Immersive Learning Research from SVR Publications: A Re-conduction of the Systematic Mapping Study

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Abstract Immersive Learning (iL) is known as a recent area of research that uses three-dimensional virtual environments and multi-sensory devices, also known as immersive technologies, to support the improvement of learning outcomes. This work aims to obtain evidence of theoretical and technological aspects of iL from the Symposium on Virtual and Augmented Reality (SVR) publications. A Systematic Literature Mapping protocol was developed and executed in order to select the primary studies to perform the analysis and data extraction. 76 primary studies helped to answer the research questions. A large part of the contributions by the SVR community are virtual environments that support education in the health area. In addition, some gaps and research opportunities were identified: virtual environments that serve audiences with special needs; development frameworks that consider pedagogical aspects; the use of biometric measures to support the validation of improved learning outcomes and more flexible tools that support educators in the development of immersive virtual environments that do not require specific knowledge in coding or 3D modeling.

Keywords: Empirical studies in HCI, Human-centered computing, Immersive Learning, SVR, Symposium on Virtual and Augmented Reality, Systematic Mapping Literature

1 Introduction

Over the years, with the growing study of immersive technologies applied to teaching, Immersive Learning (iL) has emerged as a new area of research focused on investigating innovative methods of immersion, engagement and motivation that contribute to learning gain (Freitas and Neumann, 2009).

iL is related to the use of technologies, especially computer graphics and human-computer interaction technologies, to create virtual worlds, in which learning can occur using appropriate instructional and pedagogical approaches (Freitas and Neumann, 2009; Herrington *et al.*, 2007; Schreiber and Misiak, 2018). In other words, iL is an educational modality, whose teaching and learning processes take place in 3D graphic environments, created from the use of different technologies, in which those involved in the educational process can interact in an immersive way. Therefore, iL provides learning through the development of experiences with immersive technologies, such as Augmented and Virtual Reality (AVR), independent of pedagogical approaches (i.e., participatory design, inverted classroom, problem-based learning, among others).

However, according to Dengel and Mägdefrau (2018), despite the use of immersive technologies to support teaching and learning processes, little research has been conducted to better understand the theoretical and technological aspects related to this recent area of research. In the context of Brazilian research, the main challenge is the need for research focused on Brazilian environment and culture, as well as on regional and social differences and needs more generally (Queiroz *et al.*, 2018). Therefore, mapping the Brazilian studies involving iL allows to identify gaps, overlaps, research and collaboration opportunities. Specifically, it is intended to verify the technologies and pedagogical approaches adopted, as well as the main contributions and the evolution of the studies in iL in the context of the Symposium on Virtual and Augmented Reality (SVR). From this study, researchers, educators, educational designers and managers can gain perspective on what is being developed, making them better able to prepare for innovations that are to come or to participate in the developmental process. In addition, it is worth to highlight that this work complements the results presented in Fernandes *et al.* (2021), expanding the scope of publications and extracting new data.

The motivation of this work was inspired by Barbosa and Kronbauer (2019) and Nunes *et al.* (2014). Both articles aim to obtain an overview of the SVR community from the point of view of the health area. While the first is a more recent study of the Virtual Reality (VR), the second is an older publication and the focus is on AVR. On the other hand, Queiroz *et al.* (2018) presents a study that includes CNPq Research Group's Directory with a focus on AVR lines of research that also involve education as theme. Although the objective of the work is similar to this systematic mapping, the difference lies in the population and research questions. While Queiroz *et al.* (2018) focuses on research groups, this secondary study focuses on works published in SVR.

This paper is organized as follows: Section 2 describes related work. Section 3 details the research method adopted to conduct the study. The data extracted to answer the research questions are presented in Section 4. Section 5 discusses data extracted from primary studies. Finally, conclusions and future work are presented in Section 6.

2 Related Work

The literature has some secondary studies that investigate evidence regarding the use of AVR to support teaching. Basi-

cally, secondary studies characterize the primary studies in relation to the type of immersive technology, domain area, audience profile and research questions. For a better understanding, the related works were grouped in relation to the use of technology: AR (Augmented Reality), VR (Virtual Reality) and AVR.

The works Akçayır and Akçayır (2017), Bacca Acosta *et al.* (2014), Baragash *et al.* (2020), Hedberg *et al.* (2018), Ibáñez and Delgado-Kloos (2018), Ozdemir *et al.* (2018), Pellas *et al.* (2019), da Silva *et al.* (2019) and Tekedere and Göke (2016) identify the state of the art with the use of AR in teaching, but with different audience profiles. In particular, Baragash *et al.* (2020) focuses on special education, while the other studies focus on the teaching and learning process as a whole, game-based learning, mobile learning, trends in education and teaching in Science, Technology, Engineering, Art and Mathematics (STEM).

Papers Howard and Gutworth (2020), Merchant *et al.* (2014) and Radianti *et al.* (2020) selected primary studies that used VR to support teaching in basic education, higher education and development of social skills.

Finally, works Avcı *et al.* (2019) and Kaplan *et al.* (2021) are meta-analyses of primary studies that used AVR as an intervention in teaching to improve training in real environments.

Despite an added volume of secondary studies, few works have focused on obtaining an overview of the area, from the point of view of convey the state of the art, regarding the use of AVR in education, in order to understand what the audience profiles and in which domain areas AVR has supported teaching. Thus, this work contributes to obtain an overview of AVR in education from SVR publications. SVR was chosen due to its importance regarding AVR research in Brazil.

3   Research Method

Considering that this study is an extension of Fernandes *et al.* (2021), the same Systematic Mapping Literature (SML) protocol was adapted and re-conducted, that is, one research question was added. The contribution of this extension lies specifically in the addition of a research question and studies published in the year 2021 to the analysis carried out in Fernandes *et al.* (2021).

This SML was structured in three main phases, according to Kitchenham and Charters (2007): planning, conducting and reporting the study. Next, the steps taken in each phase will be detailed.

3.1   Planning

To guide the study, the following research questions were defined, which will support the extraction and analysis of data:

- **RQ1**: What domain areas and target audiences do the solutions support?
- **RQ2**: What immersive technologies are adopted to develop the solutions?
- **RQ3**: What are the main contributions of the SVR community to iL?

- **RQ4**: What instruments were used to measure learning improvement?
- **RQ5**: What development tools were used to implement the solutions (included in this study)?
- **RQ6**: What are the main institutions that carry out research in iL?

Considering the strategy of adding studies published in 2021 with Fernandes *et al.* (2021), the search for studies was carried out through the ACM Digital Library[1], since the publications are indexed in this database.

