Journal on Interactive Systems, 2026, 17:1
ISSN: 2763-7719 • doi: 10.5753/jis.2026.7411

Research Paper

TEKOHÁ: From a Systematic Review to a Virtual Reality Environment to Teach Jesuit-Guarani Missions History in Primary Education

Renato da Veiga Martins Júnior [University of Vale do Rio dos Sinos - UNISINOS | *renatoveigamj@edu.unisinos.br*]
Vinicius Costa de Souza [University of Vale do Rio dos Sinos - UNISINOS | *viniciuscs@unisinos.br*]
Kleinner Silva Farias de Oliveira [University of Vale do Rio dos Sinos - UNISINOS | *kleinnerfarias@unisinos.br*]

Postgraduate Program in Applied Computing, University of Vale do Rio dos Sinos - UNISINOS, Av. Unisinos, 950, São Leopoldo, RS, 93022-000, Brazil.

Abstract. Virtual Reality (VR) is a technology that enables physical immersion, sensory stimulation, and interactivity, creating experiences that mentally transport users to alternative environments. While VR has demonstrated positive outcomes in adult education, such as fostering authentic learning contexts, enhancing motivation, and improving long-term retention, its application with children remains largely unexplored. This study addresses this gap through a methodological approach structured in four stages: (i) a systematic literature review on VR in primary education; (ii) a survey and design phase involving a working group of primary school teachers; (iii) the implementation of TEKOHÁ, a virtual environment that reconstructs the Jesuit-Guarani Missions at São Miguel das Missões (Brazil); and (iv) the proposition of a dedicated teaching plan. The review, conducted according to PRISMA guidelines, analyzed 953 articles published between 2013 and 2023 and identified 128 eligible studies. Based on these findings and the working group's insights, TEKOHÁ was designed to support history education as a compulsory component of the National Common Core Curriculum (BNCC). The next step will be to conduct a controlled experiment with fourth-year primary school students to assess the effects of using TEKOHÁ on the learning process.

Keywords: Virtual Reality, Primary Education, Systematic Review, Educational Technology, Jesuit Mission, TEKOHÁ

Edited by: João Marcelo Teixeira | **Received:** 16 January 2026 • **Accepted:** 26 July 2026 • **Published:** 18 August 2026

1 Introduction

The integration of digital technologies into education has accelerated in recent decades, transforming how students learn and interact with knowledge. Among these innovations, Virtual Reality (VR) stands out as a promising tool for creating immersive and interactive learning experiences [Samala *et al*., 2025]. By enabling students to engage with three-dimensional environments through multiple sensory channels, VR promotes a sense of presence, offering opportunities to enhance motivation, engagement, and knowledge retention beyond traditional teaching methods [Jerald, 2015; Brey, 2014].

Moreover, VR has been explored across a wide range of disciplines, including STEM education, chemistry, physics, biology, mathematics, geography, and language learning, especially in higher education. In primary education, VR introduces fundamental concepts such as science, mathematics, and language. In science teaching, VR provides clear spatial and visual representations of abstract concepts, enabling more direct and engaging learning experiences. Furthermore, VR allows students to virtually experience real-world or historical situations and can also include experiences, such as space travel or underwater exploration, that are physically difficult to achieve [Samala *et al*., 2025].

History content, especially in the context of primary education, presents additional challenges related to abstraction skills, perception of chronology and succession, historical empathy, and geographical distance, which can hinder engagement and understanding. Immersive technologies have the potential to overcome these barriers by recreating historical environments, promoting experiential learning, and encouraging cultural appreciation [Merchant *et al*., 2014; Makransky and Lilleholt, 2018]. However, as Radianti *et al*. [2020] emphasizes, the educational impact of VR depends on careful integration into pedagogical strategies, with attention to usability, learning outcomes, and contextual alignment. Despite these possibilities, there is a lack of immersive tools specifically designed to engage young learners with the complex historical narratives of South American missions.

In Brazil, the Jesuit Missions of the 17th and 18th centuries represent an important cultural and historical heritage, recognized by UNESCO, and constitute a mandatory component of primary education in the National Common Curriculum Base (BNCC) [Ministério da Educação, 2018]. The Jesuit Missions, which began in 1687 in Rio Grande do Sul, were indigenous settlements created and administered by Jesuit priests to disseminate Christian thought [Coutinho, 1998]. Currently, only the ruins of these missions remain, but they were responsible for the origin of prosperous cities, helped delimit borders, and gave rise to regional folklore. The culture developed in these centers reached a high level of complexity in art, urban planning, and social harmony.

Despite their historical importance, the way this content is taught in primary education presents challenges. Although schools include these studies in the classroom and occasionally conduct on-site visits to the ruins of São Miguel das Missões, many students lack motivation to learn this content. To address this, we developed a VR environment named TEKOHÁ, which allows students to experience the missions

at their architectural and social peak, bridging the gap between current ruins and historical life. The challenge, therefore, is to make the history of the Jesuit Missions more engaging and accessible.

Thus, the motivation for this study centers on the difficulty of engaging primary education children with the history of the Jesuit Missions, a mandatory curricular content stipulated in the BNCC (Brazilian National Curriculum Base) as the skill *(EF05HI01) - Identify the processes of formation of cultures and peoples, relating them to the geographical space occupied* [Ministério da Educação, 2018] and in the RCG (Rio Grande do Sul Curricular Reference) as the skill *(EF05HI01RS-2) - Know and analyze the influence of the different peoples who colonized the lands of Rio Grande do Sul, perceiving their contributions in the most diverse spheres of life and culture (architecture, art, economy, religion, education, technology, etc.* [SUL, 2018].

To overcome the challenges of teaching history to children in the early years of primary education, we developed TEKOHÁ[1], an immersive virtual environment that simulates the functioning of the Jesuit Mission of São Miguel Arcanjo at its peak, between 1735 and 1745. TEKOHÁ was specifically designed to support the teaching and learning process for children, therefore focuses on the missions of the Seven Peoples of the East, specifically on the daily life of the Guarani[2] people in the Cotiguaçu[3].

The narrative of TEKOHÁ adopts a "History from Below" perspective, prioritizing the agency and daily experiences of the indigenous population over a purely Eurocentric or institutional Jesuit narrative. This choice aims to foster historical empathy and recognize the Guaranis as active subjects in the construction of mission space.

The main contributions of this work are:

- (i) a systematic literature review providing empirical evidence and design guidelines for VR application in primary education;
- (ii) the user-centered design and development of the TEKOHÁ immersive environment, guided by pedagogical working groups with primary school teachers;
- (iii) a child-friendly VR interaction and narrative model prioritizing a "History from Below" perspective to foster historical empathy toward the Guarani people; and
- (iv) a dedicated 4-week teaching plan for integrating TEKOHÁ into history education in alignment with BNCC and regional curriculum standards.

This article is organized as follows: Section 2 describes the four-stage methodological approach used in this research. Section 3 presents the systematic literature review on VR use in primary education. Section 4 details the insights and results obtained from the working group with primary school teachers. Section 5 presents the design and implementation of the TEKOHÁ virtual environment. Section 6 proposes a teaching plan for integrating the tool into the history curriculum. Finally, Section 7 presents the conclusions and suggests future lines of research.

