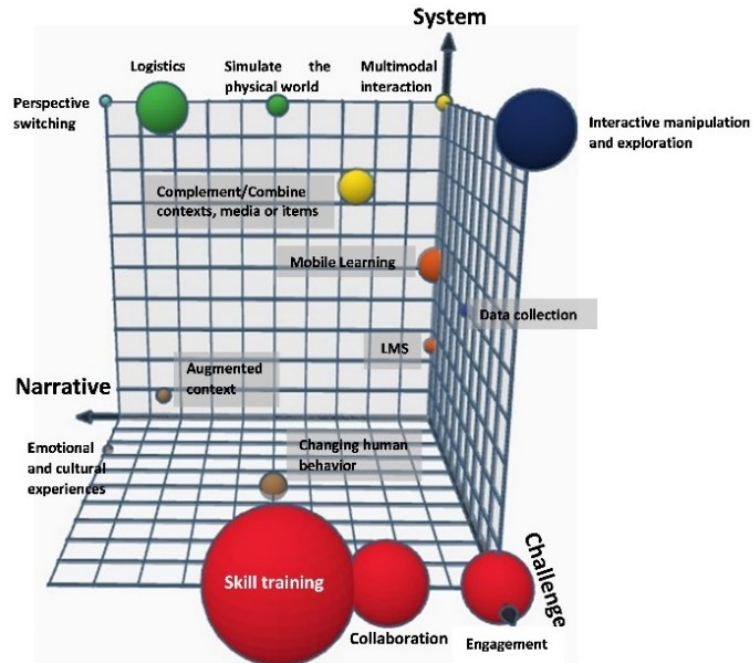


Fig. 5. Prevalence of themes of ILE for SRL by dimension immersion.

This enables us to interpret the current existence and absence of research within the immersion cube for SRL (Fig. 6).

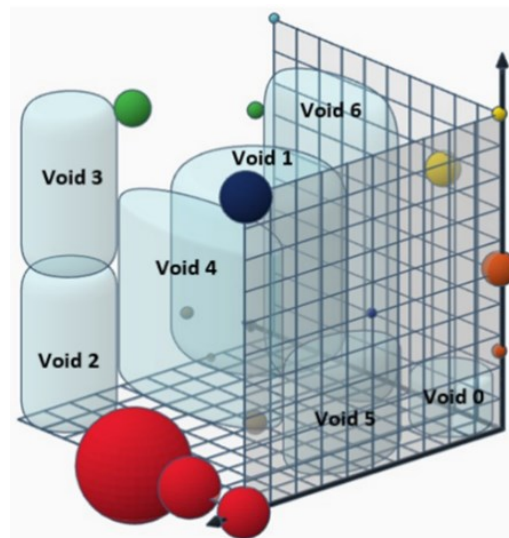


Fig. 6. Voids in research ILE for SRL.

The use of ILE studies for SRL has quite distinct prevalence differences regarding the overall use of immersive learning environments in general, provided by the reference framework (whose highest prevalence was in the clusters 5, 4, 2, & 1). In our data, focused on SRL there is greater prevalence of themes with High or Mid-High challenge-based immersion (clusters 2, 3 and 4), with a combined prevalence of 74,5%. Thus, unlike use of immersive learning environments in general, ILE use for SRL is strongly correlated with challenge-based immersion.

The remaining dimensions (system/narrative) do not exhibit a clear relationship. We find Low/Mid/High system-based immersion clusters in the most, middle, and least prevalent clusters, and similarly for narrative-based immersion.

6 Conclusions

We conclude that studies on ILE for SRL have increased recently, particularly in Higher Education and in general fields or languages. This highlights an opportunity to explore other educational contexts. Regarding approaches that combine the three immersion dimensions (Cluster 2), its combined prevalence is only 9,7% of all accounts, pointing towards the need for more research and practice reports combining the three dimensions of immersion when using ILE for SRL.

We considered the empty spaces of the representation of Fig. 2 to infer gaps in research contributions (“voids”). These can help researchers and pedagogical practitioners identify areas where innovative design interventions can be explored, tailored to different combinations of the immersion dimensions. Some of these voids reflect an overall absence of use of ILE with those characteristics, as found in the reference framework: Void 0, Void 1, Void 2, Void 3. Others are unique to this survey of ILE uses for SRL (Void 4, 5 and 6). This difference arises from different sizes of several use themes, reflecting approaches that – while present in other areas of ILE use – are not being exploited nor researched for SRL.

Void 0: Low Challenge + Low Narrative + Low System (learning environments that do not contemplate immersion).

Void 1: Mid-Low Narrative, Mid System, High Challenge (learning environments with some technology but significant learner agency). This void was larger in the framework, covering the entire span of the “challenge” dimension, but here restricted to only the “High” challenge dimension, due to higher prevalence of “Data collection” (mid challenge) and the new low challenge but mid-system themes in Cluster 7.

Void 2: High Challenge + High Narrative + Low System (learning environments with low tech, but high meaning and agency, such as role-playing games, board games, etc.).

Void 3: High Challenge + High Narrative + High System (learning environments that contemplate immersion in all dimensions).

Void 4 (new): Mid-High Challenge + Mid-High Narrative + Mid-High System. This void was also present in the framework but is less noticeable there due to their high prevalence of “Augmented context” accounts, unlike in our results. It suggests the need for more augmented context uses of ILE for SRL.

Void 5 (new): Mid Challenge + Low Narrative + Low System (learning environments with a moderate amount of challenge-based immersion, such as traditional learning activities, possibly this represents the lack of details in the descriptions of the themes “LMS” or “Mobile learning”).

Void 6 (new): Low Challenge + Mid Narrative + entire span of System (this void is a consequence of the small dimension of themes in clusters 1, 2, 5 & 6, hence points the need for more research in their themes).

7 Final Thoughts

This work offers facets of how ILE have been employed for development of SRL skills. These environments have predominantly exploited approaches highly based in the Challenge dimension of immersion, where the learner takes an active role in the development of personal, social and motivational skills: “Skill training”, “Collaboration”, “Engagement” and “Interactive manipulation and exploration”.

The opportunities for research and to innovate educational practices, partly stem from lack of accounts on ILE use in general, but partly originate in lack of accounts specifically for ILEs application to SRL (Emphasis, Accessibility, Seeing the Invisible) all highlighting potential pathways.

The paper presents as a limitation, restricted focus, in Phase 2, looking for both terms in the title and in the abstract, which may have excluded other potential works.

As future work we intend to carry out a comprehensive systematic review of the literature, considering various aspects of self-regulated learning (SRL) beyond the term itself, such as time management, planning, organization and much more. We plan to use additional search terms such as "SRL", "ILE" and others to ensure a complete search.

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