PICO approach (Participants, Intervention, Comparison and Outcome) was used to design and outline the objective of this secondary study (Kitchenham and Charters, 2007). However, the comparison variable was excluded to be a SLM, in addition to the focus of this work being on the observation of evidence without comparison criteria. The purpose of the study is defined as follows:

- *Population*: SVR publications.
- *Intervention*: works that report the use of immersive technologies to support the teaching and learning process.
- *Outcomes*: diverse solutions that support teaching through immersive technologies.

Table 1. Central Terms

Dimensions	Terms
Population	Symposium on Virtual and Augmented Reality, Symposium on Virtual Reality, SVR
Intervention	Education, Learning, Teaching, Training

Inclusion and exclusion criteria were defined to filter publications relevant to the study. Therefore, the inclusion criteria are:

- IC1: Article must be in the context of iL;
- IC2: Article must answer at least one of the research questions;
- IC3: Article must be from the latest research;
- IC4: Article must be written in Portuguese or English.

The exclusion criteria are:

- EC1: Article not being a primary study;
- EC2: Articles that cannot be accessed completely;
- EC3: Immersive solutions that support the treatment of phobias, as well as the physical and cognitive rehabilitation of human beings.

The last exclusion criterion was decided due to the fact that iL area supports human beings in the development of skills and abilities in a certain area of knowledge, such as support for teaching algorithms, training in dental surgery, training in maintenance of industrial equipment, virtual tours to museums, among others. Therefore, immersive applications for the treatment of phobias Garcia-Palacios *et al.* (2002), motor rehabilitation Sveistrup (2004), autism treatment Strickland (1997) and related fields were considered outside the scope of this study. This decision was made because the focus of iL is to support the teaching and learning process.

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[1] https://dl.acm.org/

3.2   Conducting

Fernandes *et al.* (2021) found 147 articles published in SVR through the following search string performed in Scopus: *(SRCTITLE ("Symposium on Virtual and Augmented Reality" OR "Symposium on Virtual Reality" OR svr) AND TITLE-ABS-KEY (edu* OR learn* OR teach* OR train*)).* When applying the inclusion and exclusion criteria, 76 studies were included to compose the final set of articles and answer the research questions according to the evidence obtained.

In this re-conducted iL research, 24 studies were obtained in January 2022 through the ACM Digital Library. From this initial set of articles, the study selection and eligibility process began. No studies were excluded due to duplication. When applying the inclusion and exclusion criteria in the title and abstract, all studies published in 2021 were removed. Our hypothesis that there are no studies on iL in this period is related to the COVID-19 pandemic period. We believe that researchers faced challenges in developing their research, as well as conducting assessments remotely and, especially, in person.

Therefore, for this analysis, the same 76 studies included to compose the final set of articles in Fernandes *et al.* (2021) were considered. Data referring to RQ5 were extracted and tabulated in an electronic spreadsheet, along with data from other research questions.

Figure 1 shows all the steps taken to find the final set of articles. The organization of the steps was inspired by the phases of the PRISMA method, namely: *identification, screening, eligibility* and *inclusion* (Moher *et al.*, 2009).

3.3   Threats to Validity

Despite the contribution of this study, we identified some threats to validity. The classification of works was performed according to the reading and extraction of data. This task was performed by one researcher and, after being completed, it was presented to the other researchers in order to validate the data. Despite being specialists in systematic reviews and knowing about iL, we consider that this process can be considered a threat to validity, since there were no questions regarding the classification and the extracted data.

4   Results

This section aims to present the results obtained in Fernandes *et al.* (2021) having this adapted protocol. As already mentioned, the contribution of this re-conducted of iL research is to add the research question RQ5, as well as to expand the scope of published works until 2021.

Regarding the scope, Figure 2 shows the number of papers per year. It is possible to observe that until 2020 researches in iL were carried out, highlighting 2013, 2014 and 2020, which proves to be a relevant research topic that several researchers in the area have investigated. However, in 2021 no studies met the inclusion criteria. Most of these studies compare the effectiveness of techniques to improve the performance of simulators, help motor rehabilitation through immersive technologies, secondary studies, among others, and for this
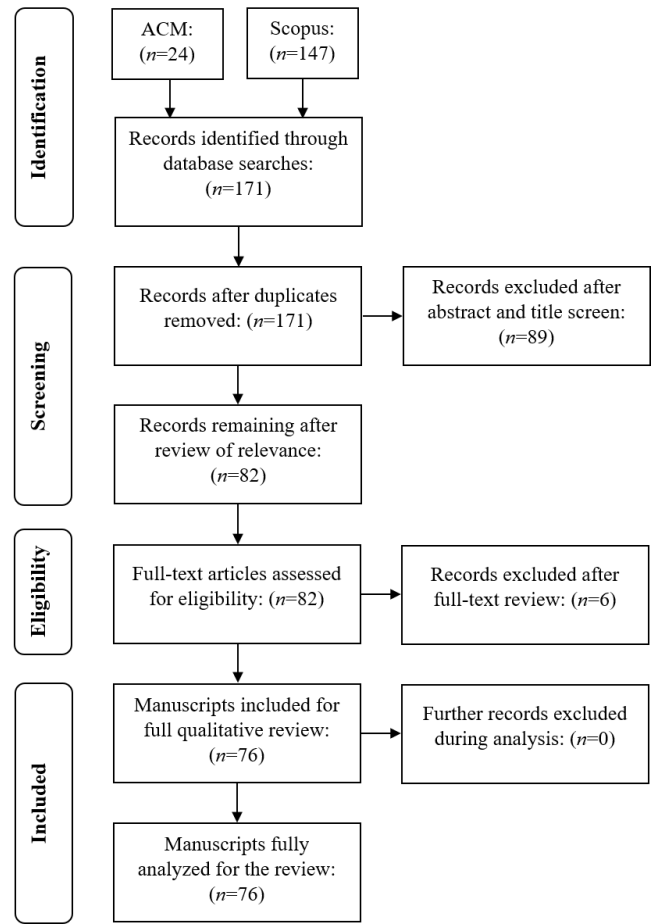

Figure 1. Flow diagram illustrating systematic search and selection process

reason they were disregarded. As expected, most of the authors who published in this period were Brazilians since the conference chosen as the scope of this work is also Brazilian. However, it is worth noting that there are also researchers from outside Brazil. Figure 3 demonstrates the chart of authors grouped by country.