[1]TEKOHÁ (pronounced: /te.ko.'a/): A Guarani word meaning "the place where we are what we are." It refers to the physical and cultural territory where the Guarani way of life is possible.

[2]Guarani: One of the most representative indigenous ethnic groups in South America, whose social and religious organization was central to the Jesuit missions.

[3]Cotiguaçu: A large communal house within the missions, typically used to house widows, orphans, and single women, serving as a social assistance and educational space.

2 Methodological Approach

The methodology of the work was structured in four stages, presented below:

1. **In-depth Study:** systematic literature review on the use of VR in primary education, using the PRISMA method [Liberati *et al*., 2009];
2. **Survey and Design:** working group with 4th-grade teachers to assess their prior knowledge of VR, enable them to experience VR, and gather suggestions for designing a virtual environment for Jesuit Missions education;
3. **Implementation:** development of a virtual environment that depicts the Jesuit Mission of Saint Michael the Archangel at its peak (17th and 18th centuries);
4. **Teaching Plan**: proposition of a lesson plan for the TEKOHÁ virtual environment use in primary education.

3 Systematic Literature Review

This section presents the results of a Systematic Literature Review (SLR) that maps the current landscape of Virtual Reality (VR) applications in primary education. By analyzing the state of the art, we aimed to identify successful pedagogical strategies, prevalent technological constraints, and existing gaps in the use of VR in educational contexts among children. The findings provide the empirical evidence necessary to justify the design requirements and educational goals of the TEKOHÁ environment, ensuring that its development is grounded in best practices and curriculum-aligned needs.

3.1 Protocol

The SLR was conducted following the PRISMA guidelines [Liberati *et al*., 2009], and the Mendeley [4] tool was used as a bibliographic reference manager.

To meet the research's central objective, the study was limited to mapping articles on the use of VR in primary education across different contexts, as well as those that analyze the possible influence of this tool on educational outcomes. The information was collected through database searches of scientific journals, magazines, transactions, and conference and congress proceedings. Table 1 presents the Research Questions for this SLR, with a focus on primary education.

Table 1. Research Questions.

#	Research Question (RQ)
RQ1	For what purposes is VR utilized ?
RQ2	Which knowledge domains are addressed?
RQ3	Which VR technological resources are employed ?
RQ4	What are the main contributions?
RQ5	What methodological strategies were used?
RQ6	What evaluation metrics have been used?

[4]https://www.mendeley.com/, Accessed: 28 July 2026.

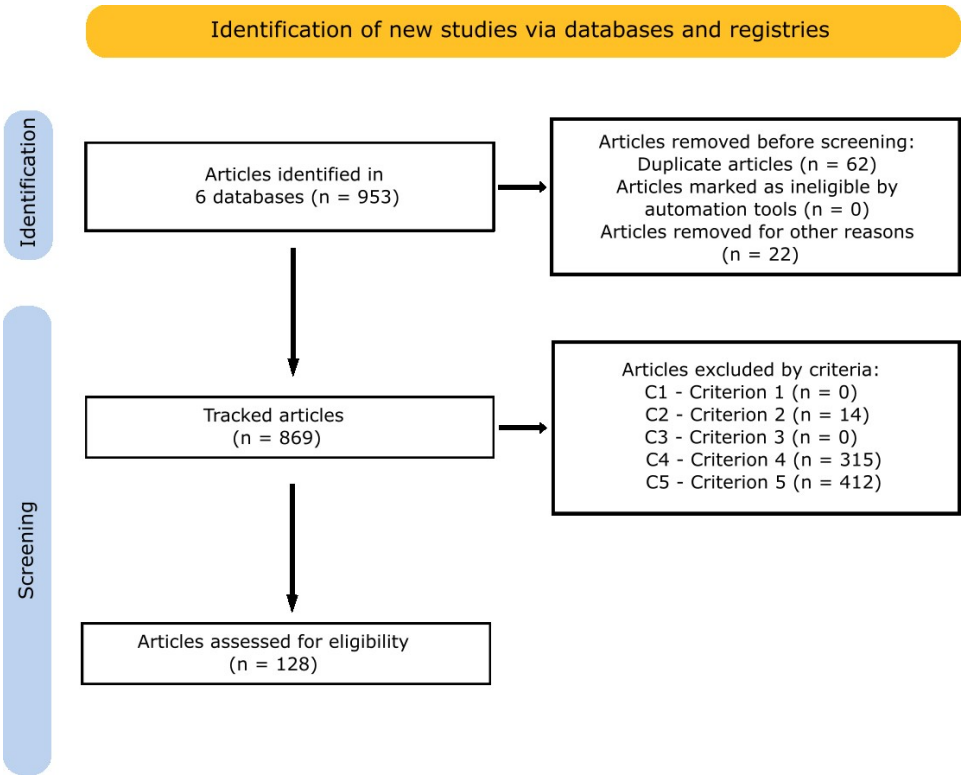

Figure 1. PRISMA workflow diagram.

Table 2 presents the search string created using the following keywords: virtual reality, children, teaching, education, learning, and primary education. Table 3 shows the criteria used to filter the search results in selected databases: ACM, IEEE, ScienceDirect, Scopus, Springer, and Web of Science. This article presents the results of a 2024 study, so the systematic review covered articles published between 2013 and 2023.

Table 2. Search String.

(“virtual reality” OR “vr”) AND (“children”) AND (“teaching” OR “education” OR “learning” OR “primary school”)

Table 3. Criteria used to filter results.

#	Description
C1	Restrict publications to the last 10 years.
C2	Remove books and book chapters.
C3	Remove documents that are not in English.
C4	Remove publications that do not use VR in primary Education.
C5	Remove publications that do not use VR in education for children aged 6 to 12.

The PRISMA Identification and Screening stages outline the procedure for identifying and selecting studies. In the first phase, studies were identified through database searches using the search string (Table 2). The results were stored in the Mendeley Reference Manager library, and duplicates were removed. Subsequently, the studies were screened for relevance based on their titles and abstracts. The records were then assessed to determine whether they met the inclusion criteria (Table 3). In the following phase, a more in-depth analysis of the identified documents was conducted through full-text reading to decide on their inclusion in the review.

The PRISMA flow diagram is shown in Figure 1. A total of 953 studies, published between 2013 and 2023, were identified; these records included journal articles, conference proceedings, and reviews. In total, 825 studies were excluded (62 of which were duplicates). Following this, 128 studies that met the eligibility criteria were included in the review. No additional relevant studies were included thereafter. The selected databases and the resulting data are presented in Table 4.

Table 4. Selected databases and quantitative results.

Databases	Identified articles	Included articles
ACM	126	24
IEEE	118	21
ScienceDirect	123	6
Scopus	225	52
Springer	56	1
Web of Science	237	25
Total	953	128

3.2 Bibliometric

Bibliometric analysis is an essential tool for understanding the trends and development of a research field over time. This approach allows identification of publication growth, the most prominent authors, countries of origin, and the journals with

the highest number of publications.

This literature review found that publications on the use of virtual reality (VR) in primary education have increased over time. There has been a steady increase in the volume of published articles, with a notable peak during the COVID-19 pandemic, when the demand for remote educational solutions accelerated VR research [Elaish *et al*., 2024]. Figure 2, which presents the annual number of publications, demonstrates this growth.