Throughout the search, 171 papers were identified, to which the inclusion/exclusion criteria were applied, leaving 76 to read and analyze. The keywords of each of them were extracted and originate the cloud of words in Figure 4. Some keywords were excluded, such as "augmented", "virtual", "reality", "education" and "learning". From this, it is possible to understand which themes were most addressed in the papers.
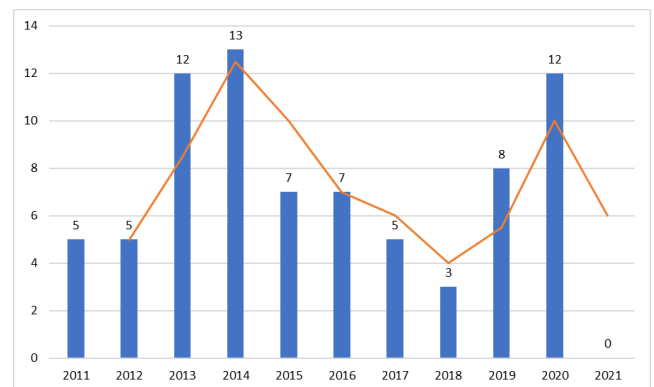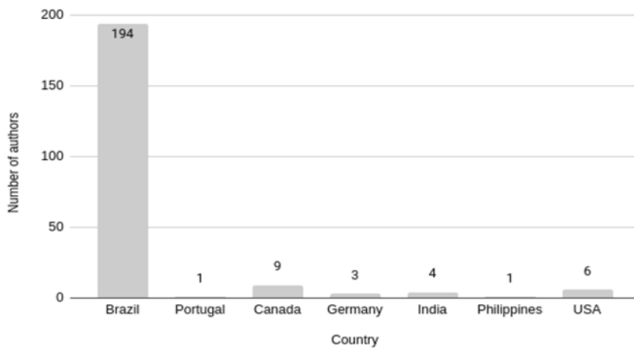

Figure 2. Primary studies per year

Figure 3. Number of authors per country

Figure 4. Word cloud from keywords

4.1 What Domain Areas and Target Audiences do the Solutions Support (RQ1)?

The classification of studies in relation to the domain area was built along the reading of the articles, which was constantly revised. Figure 5 shows the number of articles by domain area. It is noted that most of the studies are in the *health* area. Simulations to improve surgeries and immersive environments to support health education are examples of the identified works.

On the other hand, studies that did not focus on a certain area of knowledge were classified as general. Studies in this category are largely AVR systems whose aim is to support the teaching and learning process regardless of the domain area or focus on specific characteristics of the audience. For example, the study [PS03] reports on an immersive teleconferencing system to support distance education; the study [PS06] proposes a knowledge assessment model in
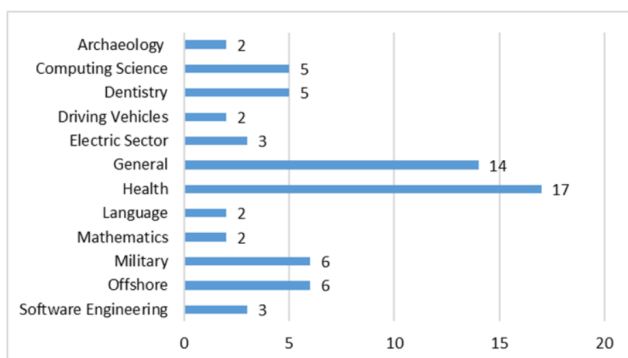

Figure 5. Number of articles by domain area

three-dimensional virtual learning environments; the study [PS53] developed a game to support learning for children with autism, among others. Other domain areas were identified, but each with one related study. Table 2 shows the relationship between domain areas and primary studies.

Table 2. Relation between primary studies and domain areas

Domain Areas	Primary Studies
Agriculture	PS63
Archaeology	PS07, PS39
Computing Science	PS04, PS16, PS21, PS54, PS62
Dance	PS58
Dentistry	PS46, PS49, PS51, PS56, PS60
Driving Vehicles	PS27, PS43
Electric Sector	PS12, PS36, PS38
Engineering	PS25
Farming	PS10
General	PS02, PS03, PS05, PS06, PS11, PS13, PS15, PS26, PS28, PS33, PS50, PS53, PS65, PS66
Health	PS08, PS14, PS17, PS18, PS19, PS23, PS30, PS32, PS35, PS44, PS52, PS68, PS69, PS70, PS71, PS72, PS73
Industry	PS55
Language	PS24, PS75
Mathematics	PS41, PS59
Military	PS09, PS37, PS45, PS64, PS67, PS74
Mining	PS76
Music	PS29
Offshore	PS01, PS20, PS22, PS31, PS42, PS47
Physical Activity	PS40
Software Engineering	PS34, PS48, PS61
Sport	PS57

Figure 6 shows the number of studies by audience. The main profiles that the studies focused on are academy and professionals. The *academy's* target audience is undergraduate students and professors, and *professionals* are people in training, that is, those who work in a certain area and are updating their knowledge outside the traditional academic environment (schools and universities). Studies that had students from kindergarten to high school as an audience were classified as *basic education*. Studies that focused on activities for children, but without instructional content, were classified as *children*. The *general* category classifies studies that benefit any type of audience profile. For example, the study [PS66] proposes a model for the development of immersive virtual learning environments to achieve distance learning. Studies classified as *students with disabilities* have an audience with disabilities, which present, on a temporary or permanent basis, significant physical, sensory or intellectual differences, resulting from innate or acquired factors. The study [PS13] developed educational software with AR for pupils with disabilities. The study [PS24] used AR to support the teaching of Brazilian Sign Language. The study [PS53] focuses on children with autism. Table 5 shows the relationship between
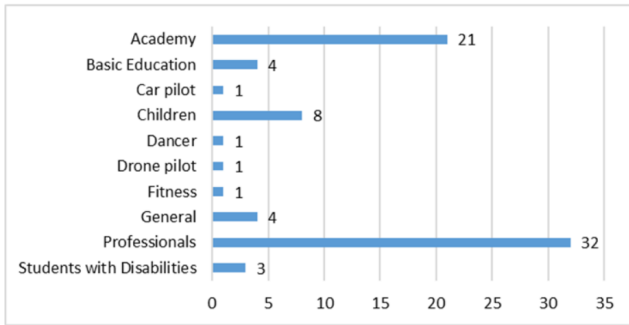
Figure 6. Number of studies by audience

audiences and primary studies.

Table 3. Relation between primary studies and domain areas

Audiences	Primary Studies
Academy	PS04, PS14, PS16, PS21, PS23, PS25, PS30, PS32, PS33, PS34, PS44, PS46, PS48, PS51, PS52, PS54, PS61, PS65, PS69, PS72, PS73
Basic Education	PS07, PS26, PS39, PS41
Car Pilot	PS27
Children	PS02, PS05, PS11, PS15, PS28, PS29, PS59, PS62
Dancer	PS58
Drone Pilot	PS43
Fitness	PS40
General	PS03, PS06, PS66, PS75
Professionals	PS01, PS08, PS09, PS10, PS12, PS17, PS18, PS19, PS20, PS22, PS31, PS35, PS36, PS37, PS38, PS42, PS45, PS47, PS49, PS50, PS55, PS56, PS57, PS60, PS63, PS64, PS67, PS68, PS70, PS71, PS74, PS76
Students with Disabilities	PS13, PS24, PS53

Figure 7. Frequency of immersive technologies

Figure 8. Number of studies by type of contribution

It can be seen from Figure 7 that most studies (76%) use VR technology to support iL, while 21% use AR and only 3% use AVR. Table 4 shows the relationship between immersive technologies and primary studies.

Table 4. Relationship between primary studies and the immersive technologies

Immersive Technologies	Primary Studies
AR	PS02, PS03, PS05, PS11, PS13, PS14, PS15, PS24, PS25, PS26, PS29, PS57, PS62, PS65, PS68, PS75
AVR	PS39, PS53

4.2 What Immersive Technologies are Adopted to Develop the Solutions (RQ2)?

It was considered as immersive technologies the elements of the virtuality continuum (Milgram and Kishino, 1994), together with the classification of the authors of each work. Thus, the studies were classified into three types of immersive technologies: VR; AR and AVR. VR systems can be classified according to the sense of presence as immersive and non-immersive (Gordy and Ingrid, 2020). VR is immersive when the user is predominantly transported to the application domain, through multi-sensory devices, which capture their movements and behavior, causing a feeling of presence within the virtual world. When the user is partially transported to the virtual world but continues to feel predominantly in the real world, the VR system is considered non-immersive. However, in our analysis, we grouped immersive and non-immersive systems as VR. Therefore, studies classified as VR use different types of hardware, such as monitor, HMD, smartphone, simulators, among others.
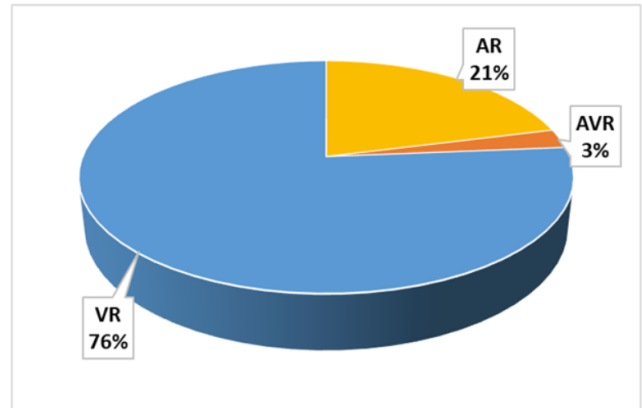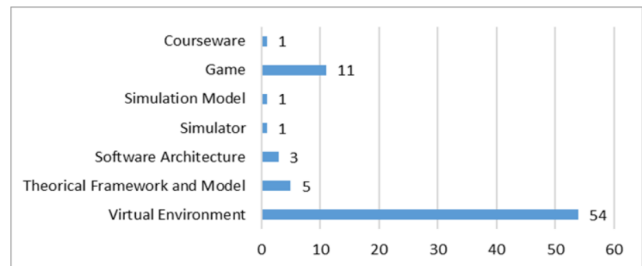
4.3 What are the Main Contributions of the SVR Community to iL (RQ3)?

This research question sought to identify how the SVR community has contributed to iL, from the point of view of the types of proposed solutions. According to Figure 8, 54 studies are virtual environments developed to support learning. Although game and gamification are different concepts, virtual environments based on games and gamification were classified as *game*.

The *simulator* classification is directly related to the study [PS08]. In this work, the authors developed a cardiopulmonary resuscitation training system that involves both hardware and software. The hardware used was a specific scale for data capture, a bluetooth adapter and a training dummy. The developed software help in training by showing the user, in real time, all their actions and the results of the cardiac massage, such as the force that the individual applies to the mannequin, the angle of the arms along with the position of hands and the frequency of compressions. However, the

graphical interface of the software is WIMP standard (Window, Icon, Menu, Pointing device). Thus, considering that the work does not use a virtual and three-dimensional environment, it was decided to classify this work from the point of view of physical actions (massage) that are simulated in training. *Simulation model*, on the other hand, concerns simulation only at the software level. As it is the case of the study [PS32], whose object was to develop a model that realistically simulates soft tissue deformation, aimed at medical training procedures.

In addition to software and simulator, the SVR community has contributions in the theoretical field of iL, more specifically in the proposal of frameworks and software architectures. The works identified as theoretical framework and model, in general, are solutions to support the development of immersive applications and learning assessment. The study [PS30] brings together a set of natural interaction techniques to help health educators. The study [PS45] proposes a set of requirements needed to implement a simulator for training shooting fundamentals. The authors of the study [PS50] developed a classification and methodology for the design of collaborative virtual environments for team training. The study [PS66] proposes a model to design immersive virtual environments based on distance learning. Finally, a theoretical model of learning assessment, from the perspective of cognitive theories, from three-dimensional virtual learning environments is proposed by the study [PS06].

The studies [PS17, PS31, PS33] describe *software architectures* of immersive solutions, that is, they present the modeling, the main components and how they will communicate to achieve the purpose of supporting the improvement of learning outcomes.

4.4 What Instruments Were Used to Measure Learning Improvement (RQ4)?

The answers to this research question aim to show evidence of the measurement of improvement in learning outcomes, from the point of view of the instruments used for data collection.

During the analysis, only the instruments used by the participants in the experiments were considered, for recording their experience and feedback when interacting with the object of study of each work. Thus, research design, research method (qualitative, quantitative or mixed), experimental design, among other elements, are outside the scope of this research question. We agree that it is necessary to investigate the methods and research design used in the works to identify how learning was evaluated. However, considering that this work is a systematic mapping, we focus only on the instruments used to give an overview. This decision was taken because we would like to obtain evidence on our hypothesis that a large part of the works carry out evaluations through usability and user experience questionnaires, and that this way is not very adequate to measure the learning gain.