Bibliometric analysis also identifies the most prolific and influential authors in the VR field. Figure 3 presents this information through a chart highlighting several high-impact publications. These authors collaborate with renowned institutions, thereby broadening the reach and influence of their research.

The geographical distribution of research on virtual reality in primary education reveals that countries such as the United States, China, and Germany are among the most productive in terms of publications. Figure 4 demonstrates that these nations have invested significantly in educational technology, which is reflected in both the volume and quality of published research.

3.3 Research Purpose and Knowledge Domains

Based on the 128 selected articles, 24 distinct knowledge domains were identified in which VR has been used in primary education (Figure 5). These domains are organized into four main categories:

- Curriculum Teaching (53 articles) — studies that represent how VR can be integrated and directly applied into educational curricula;
- Safety (24 articles) — studies on VR applications in training and simulation environments focusing on safety;
- Social Behavior (47 articles) — studies that explore social interaction in virtual environments, communication, collaboration, and group learning, as well as ethical and social issues;
- Basic Research (4 articles) — studies that provide a comprehensive overview of existing knowledge on specific topics related to VR in children's education.

The Curriculum Teaching category was the most significant, with 53 articles selected, covering the following areas of knowledge: History (5), Art and Design (5), Chemistry (2), Languages (13), Mathematics (8), Physical Education (4), Computational Thinking (1), Music (1), Science (6), Physics (2) and STEAM (6). Among these studies, Gkoumas and Izzouzi [2023] investigated the benefits of using VR in basic education, allowing students to visit sites such as the Roman archaeological site Augusta Emerita and the solar system. Lahovsky *et al*. [2023] follows a similar line, presenting research on three applications whose primary objective is to educate and encourage children's scientific exploration. Li [2021] explored the effectiveness of linguistic structures and textual cues, learning performance, and cognitive load in a VR environment.

In the components of history, arts, and culture teaching, **?** present an original contribution to the complex field of public studies in museums from the perspectives of communication and education. Luigini *et al*. [2020] writes about an educational VR journey, with a focus on cultural heritage and the relative experimentation centered on the production of traditional bread from Val Pusteria and the rural life surrounding it. Combining languages and history, Chiu [2017] presents a VR game developed for primary school students to learn about indigenous tribes in Taiwan. In the arts, Chu [2022] believes that VR technology can overcome time and space constraints, restoring traditional cultural history and providing vivid imagery that helps children understand the traditional culture and art of their own country.

In natural sciences such as chemistry, physics, and biology, Guo and Mogra [2022] proposes a system that supports the combined use of Web3D and WebXR technologies, including elements of virtual reality and augmented reality (AR), to raise awareness about plastic recycling. Modibane *et al*. [2021] presents a VR application for the concept of inertia, utilizing various techniques such as 3D visualization in computer graphics. In line with serious games, Cao *et al*. [2021] uses interaction in their research to create a VR game for practical laboratory experiments in primary school science. Concerned with interest in physics studies, Damekova *et al*. [2021] develops research with a 3D laboratory for children and examines student performance through physics projects using this lab. Similarly, Bogusevschi and Muntean [2019] seeks to develop an application containing computer-based 3D immersive virtual reality and an experimental simulation lab. van Limpt - Broers *et al*. [2020] investigates the interaction of immersive experiences that evoke awe, willingness, and compassion in learning with gains in nature conservation skills. Zhang *et al*. [2019] explores the VR locomotion experience through objective and subjective dimensions, designing an experiment where subjects complete the task of moving their bodies and touching underwater animals. Karkar *et al*. [2018] proposes an immersive VR system that allows children to prepare their breakfast through direct interaction with food. Iquira Becerra *et al*. [2018] promotes research offering the development of a VR-based application for teaching zoology.

In music education, studies also focus on learning. Lu *et al*. [2022] is developing an innovative tool to teach introductory music theory through VR. Michałko *et al*. [2022] uses virtual reality and smart wearable technologies in initial instrumental training, evaluating usability through user attitudes toward the project design. Similarly, Serafin *et al*. [2017] proposed that virtual reality can offer children an alternative approach to acquiring musical skills. Wang [2021], in more advanced research, concludes that VR technology is feasible and important to introduce into current music education classrooms and to explore the development of multiple intelligences education.

In addition, proposals for new curriculum components are presented, including robotics, computational thinking, and STEAM (Science, Technology, Engineering, Arts, and Mathematics). Araiza-Alba *et al*. [2021] developed a tool called URA, useful for teaching and practicing logical reasoning problem-solving skills. Hsiao and Su [2021] intended to integrate the concept of sustainability into STEAM education, aided by a VR system. Sharaf *et al*. [2020] proposes a new way to teach programming to children using VR. Peltekova

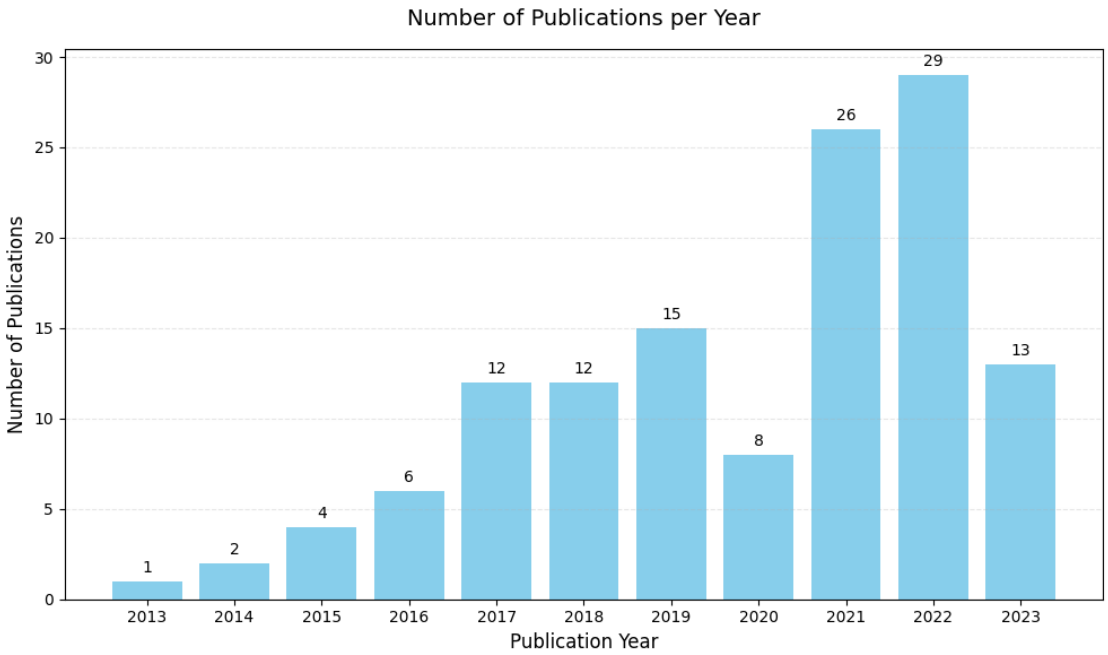

Figure 2. Publications per year.