Out of 76 studies, 45 present the methods and instruments used to develop the solution and have no user evaluation. However, two of these studies performed an evaluation from the point of view of the computational performance of the tool [PS19, PS32].
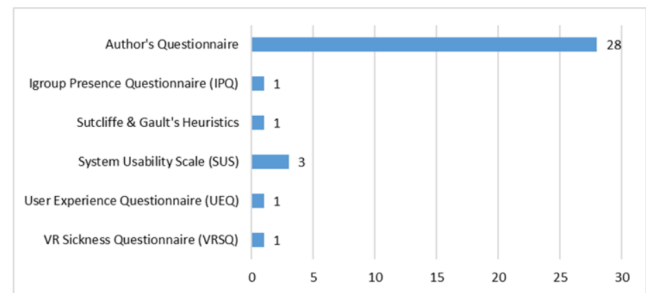
Figure 9. Frequency of evaluation questionnaires

As result, 31 studies carried out experiments with participants to evaluate the proposed solution. As can be seen in Figure 9, all data collection instruments are questionnaires. Most of the questionnaires were elaborated by the authors and can be adapted from another questionnaire consolidated in the literature or created specifically to validate the proposed solution. The questionnaires used in full by the primary studies are: System Usability Scale (SUS) (Brooke, 1996); VR Sickness Questionnaire (VRSQ) (Kim *et al.*, 2018); User Experience Questionnaire (UEQ) (Köhler *et al.*, 2019); Sutcliffe & Gault's Heuristics (Sutcliffe and Gault, 2004) and Igroup Presence Questionnaire (IPQ) (Schwind *et al.*, 2019). The use of the questionnaires depends on the focus of the evaluation of each work. Therefore, it is beyond the scope of this SLM to identify details on how each questionnaire can measure learning improvement.

4.5 What Development Tools Were Used to Implement the Solutions (RQ5)?

In this research question, the interest is to collect information regarding the tools that have been used to implement solutions in iL. During data extraction, the tools were collected and categorized through 57 primary studies. Some studies do not mention which tools were used for implementation, for example [PS03, PS06, PS07, PS08, PS09, PS13] and others. Table 5 shows the primary studies and what types of tools were used. Figure 10 shows the number of studies by category.

As can be seen, most studies reported using engines, programming language, libraries, 3d modeling and animation, APIs and others, to support development. From 34 studies, 79.41% used Unity[2], while 8.82% used Unreal Engine[3] and 2.94 % used Irrlicht graphics[4], FMOD[5], Tesseract OCR[6] and OGRE3D[7].

Regarding the programming language, 52.63% of the solutions were implemented with C#, while 21.05% of the solutions were in C++, 10.53% used Java and 5.26% C, PHP and JavaScript. The greater usage by the C# language can be explained due to the fact that Unity supports this programming language. Thus, since this game engine was adopted by most implementations, this factor led to this conclusion.

In terms of immersive virtual environments, some 3d mod-

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[2] https://unity.com/
[3] https://www.unrealengine.com/
[4] https://irrlicht.sourceforge.io/
[5] https://www.fmod.com/
[6] https://opensource.google/projects /tesseract
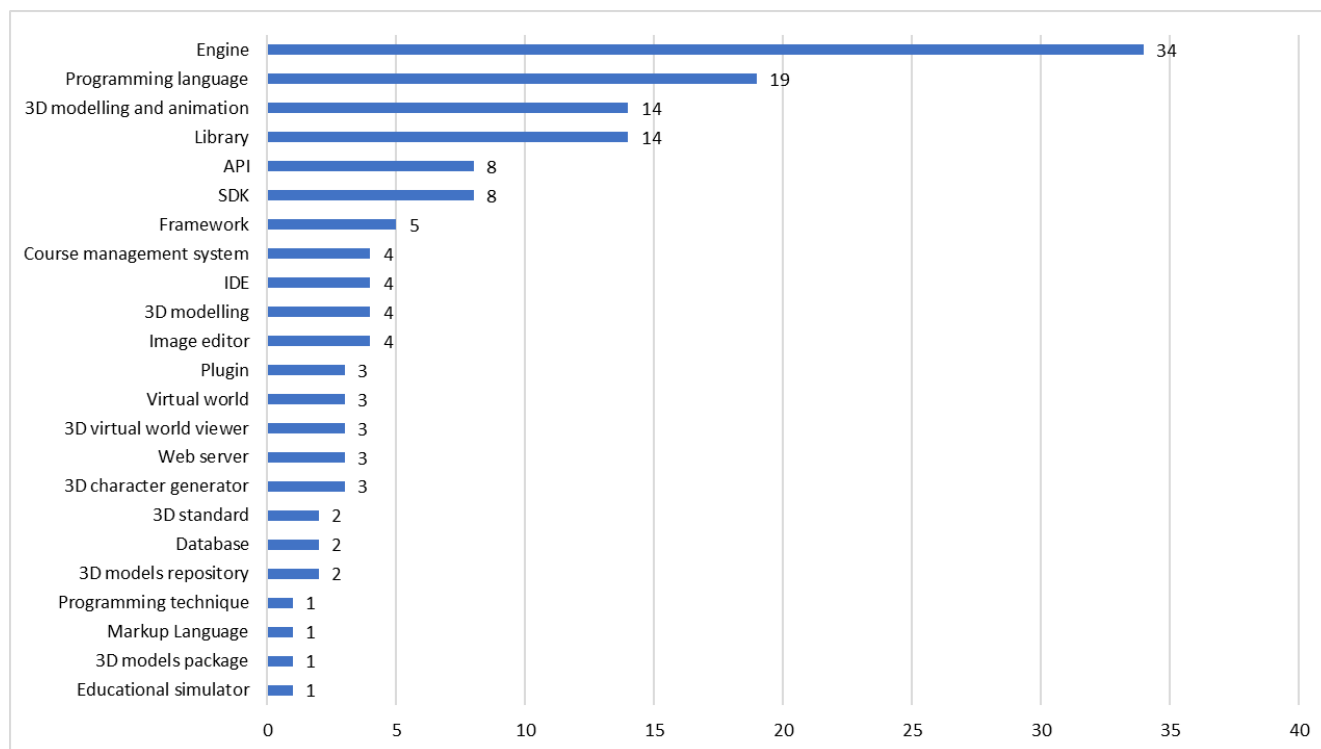[7] https://www.ogre3d.org/

Figure 10. Frequency of primary studies grouped by development tools categories

eling tools were expected to be found. In this sense, Blender[8] and 3ds Max[9] were the most used 3d editors among the solutions . In addition, 3d model repositories (GenMyModel[10] and Blendswap[11]) and 3d character generators (Anatomium P1[12], MakeHuman[13] and Character Generator[14]) also supported building the environments.