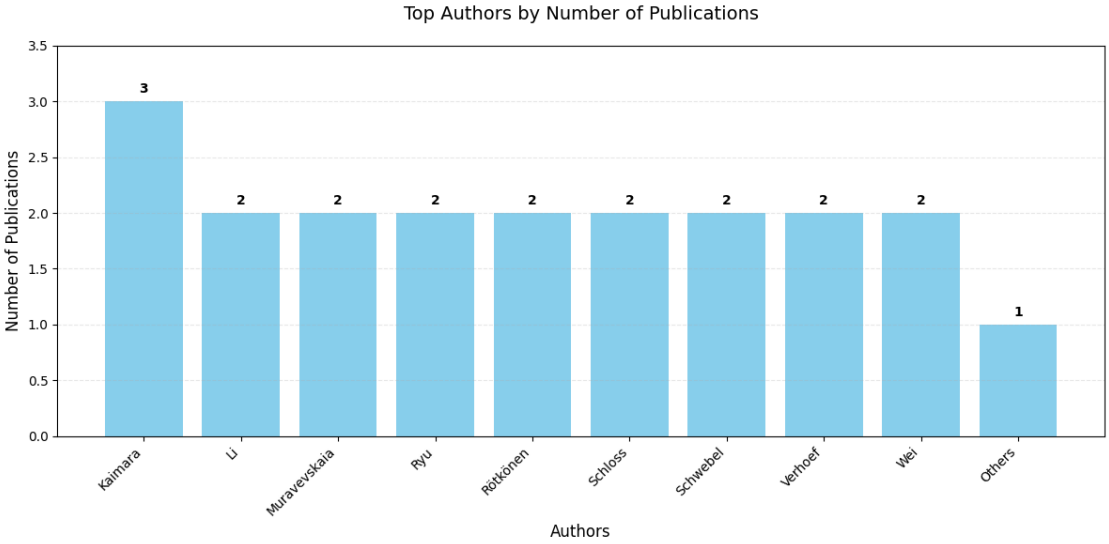

Figure 3. Distribution of the most prolific authors.

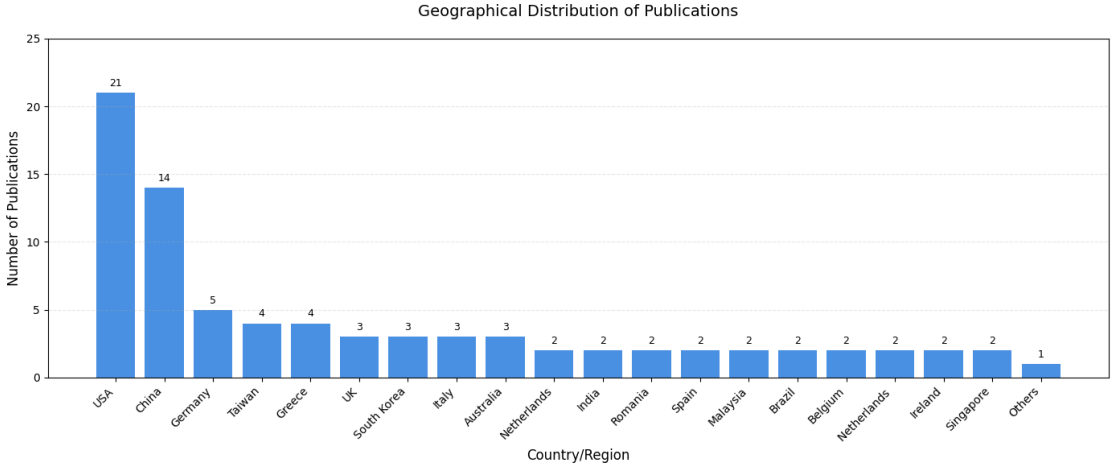

Figure 4. Geographical distribution of publications.

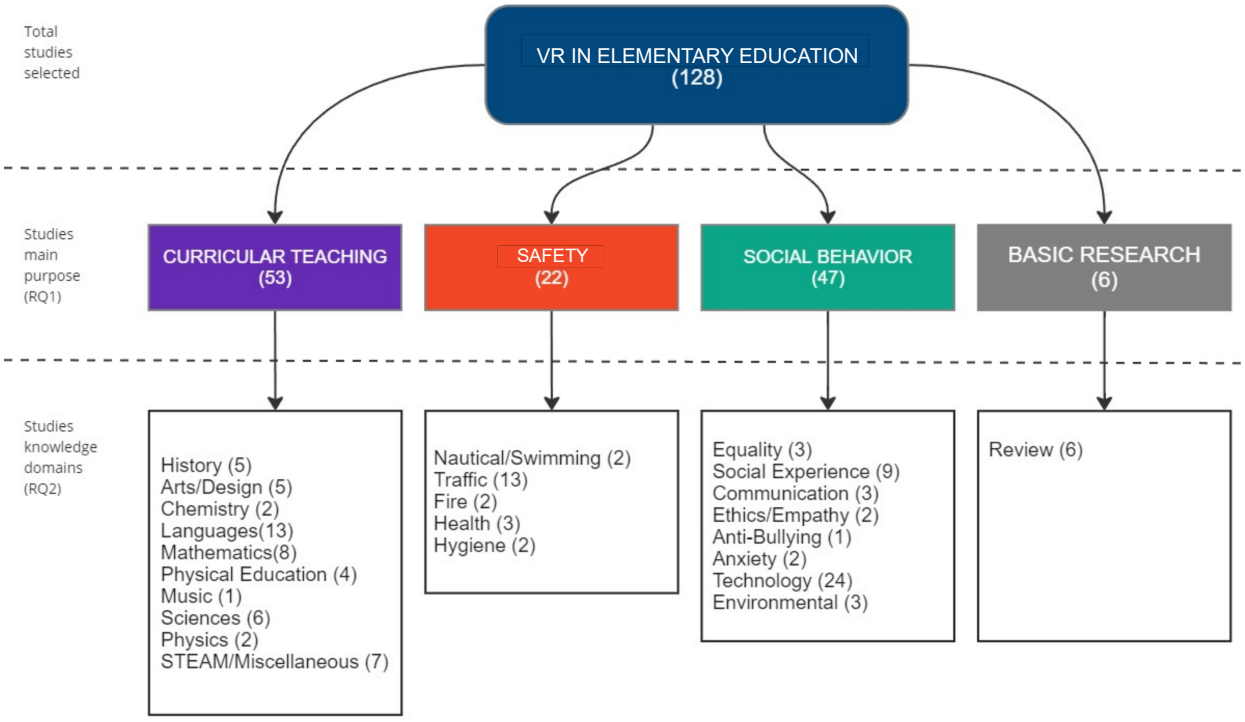

Figure 5. Classification of selected studies by research purpose and knowledge domains (RQ1 and RQ2).

et al. [2019] presents evidence that an inquiry-based learning approach, combined with traditional tools (paper star maps) and information technologies (VR goggles, interactive whiteboard, online inquiry-based learning platform), could help educators increase students' interest in STEM and improve their outcomes.

3.4 Thematic Categorization and Design Implications

In addition to bibliometrics, the reviewed studies were categorized into three analytical dimensions:

- Learning Outcomes: 65% of the studies focus on empathy with some context linked to a story and on the retention of facts through immersion.
- Types of Interaction: The majority (70%) use "point and click" or teleportation to reduce motion sickness in children.
- Pedagogical Strategies: Inquiry-based learning is the dominant approach.

Based on evidence gathered through the Systematic Literature Review (SLR), several critical design implications were identified to address the challenges in primary education VR environments. Table 5 synthesizes these findings, mapping the core limitations, such as motion sickness risks, the need for instructional scaffolding, and cognitive load issues, to actionable development strategies.

3.5 Discussion and Synthesis

First, it is noteworthy that few studies have conducted controlled experiments with children. Only 21.8% of the works (28 out of 128) reported experiments involving children, most of which used small sample sizes and legacy VR headsets,

Table 5. Design Implications from SLR.

SLR Finding	Design Implication
High risk of motion sickness in kids.	Implementation of teleportation-only movement.
Need for clear learning goals.	Integration of the virtual guide to scaffold the experience.
Cognitive overload with complex UI.	Use of "Gaze selection" and simplified hand-trigger interactions.

such as the Oculus Rift and HTC Vive. Possible explanations include greater complexity and the lack of specific guidelines for conducting VR experiments with children. Protocols previously established for VR experiments with adults needed to be adapted for use with a younger audience. Furthermore, a smaller proportion of studies involving children received approval from a Research Ethics Committee (REC), demonstrating that, while this process is time-consuming, it is of utmost importance, especially for studies involving minors.

Another significant highlight is that no previous works were found that recreated the Jesuit Missions of São Miguel in an immersive virtual environment. The only five studies related to the field of History found in the systematic review are briefly presented below.

Debailleux *et al*. [2018] developed a virtual model that was used with 19 children to evaluate its effectiveness on learning outcomes related to the cultural heritage of the city of Mons in Belgium. Pradeep Raj *et al*. [2018] developed a tool for designing a flexible, easily configurable VR storytelling creation screen. Luigini *et al*. [2020] presents an immersive serious game for teaching about cultural heritage related to traditional bread from the Puster Valley and Italian rural folk traditions. **?** analyzed the usage and consumption habits

of museum visitors in the Castile and León region of Spain, utilizing an Educommunication framework through digital tools and social media. Finally, Gkoumas and Izzouzi [2023] conducted a usability study of a VR tool that allows users to explore sites in the first person and interact with sites such as the Roman archaeological site of Augusta Emerita in Spain.

In synthesis, the key findings of this systematic literature review are:

- Significant increase in the number of publications, particularly during the COVID-19 pandemic;
- Absence of a dominant researcher in the field; the most prolific author recorded three publications within this research area;
- The majority of publications originate from the USA and China;
- Among the various purposes for using VR with children, supporting learning and enhancing engagement are the most prominent;
- Regarding the knowledge domain, the fields of Linguistics, Science, Mathematics, and Behavioral Studies were the most frequent;
- Dominant methodological strategies included the development of VR applications and case reports of their use;
- The primary metrics used to evaluate VR in primary education were engagement, motivation, academic performance, immersion, and presence.

In the broader context of interactive systems and immersive technologies, recent studies in the Journal on Interactive Systems (JIS) have addressed key challenges in designing and evaluating virtual and augmented reality environments. For instance, tools such as EduVR Collab [Viol *et al*., 2025] explore management strategies for collaborative immersive learning, while systems like DinosaurVR [Souza *et al*., 2023] demonstrate how virtual reality can enhance engagement and narrative immersion in cultural and museum exhibitions. Furthermore, human-centered evaluations in extended reality, such as case studies on augmented reality applications and multidisciplinary design for large-scale heritage experiences [Adachi *et al*., 2026], highlight the importance of balancing usability, presence, and pedagogical goals when designing VR environments for diverse audiences, including primary education.

The systematic review revealed a lack of immersive environments specifically tailored for history education in primary schools, particularly those aligned with regional curriculum standards, and served as the foundation for the development of TEKOHÁ, which will be detailed in the following sections.

4 Working Group

To gain insights from primary school teachers for the design of the TEKOHÁ virtual environment, a working group was established that allowed educators to experience virtual reality technology and contribute ideas for its development (Figure 6). The working group consisted of 12 teachers (M = 42.5, SD = 4.2) with teaching experience (M = 15.2 years, SD = 3.8). Most participants (80%) had no prior experience with VR. This lack of experience initially led to "novelty bias", but subsequently allowed the team to identify usability barriers that "expert" users might overlook. Data were collected via semi-structured interviews and low-fidelity prototyping sessions. This research followed Brazilian national ethical guidelines for human subjects research (National Health Council Resolutions No. 466/2012 and No. 510/2016) and was approved by the Research Ethics Committee of Universidade do Vale do Rio dos Sinos (CEP/Unisinos) under CAAE protocol No. 76302623.5.0000.5344.

Twelve primary school teachers from a private school in Porto Alegre participated in this working group (1 man and 11 women). Regarding academic background, two held a bachelor's degree, seven were specialists, two held a master's degree, and one held a doctorate. Nine had degrees in Pedagogy, one in Literature/Linguistics, one in Physical Education, and one in Mathematics, with graduation dates between 1982 and 2013. Their experience teaching 4th-grade primary school students ranged from 2 to 25 years (average of 15.2 years). Regarding experience with virtual reality, six participants had never used it; one stated they had used VR only once; two teachers indicated a frequency of use between two and five times, while three teachers reported having used the technology on more than 5 occasions.

Regarding the pedagogical strategies employed in teaching the history of the Jesuit Missions, participants mentioned gamification, the use of maps and QR codes, the exploration of puzzles, Google Earth, and specialized websites. Traditional methods, such as reading and interpreting texts, educational games, storytelling, mind maps, model building, and slide presentations, were also cited. Other approaches included research, lectures, group work, video analysis, and the construction of replicas of the missions in the school environment. Some teachers also reported organizing study trips to the Missions region to observe the ruins and building large-scale models to promote student immersion in the space of the reductions.

The coexistence of innovative pedagogical practices, such as gamification and Google Earth, with already established methods, such as reading and model building, suggests a multifaceted approach to teaching the history of the Jesuit Mission and a predisposition on the part of the teachers to experiment with new approaches, which could increase student engagement through the possibility of virtually experiencing historical contexts, providing them with a deeper and more multisensory understanding of the past.

Regarding the teachers' suggestions, it was proposed that the virtual environment include elements and characters fundamental to the historical and cultural understanding of the São Miguel Arcanjo Missions, such as the Jesuits, the indigenous peoples, and historical leaders like Sepé Tiaraju and Nicolau Neenguiru. These characters are essential to represent the different missionary centers and their interactions. The environments suggested for reconstruction in virtual reality include the church, the central square, the town hall, the school, the workshops, and other spaces that made up the reductions, such as the orchard, the corral, and the dwellings. The representation of these environments reflects the historical and functional context of the time, allowing students to experience the daily routine of the mission's inhabitants.

To ensure a comprehensive representation, the teachers stated that it is essential to portray people living their daily

Figure 6. Workshop with primary education teachers.

routines within the geographic and historical context of the period, including attire, behaviors, languages, and narratives. Experiencing the "golden age" of the reductions, including the Mission Cross and the established social relationships, is also crucial.

Besides this, teachers envisioned that the experience of exploring the Saint Michael Missions through VR should be interactive, engaging, and thought-provoking. Suggestions in this context included creating a virtual guide and using a gamified narrative with tasks and challenges. The suggested maximum duration for the VR experience ranged from 5 to 20 minutes, with most teachers identifying 10 to 15 minutes as ideal. The virtual tour script should begin at the main square and the church, then move on to other locations, such as the workshops and dwellings. The visit could include tasks to complete and help students understand the significance of each space. An interesting proposal was to begin at the height of the missions and conclude with the current state of the ruins, providing a complete overview of the site's historical evolution.