Regarding the use of reusable software components as implementation support, Application Interfaces (APIs), frameworks, libraries and Software Development Kits (SDKs) stand out. For categorization, the following definitions were used: API is the interface for a reusable software entity used by several clients outside the developer organization, and which can be distributed separately from the environment code (Robillard *et al.*, 2012); a framework is a reusable design that is decomposed into a set of cooperating classes, which can be specialized to produce custom applications (Ding *et al.*, 2014); libraries are reusable code that serve a particular purpose (Mili *et al.*, 1995) and SDK is a library or group of libraries that help in developing code for a specific system (Lusk *et al.*, 2006).

In this set of reusable components it is possible to obtain a series of programs with specific functionalities. For example, Java 3D[15] is a Java API for building virtual and three-dimensional objects and Sloodle[16] an API that helps in the integration between 3D virtual environments and Course Management Systems (CMSs). Among the frameworks, ViMeT

stands out, an object-oriented framework for medical training that uses Virtual Reality techniques (Oliveira *et al.*, 2007) and JADE[17], a middleware for the development of applications, both in the mobile and fixed environment, based on the Peer-to-Peer intelligent autonomous agent approach. OpenGL[18] and OpenCV[19] are the most used computer vision libraries among the implemented solutions. Regarding the SDKs, ARToolKit[20] and FLARtoolKit[21], these are technologies that support the development of AR applications. The implications of these new findings are discussed in Section 5.2.

4.6 What are the main institutions that carry out research in iL (RQ6)?

Finally, in this research question, we intend to find out the main institutions that contributed to iL in the context SVR community. Data analyzed correspond to the numbers of affiliation of the authors by institution involved in each paper, that is, the frequency of contribution of institutions of one work that has authors of the same institution will be equal to the number of authors.

First clipping shows the frequency of institutions by country. According to Table 6, the expressive number of institutions is from Brazil. Although the SVR is a Brazilian conference, we can see that institutions from other countries also participate in the SVR.

Considering that Brazilian institutions are more expres-

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[8]https://www.blender.org/
[9]https://www.autodesk.com/products/3ds-max/
[10]https://www.genmymodel.com/
[11]https://www.blendswap.com/
[12]Discontinued software.
[13]http://www.makehumancommunity.org/
[14]https://www.character-generator.org.uk/
[15]https://www.oracle.com/java/technologies/javase/java3d.html
[16]https://sourceforge. net/projects/sloodle/

[17]https://jade.tilab.com/
[18]https://www.opengl.org/
[19]https://opencv.org/
[20]http://www.hitl.washington.edu/artoolkit/documentation/
[21]https://artoolworks.com/products/open-source-software/flartoolkit-2 .html

Table 5. Relation between primary studies and Development tool categories

Development Tool Categories	Primary Studies
3D character generator	PS18, PS40, PS69
3D modelling	PS10, PS16, PS24, PS40
3D modelling and animation	PS18, PS35, PS38, PS40, PS43, PS51, PS54, PS69, PS71, PS72, PS76
3D models package	PS35
3D models repository	PS34, PS55
3D standard	PS20, PS42
3D virtual world viewer	PS16, PS21, PS34
API	PS01, PS10, PS21, PS23, PS32, PS34, PS46, PS53, PS60
Course management system	PS21, PS34
Database	PS34, PS41
Educational simulator	PS33
Engine	PS04, PS09, PS11, PS12, PS15, PS22, PS35, PS36, PS38, PS39, PS40, PS43, PS46, PS48, PS49, PS51, PS52, PS54, PS55, PS56, PS59, PS61, PS62, PS63, PS64, PS65, PS67, PS69, PS71, PS72, PS73, PS74, PS76
Framework	PS01, PS19, PS23, PS42
IDE	PS02, PS18, PS52, PS74
Image editor	PS05, PS40, PS67, PS71
Library	PS02, PS08, PS09, PS11, PS20, PS24, PS26, PS35, PS63, PS70
Markup Language	PS28
Plugin	PS20, PS52, PS69
Programming language	PS01, PS02, PS08, PS10, PS11, PS12, PS20, PS27, PS28, PS34, PS36, PS40, PS63, PS64, PS71, PS72, PS74
Programming technique	PS01
SDK	PS05, PS15, PS25, PS27, PS39, PS65
Virtual world	PS16, PS21, PS34
Web server	PS16, PS34

Table 6. Contributions of the institutions grouped by country

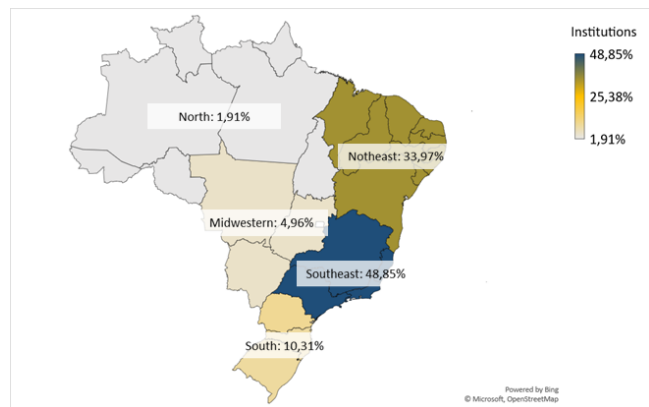| Countries	# Contributions
Brazil	262
Spain	5
Peru	2
Canada	2
United States of America	2
India	1
Portugal	1
Philippines	1
Colombia	1
Scotland	1
Netherlands	1
Japan	1
Germany	1
Mexico	1

Figure 11. Frequency of institutions grouped by regions of Brazil
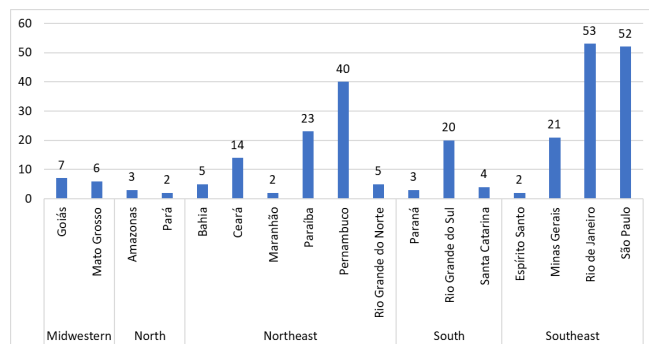

Figure 12. Frequency of institutions by state

stitutional links by author from the Southeast, Northeast and South regions.