Regarding the graphic style, seven teachers suggested High-Poly (realistic graphics and textures), two suggested Mid-Poly (intermediate graphics with lighter textures), and only one suggested Low-Poly (graphics closer to bright, stylized animations). Most educators believe that High-Poly graphics with realistic textures are ideal for providing a deeper and more immersive experience for children. These graphics provide a more detailed and faithful representation of the environment, helping students connect more effectively with the presented content. Conversely, Mid-Poly offers intermediate quality with lighter textures, which can be advantageous for devices with lower processing power, maintaining visual quality without overloading the system. Finally, the Low-Poly style, while less realistic, may be more accessible and appealing to younger children, facilitating comprehension and engagement.

The collaborative insights gathered from this working group were instrumental in defining the technical and pedagogical requirements for the TEKOHÁ environment. By synthesizing the teachers' emphasis on historical authenticity—specifically the inclusion of key figures like Sepé Tiaraju and the reconstruction of functional spaces like the central square—with their recommendations for a 10-to-15-minute gamified narrative, we established a design framework that balances immersion with classroom feasibility. Furthermore, the strong preference for high-poly realistic textures guided our graphic development to ensure that the final environment not only meets the BNCC and RCG curricular standards but also provides the multisensory 'time travel' experience envisioned by the educators. These requirements directly informed the virtual environment design and implementation, bridging the gap between historical theory and immersive educational practice

5 The TEKOHÁ Virtual Environment

The name TEKOHÁ was chosen for this study's virtual environment due to its profound meaning in Guarani culture [Montoya, 2026]. In Guarani, "tekohá" represents much more than a simple physical location; it is the space where the customs, laws, habits, and values of the Guarani people manifest [dos Santos, 2016]. This term encapsulates the essence of being Guarani, reflecting their cultural identity and their intrinsic relationship with the natural environment.

The environment was conceived to provide students with an immersive living experience in the Jesuit Reduction of São Miguel Arcanjo, allowing them to explore and interact with virtual scenarios that recreate the historical missions at their peak. The development of TEKOHÁ involved a team of three undergraduate students from the Digital Games course at Vale dos Sinos University (Unisinos) and began in September 2023, with the first version completed in August 2024.

According to Jerald [2015], the design of VR interfaces must consider not only usability but also the capacity to emotionally engage users. This implies a deep understanding of users' needs and expectations, as well as technological and ergonomic limitations. In developing the visual elements, historical information was incorporated into the design of the immersive virtual environment for the São Miguel Arcanjo Missions. Given the comprehensive technological possibilities, the historical period chosen for reconstructing the Jesuit mission was at its height, during the late 17th and early 18th centuries. In the modeling, the decision was made to maintain

the scale of the architectural structures, based on historical records cataloged by IPHAN (National Institute of Historic and Artistic Heritage), as shown in Figure 7, which depicts the Jesuit church.

Figure 7. The Jesuit Church in TEKOHÁ.

The materials used in the objects, walls, openings, and textures of the buildings also followed the same logic, ensuring that all these considerations were consistent with the structure of the São Miguel Arcanjo Mission. Given that colors and lighting influence the user experience in the virtual reality environment, these features were carefully defined to ensure that the model visualizations were not compromised.

To aid navigation and guide the immersive experience, a character named Apoena was created (Figure 8). Her name, of Tupi-Guarani indigenous origin, means “she who sees further” or “she who goes further,” reflecting her vision and determination. Apoena is a twelve-year-old pre-teen, full of curiosity and courage, who invites children on a fascinating journey to explore the historical sites of the Jesuit missions. During the virtual reality immersion, Apoena shows important locations (Figure 9) and offers interactive virtual models to make the experience even more engaging and fun. With her adventurous spirit and deep knowledge, Apoena transforms the visit into a true journey into the past.

Figure 8. Virtual guide called Apoena (Nod your head).

Sound design played a fundamental role in the experience, especially given that the target audience was children, with the didactic approach through the characters’ dialogue facilitating the students’ attention. The sound design created a learning space through the culture of Baroque music, culminating in a choir of indigenous children at the end of the experience.

Figure 9. Apoena presenting Cotiguaçu.

Figure 10. Indigenous Choir, Priest Antônio Sepp and Missionary Cross.

TEKOHÁ was conceived to overcome the limitations of traditional teaching of the history of the Jesuit Missions, which often prevents students from achieving a deeper and more meaningful understanding of the subject. By recreating the daily life of the São Miguel Arcanjo Mission, the virtual environment seeks to engage students with examples from the daily lives of indigenous peoples and Jesuit priests (Figure 10), making historical content more accessible, tangible, and memorable. The intention is that, by experiencing and interacting directly with a virtual representation of the past, students will develop a deeper and more lasting understanding of the subject, contributing significantly to the teaching and learning process and to the retention of historical knowledge.

The system was developed using Unity 2022.3 LTS. It was designed for standalone Head-Mounted Displays (HMDs), specifically Meta Quest 2 and 3, to ensure portability in school environments without the need for high-performance PCs.

Following Southgate [2018] guidelines for immersive VR in schools, TEKOHÁ limits sessions to 10 minutes to respect children’s attention spans and avoid vestibulo-ocular discomfort. The interpupillary distance (IPD) is manually adjusted for younger students. To ensure safety, the "Guardian" system is rigorously applied, and teachers are instructed to maintain an “observer” system for students to use the virtual environment safely.

The current version of the project is available to the community on GitHub.[5]

6 Teaching plan for using TEKOHÁ

Regarding the current educational guidelines in Brazil (LDB and BNCC) [BRASIL, 1996; Ministério da Educação, 2018]),

[5] `https://github.com/renatoveigamartinsjr/project_tekoha_vr/`, Accessed: 28 July 2026.

one of the objectives is fostering the effective use of digital technologies across various educational contexts. Although VR is still relatively new in education, we must promote the potential this immersive resource offers for improving the teaching and learning process by fostering teacher and student engagement through its attractive, innovative nature. However, as Radianti et al. [2020] emphasize, the educational impact of VR depends on careful integration into pedagogical strategies, with attention to usability, learning outcomes, and contextual alignment.

From the working group of fourth-grade primary school teachers, it was possible to observe and record their needs regarding the teaching of the Jesuit missions of São Miguel, and thus identify their difficulties with students when faced with an abstract process that is difficult to present and assimilate.

Thus, based on curricular foundations and working group results, a detailed lesson plan is proposed to teach the history of the Seven Peoples of the Missions using the TEKOHÁ virtual environment, which will be validated in future work. The proposal is designed to be implemented over 4 weeks, totaling 8 classes. The general objective is to understand the historical and cultural significance of the Seven Peoples of the Missions, with a specific focus on the ruins of São Miguel das Missões, utilizing diverse didactic and technological resources.

The following resources are necessary to carry out the planned activities:

- Teaching materials, including books, texts, and maps;
- Computer or tablet for digital visit;
- Virtual reality headset for the TEKOHÁ use;
- Transportation for in-loco visit;
- Smartphone for documentation and recording.

The pedagogical activities are organized into four thematic weeks, as detailed in Tables 6 and 7.

Table 6. Introduction and Digital Visitation (Weeks 1-2).

Lesson 1	**Introduction**
Objective	Present the historical context.
Activities	Oral presentation on Jesuit missions, educational videos, and group discussions on local culture.
Lesson 2	**Teaching Material**
Objective	Explore didactic materials about the missions.
Activities	Text analysis, interpretation of historical maps, and creation of an information mural.
Lesson 3	**Virtual Visit**
Objective	Visit the ruins through a virtual tour.
Activities	Guided virtual tour, discussion of impressions, and drawing or writing activities.
Lesson 4	**Analysis and Reflection**
Objective	Reflect and deepen knowledge.
Activities	Debate on heritage preservation and group research on architecture and culture.

The proposed teaching plan establishes a hybrid pedagogical journey that bridges the gap between traditional historical study and cutting-edge immersive technology. By sequencing the lessons to culminate in the TEKOHÁ immersion, after the physical visit to the ruins, students are provided with a unique comparative framework: the opportunity to witness the historical 'peak' of the mission within the same space where only ruins remain today. This approach directly fulfills the BNCC requirement of relating cultural processes to the geographical spaces they occupy (skill EF05HI01) and the RCG's focus on analyzing colonial influences (skill EF05HI01RS-2). Ultimately, this structured integration ensures that the use of virtual reality transcends mere novelty, serving as a critical tool for historical empathy and the concretization of abstract concepts for fourth-grade primary school students.

Table 7. On-site Visit and VR Immersion (Weeks 3-4).

Lesson 5	**Preparation for the On-Site Visit.**
Objective	Prepare students for the on-site visit.
Activities	Planning of logistics and behavior rules, and development of a question guide.
Lesson 6	**In-person visit to the Ruins of São Miguel das Missões**
Objective	Experience the history of the missions *in loco*.
Activities	Guided tour of the ruins, photographic records, and interviews with local guides.
Lesson 7	**Virtual Reality Immersion**
Objective	Virtual immersion in Jesuit Missions.
Activities	Virtual reality session showing the missions' peak and a comparative analysis with the physical visit.
Lesson 8	**Conclusion and Evaluation**
Objective	Conclude the project and evaluate learning.
Activities	Final essay or presentation, continuous participation assessment, and student feedback.

7 Conclusion

This study provided a comprehensive overview of the role of Virtual Reality (VR) in education, specifically focused on the historical and cultural preservation of the Jesuit Missions of Saint Michael the Archangel. The bibliometric analysis conducted between 2013 and 2023 demonstrated a significant upward trend in research within this field, particularly accelerated by the demand for remote educational solutions during the COVID-19 pandemic. The data highlighted global interest, led by the USA and China, and identified the most prolific authors and publication venues shaping the current academic landscape.

To provide a comprehensive evaluation of the TEKOHÁ platform, we adopted a dual-pronged assessment strategy. First, we analyze Learning Outcomes by comparing knowledge gain via pre- and post-test assessments. Second, we evaluate the system's Usability through the System Usability Scale (SUS). This approach allows for a holistic understanding of how the virtual environment affects both the student's learning curve and their interaction with the technology. The user evaluation complete results and comparative analysis will be the subject of an article to be published soon.

The pedagogical survey involving educators was fundamental in defining the requirements for an effective VR educational tool. The teachers emphasized that for a virtual environment to be truly meaningful, it must move beyond simple visualization to include interactive, gamified elements and historical characters. The preference for high-poly archi-

tectural models combined with low-poly characters reflects a balanced approach between immersive realism and student engagement.

Furthermore, the results indicate that although 50% of the surveyed teachers had never used VR, there is a strong willingness to integrate this technology into the classroom to foster "meaningful experiences" and "historical empathy". By bridging the gap between the "golden age" of the missions and their current state as ruins, the proposed VR experience offers a powerful pedagogical bridge for students to comprehend the routine, language, and complex social interactions of the period.

While the current stage established the theoretical and design foundations through a systematic review and teacher surveys, future work will focus on the practical implementation of the environment in classroom settings. Subsequent publications will present empirical results regarding the tool's usability and its specific impact on children's learning outcomes and knowledge retention.

Declarations

Acknowledgements

The authors would like to express their sincere gratitude to Colégio Anchieta for their valuable partnership, support, and collaboration during the execution of this research project.

Funding

This research was supported by undergraduate research grants from the National Council for Scientific and Technological Development (CNPq - Brazil, PIBIC program) and Universidade do Vale do Rio dos Sinos (Unisinos, UNIBIC program).

Authors' Contributions

RVMJ contributed to the conception of this study, performed the experiments, and is the main contributor and writer of this manuscript. VCS and KSFO supervised the project, contributed to the study design, and revised the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets and software generated and analyzed during the current study are available on GitHub at: https://github.com/renatoveigamartinsjr/project_tekoha_vr.

Further relevant information

Artificial Intelligence Disclosure: The authors used Gemini Pro (Google) solely as an assistance tool for copyediting, grammar correction, and English language refinement during the drafting of this manuscript. AI tools were not used to generate research data, analyze results, or draw conclusions. The authors carefully reviewed, edited, and approved all suggestions, taking full responsibility for the accuracy and integrity of the submitted text.

Ethics Approval: This study was conducted in accordance with the ethical principles established by Brazilian Resolution CNS 466/2012 and CNS 510/2016 for research involving human participants. Approval was granted by the Research Ethics Committee of Universidade do Vale do Rio dos Sinos (CEP/Unisinos) under CAAE protocol No. 76302623.5.0000.5344. All participants and their legal guardians provided informed consent prior to participation.

Citation Diversity Statement: We recognize the importance of citation diversity in scientific literature and actively worked to promote equity, inclusion, and representation in our reference list. We reviewed our citations to ensure proper credit is given across diverse genders, geographic regions, and career stages within the fields of Virtual Reality and Educational Technology.

References

Adachi, B., Gonzaga, J., Fernandes, P., Bim, S., Boss, S., Delabrida, S., and Valentim, N. (2026). Lessons learned in human evaluation: A case study of augmented reality in books. *Journal on Interactive Systems*, 17(1):652–673. DOI: https://doi.org/10.5753/jis.2026.6605.

Araiza-Alba, P., Keane, T., Chen, W. S., and Kaufman, J. (2021). Immersive virtual reality as a tool to learn problem-solving skills. *Computers Education*, 164:104121. DOI: https://doi.org/10.1016/j.compedu.2020.104121.

Bogusevschi, D. and Muntean, G. (2019). Water cycle in nature – an innovative virtual reality and virtual lab: Improving learning experience of primary school students. In *Proceedings of the 11th International Conference on Computer Supported Education - Volume 1: CSEDU*, pages 304–309. INSTICC, SciTePress. DOI: https://doi.org/10.5220/0007760803040309.

BRASIL (1996). Lei nº 9.394, de 20 de dezembro de 1996. estabelece as diretrizes e bases da educação nacional. Diário Oficial da União. Available at: `http://www.planalto.gov.br/ccivil_03/leis/l9394.htm`, Accessed on 27 July 2026.

Brey, P. (2014). The Physical and Social Reality of Virtual Worlds. In *The Oxford Handbook of Virtuality*. Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780199826162.013.029.