5   General Discussions

This work analyzed the state of the art of research carried out by the SVR community on iL from SVR publications. In order to adhere to the focus of the study, other conferences and journals in the area were not considered. From the research questions answered, some critical gaps were identified, which are divided into students with disabilities, development and evaluation of immersive educational virtual environments and development tools.

sive, we cut them by region of Brazil. According to Figure 11, the regions with the highest contributions are Southeast (48.85%), Northeast(33.97%) and South (10.31%). In addition to these data, we present in Figure 12 the number of contributions from institutions by state. As can be seen, the states of Rio de Janeiro, São Paulo and Pernambuco have more contributions to iL in the context of the SVR.

Finally, we selected the main institutions that contributed to the development of iL in the context of the SVR. Table 7 shows the institutions, as well as the total number of contributions considering the affiliation per author of each work. We chose to list only the institutions belonging to the 4th quartile, that is, the top 25% contributions from a total of 244 in-

Table 7. Main Brazilian institutions that contributed in iL

Main Institutions	# Contributions
University of São Paulo	34
Federal University of Pernambuco	30
Federal University of Paraíba	19
Federal University of Uberlândia	10
National Laboratory of Scientific Computing	8
Pontifical Catholic University of Rio de Janeiro	7
University of Fortaleza	7
Federal University of Ceará	7
Military Institute of Engineering	7
National Laboratory for Scientic Computing	5
Federal University of Rio Grande do Sul	5
Rural Federal University of Pernambuco	4
Federal University of São Carlos	4
National Institute of Science and Technology in Computer-Assisted Medicine	4
Laboratory of Collaborative Environments and Applied Multimedia	4

5.1   Students with Disabilities

Educational, social and digital inclusion of children with disabilities is increasingly depending on computing resources, which have the potential to be used as a pedagogical resource, favoring the quality level of teaching-learning (Cole, 2005). According to Brazilian Institute of Geography and Statistics, 45 million Brazilians claimed to have some type of disability. This number represents approximately 24% of the Brazilian population (IBGE, 2021). However, there is a lack of immersive solutions that meet this type of audience. More precisely in this study, only 3.9% represent works that focus on people with special needs [PS13, PS24, PS53].

5.2   Development of Immersive Educational Virtual Environments

One of the main characteristics of immersive technologies is the ability to simulate environments and sensory stimuli in order to provide users with an experience that is as close to reality as possible. Possibly, this explains the high work rate in the health area. Traditionally, surgical training and the study of anatomy are performed using mannequins and cadavers. According to Arulsamy (2012), cadavers cannot provide the appropriate physiological response. Corpses are expensive and cannot demonstrate the changes resulting from disease. Therefore, simulation is an essential part of medical education because it helps surgeons to develop and acquire skills through practice.

From the viewpoint of visualization, following Diehl's classifications, it was possible to group studies that simulate real environments, such as scientific visualization, and studies that work with abstract data, such as information visualization (Diehl, 2007). Studies in the areas of *Archeology*,

Dentistry, *Driving Vehicles*, *Electric Sector*, *Health*, *Military* and *Offshore* were classified as scientific visualization and information visualization studies in the areas of Computing Science, Language, Mathematics and Software Engineering (SE). The main difference lies in the fact that in scientific visualization data are intrinsically three-dimensional, while in information visualization data are abstract, that is, it does not have a defined form.

This emerges as a challenge in the development of immersive virtual learning environments. When designing, in addition to being concerned with pedagogical aspects, the modeling of the virtual environment and its elements is important, so that the user has the feeling of "being there" when interacting with the application. Thus, one of the recommendations is that developers should insert elements common to users, in order to allow recognition and setting in the virtual world. For example, the study [PS61] proposes to support the teaching of the Object-Oriented Paradigm through VR. Traditionally, some object-oriented programming language is used, which can be combined with class diagrams from the Unified Modeling Language (UML). The authors used the common elements of SE that is UML and combined them with the abstract virtual environment and game dynamics. Thus, users create three-dimensional drawings from the basic sphere and cube shapes. To insert a basic shape in the virtual environment, it is necessary to create a class that represents it and then the instances, that is, the objects, are created from it. To change the state of the cube or sphere (object), it is necessary to create attributes and methods in the class and then change the parameters in each object. Similarly, the study [PS48] uses UML to support the teaching of system modeling, but the study contribution focuses on interaction through gestures. In this way, the tool facilitates communication and collaboration between those involved during modeling.

5.2.1   Theorical Frameworks

From a SE point of view, AVR systems have hardware and software elements which are developed and integrated. Most of the studies in this MS are software developed by the authors and integrated with some hardware (Head-Mounted Display, Kinect, Leap Motion) developed by a manufacturer. Developing software minimally requires a process model to guide solution development (Pressman, 2005). One of the main benefits of establishing a development method is software product quality assurance (Pressman, 2005). However, few studies were identified that guide the development of immersive virtual learning environments. These studies were classified as *theoretical framework and model*. The studies [PS50, PS66] are proposed models to support the development of immersive environments as a whole, but the study [PS50] focuses on collaborative training, while [PS66] focuses on Distance Learning.

In the study [PS50], the model consists of 5 steps. The simulation scope definition stage establishes the main points of the project, such as target audience, level of graphic detail and realism of the simulated procedure, general objectives, and task assignments. The acquisition of specialist knowledge stage defines that the development team's contact with the content to be virtually represented is essential so that it

can be modeled more reliably, both as regards to the graphical aspects of the 3D simulation, as well as the aspects of decision modeling for evaluation in the evaluation systems. The step definition of tasks and sub-tasks involved defines the nature of the tasks performed (collaborative or individual), the members involved and the mode of collaboration of each one of them. In the survey of the main variables for evaluation, designers must carefully define the set of variables responsible for classifying individual and collaborative performance. Finally, the last stage of defining the network architecture defines important computational requirements of the evaluation systems, such as the execution platform, network architecture, reliable communication protocol, among others. In the study [PS66], the authors based themselves on the Design Science Research (DSR) methodological approach and the proposed model is composed of three cycles. Relevance Cycle voided the problems and opportunities across the environment to be taken into account by the design cycle. The rigor cycle provides prior knowledge to ground the artifact creation, as well as seeks to find gaps for contributions to the scientific body of knowledge. Design cycle considers the theoretical foundations discussed regarding immersive technologies.

The studies [PS06, PS30, PS45] support a certain part of the environment development. The study [PS45] performed a comparative analysis of firing simulators and, as a result, proposed hardware requirements, functional requirements and non-functional requirements for the development of low-cost firing simulators. The study [PS30] conducted a survey of healthcare professionals who teach disciplines in which there is a need for 3D visualization of anatomical structures. They also carried out a literature review on VR systems using gestures. In the end, they proposed a set of natural interactions through gestures that are best suited to certain tasks in health education. Finally, the contribution of the study [PS06] is that it is a theoretical model to assess the learning gain in immersive environments. The model has two modules. The pre-test diagnostic evaluation module has the function of diagnosing how much the learner knows about the topic that will be addressed in the virtual training. The post-test diagnostic assessment module uses the same assessment tools applied in the pre-test module. However, the difference is the fact that the post-test module includes a third assessment instrument that seeks to verify the learner's interactions within the virtual environment during the training phase, in order to collect data to identify how the learner's behavior was during the knowledge acquisition process, and thus be able to assess its evolution. By comparing the results obtained in the pre-test and post-test evaluations, it is possible to diagnose whether the training was successful and whether the virtual environment contributed to increasing the participant's knowledge of the topic addressed.

In general terms, the works above have the limitation that they only contribute to a certain part of the development of immersive applications and do not consider pedagogical aspects. Frameworks that help establish key aspects of applications have the advantage of supporting both the quality of development and the improvement of learning outcomes. An example is the work of Fernandes and Werner (2021), whose framework establishes a set of guidelines grouped into ob-

jective and subjective factors to support the development of immersive applications to support SE Education.

5.2.2 Software Architecture

Following the SE line, the software architecture of a program or computational system is the structure, or structures, of the system that encompasses the software components, the externally visible properties of these components and the relationships between them (Bass *et al.*, 2003). The study [PS33] describes the extension of the architecture evaluation module proposed by Paiva *et al.* (2013). Due to the exclusion criteria, it was considered the most recent study by the authors to compose the final set of articles. However, an overview of the architecture is presented below. The authors defined that the architecture must take into account system requirements, assessment, network and graphical modules. In system requirements, conditions are established to guarantee collaboration between users, from the point of view of distributed computing and interaction devices. The assessment module includes both multiple users' assessment system for evaluating team members, as well as the single users' assessment system for evaluating each user. The network module defines questions about communication between devices connected in a network, such as defining which communication protocols are most suitable. The graphical module, basically, should be responsible for generating and processing the graphical environment, which will simulate the operating room.

In the Multiple Users' Assessment System (MUAS), the architecture proposed in the study [PS17] can be used for assessment of several kinds of training in medicine, as procedures in surgical rooms, training of paramedics groups in emergency situations, etc. However, it is a generic architecture that can be used also in training systems for other areas. Architecture consists of the following elements: user/group; interactions; statistical measures; statistical models; testing of hypothesis; fuzzy rule based expert system and classes of performance and reports.

The study [PS31] proposes an architecture for the creation of serious games, which is based on the client-server model. A server concentrates functionalities that can be accessed by different clients. The way in which these clients are implemented is independent of the server, as long as the communication protocols are respected.

5.3 Assessment of Immersive Educational Virtual Environments

From the point of view of validating the proposed solutions, the instruments used were questionnaires answered by the participants in the experiments. Despite its advantages, using questionnaires can infer threats to the validity of the study, that is, participants can misinterpret the questions and the answers are biased by this error. In this sense, it is recommended that future research includes the use of biometric data to studies. The use of sensors for the analysis of biometric measurements can help in studies and obtain reliable data on the experience felt by the user Kalantari *et al.* (2018).

In addition, most studies assess the solution from the standpoint of technology adoption or user experience and do not

focus on measuring the improvement in learning outcomes after participants use the solutions.

5.4   Development Tools

In Section 4.5, tools used to implement the solutions were identified. Most of the technologies are game engines, programming languages, 3d modeling, APIs, frameworks, that is, most technologies need consolidated knowledge in coding and in three-dimensional drawing techniques.

Considering the educators' point of view, they are dependent on the solutions developed for a certain application domain. And if there is no implemented solution, when choosing to develop, they will face great challenges, as the tools require very specific technical knowledge and educators are not prepared to overcome these obstacles.

In this review of SVR publications, we identified that solutions could be more adaptable and flexible to the needs of educators. For example, FrameVR[22] and Mozilla Hubs[23] are virtual spaces that are easy to customize. Both are web tools, that is, they run through the browser, and allow educators to create environments in which students can interact and communicate with each other through avatars. From a functionality point of view, FrameVR stands out for allowing uploading stereoscopic images, 360º videos, importing 3d models directly from the Sketchfab[24] repository, voice zone, whiteboard and other features.

6   Conclusions

This work aimed to obtain the state of the art on Immersive Learning, from the point of view of the SVR community. A systematic literature mapping protocol was performed and 76 articles were selected for analysis and data extraction. With this study, it can be noted that the main contribution of the community is the development of virtual environments, although there are proposals for models that support the development of virtual environments. Furthermore, although the conference is Brazilian, there was the participation of researchers from Canada, USA, India, Germany, Philippines and Portugal.

Some gaps were identified: few works that serve the audience with special needs; generic frameworks that support the development of immersive applications and that consider pedagogical aspects; and more effective strategies, in addition to questionnaires, in measuring user experience and improving learning outcomes, as well as tools that are more flexible and support the personalization of instructional content by educators.

Although the clipping is from works published on SVR, we believe that one of our contributions in relation to related works is to obtain an overview of the works regardless of the type of technology or audience. Thus, we were able to verify which audiences were reached, development tools adopted, types of applications developed (VR or AR), among others.

In addition, we also believe that our work has an impact on some directions and reflections, such as: why are the main institutions located in the Southeast and Northeast regions of Brazil; the need to carry out more research and develop educational applications based on AR, as well as reaching out to other domains (computational thinking, history, physics, etc.); and, mainly from our point of view, awaken the SVR community to solutions focused on people with disabilities. According to Fernandes (2022), there is still a need for more research so that people with disabilities can interact with immersive systems and also obtain gains in learning outcomes through immersive technologies.

As future work, the results of this systematic literature mapping can be used to investigate effective and alternative methods to measure experience and real gain in improving learning outcomes, and also to understand why some years have a greater amount of published works and in other years few publications. In addition, another secondary study comprising more journals can be designed in order to obtain an overview of the area of iL.

Acknowledgements

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7 Appendix

7.1 Primary Studies Selected

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