Cao, Q., Png, B., Cai, Y., Cen, Y., and Xu, D. (2021). Interactive virtual reality game for online learning of science subject in primary schools. In *2021 IEEE International Conference on Engineering, Technology Education (TALE)*, pages 383–389. DOI: https://doi.org/10.1109/TALE52509.2021.9678916.

Chiu, F.-Y. (2017). Virtual reality for learning languages based on mobile devices. In *2017 16th International Conference on Information Technology Based Higher Education and Training (ITHET)*, pages 1–3. DOI: https://doi.org/10.1109/ITHET.2017.8067813.

Chu, Y. (2022). The application of vr technology in traditional culture and art immersive teaching for chinese children. In *Proceedings of the 13th International Conference on Education Technology and Computers*, ICETC '21, page 99–104, New York, NY, USA. Association for Computing Machinery. DOI: https://doi.org/10.1145/3498765.3498780.

Coutinho, M. (1998). *Imaginária guarani nas missões jesuíticas do Brasil*. Editorial Minerva. Available at: `https://books.google.com.br/books?id=kc8rAAAAYAAJ`, Accessed on 27 July 2026.

Damekova, S., Shuyushbayeva, N., Altayeva, G., Kaliyeva, A., and Tanasheva, N. (2021). Additional education of schoolchildren in physics at the children's university. *Bulletin of the Karaganda University Physics Series*, 101:63–70. DOI: https://doi.org/10.31489/2021Ph1/63-70.

Debailleux, L., Hismans, G., and Duroisin, N. (2018). *Exploring Cultural Heritage Using Virtual Reality*, pages 289–303. Springer International Publishing, Cham. DOI: https://doi.org/10.1007/978-3-319-75826-8_24.

dos Santos, J. (2016). *Missões: reflexões & questionamentos*. Editora e Gráfica Caxias. Available at: https://books.google.com.br/books?id=2N2GAQAACAAJ, Accessed on 27 July 2026.

Elaish, M., Yadegaridehkordi, E., and Ho, Y.-S. (2024). Publication performance and trends in virtual reality research in education fields: a bibliometric analysis. *Multimedia Tools and Applications*, pages 1–28. DOI: https://doi.org/10.1007/s11042-024-19238-0.

Gkoumas, C. and Izzouzi, L. (2023). Is immersive virtual reality in k-12 education ready for primetime? challenges, possibilities, and considerations. In *2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pages 541–544. DOI: https://doi.org/10.1109/VRW58643.2023.00119.

Guo, X. and Mogra, I. (2022). Using web 3D and WebXR game to enhance engagement in primary school learning. In *2022 IEEE International Symposium on Multimedia (ISM)*, pages 181–184. DOI: https://doi.org/10.1109/ISM55400.2022.00040.

Hsiao, P.-W. and Su, C.-H. (2021). A study on the impact of steam education for sustainable development courses and its effects on student motivation and learning. *Sustainability*, 13(7). DOI: https://doi.org/10.3390/su13073772.

Iquira Becerra, D. A., Castro, B. D. S., Conislla, M. M. F., and Corrales-Delgado, C. (2018). Augmented reality applied in the design of learning activities in zoology. In *2018 XIII Latin American Conference on Learning Technologies (LACLO)*, pages 121–126. DOI: https://doi.org/10.1109/LACLO.2018.00036.

Jerald, J. (2015). *The VR Book: Human-Centered Design for Virtual Reality*. Association for Computing Machinery and Morgan & Claypool. https://doi.org/10.1145/2792790.

Karkar, A., Salahuddin, T., Almaadeed, N., Aljaam, J. M., and Halabi, O. (2018). A virtual reality nutrition awareness learning system for children. In *2018 IEEE Conference on e-Learning, e-Management and e-Services (IC3e)*, pages 97–102. DOI: https://doi.org/10.1109/IC3e.2018.8632634.

Lahovsky, P., Ljubek, A., Mišura, K., and Žilak, M. (2023). Bringing children closer to science and the universe with new technology. In *2023 46th MIPRO ICT and Electronics Convention (MIPRO)*, pages 448–453. DOI: https://doi.org/10.23919/MIPRO57284.2023.10159718.

Li, J. (2021). Research on the reform and innovation of preschool education informatization under the background of wireless communication and virtual reality. *Wireless Communications and Mobile Computing*, 2021(1):3176309. DOI: https://doi.org/10.1155/2021/3176309.

Liberati, A., Altman, D., Tetzlaff, J., Mulrow, C., Gøtzsche, P., Ioannidis, J., Clarke, M., Devereaux, P., Kleijnen, J., and Moher, D. (2009). The prisma statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Journal of clinical epidemiology*, 62:e1–34. DOI: https://doi.org/10.1016/j.jclinepi.2009.06.006.

Lu, Y., Wang, X., Gong, J., and Liang, Y. (2022). Chordar: An educational ar game design for children's music theory learning. *Wireless Communications and Mobile Computing*, 2022(1):5268586. DOI: https://doi.org/10.1155/2022/5268586.

Luigini, A., Parricchi, M. A., Basso, A., and Basso, D. (2020). Immersive and participatory serious games for heritage education, applied to the cultural heritage of south tyrol. *Interaction Design and Architecture(s)*, (43):26. DOI: https://doi.org/10.55612/s-5002-043-003.

Makransky, G. and Lilleholt, L. (2018). A structural equation modeling investigation of the emotional value of immersive virtual reality in education. *Educational Technology Research and Development*, 66. DOI: https://doi.org/10.1007/s11423-018-9581-2.

Merchant, Z., Goetz, E., Keeney-Kennicutt, W., and Davis, T. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in k-12 and higher education: A meta-analysis. *Computers Education*, 70:29–40. DOI: https://doi.org/10.1016/j.compedu.2013.07.033.

Michałko, A., Campo, A., Nijs, L., Leman, M., and Van Dyck, E. (2022). Toward a meaningful technology for instrumental music education: Teachers' voice. *Frontiers in Education*, 7. DOI: https://doi.org/10.3389/feduc.2022.1027042.

Ministério da Educação (2018). Base nacional comum curricular. Available at: http://basenacionalcomum.mec.gov.br/a-base, Accessed on 27 July 2026.

Modibane, B. S., Owolawi, P. A., Mapayi, T., Malele, V., and Aiyetoro, G. (2021). Virtual reality application based on inertia. In *Proceedings of the International Conference on Artificial Intelligence and Its Applications*, icARTi '21, New York, NY, USA. Association for Computing Machinery. DOI: https://doi.org/10.1145/3487923.3487931.

Montoya, A. R. (2026). Biblioteca brasiliana guita e josé mindlin: Tesoro de la lengva gvarani. https://digital.bbm.usp.br/handle/bbm/4922. Accessed on 27 July 2026.

Peltekova, E., Stefanova, E., and Nikolova, N. (2019). Space safari: Challenge for stem rangers. In *Proceedings of the 20th International Conference on Computer Systems and Technologies*, CompSysTech '19, page 292–298, New York, NY, USA. Association for Computing Machinery. DOI: https://doi.org/10.1145/3345252.3345273.

Pradeep Raj, K. B., Sinha, S., Arvind, R. S., Solanki, D., and Lahiri, U. (2018). Design of virtual reality based intelligent storytelling platform with human computer interaction. In *2018 IEEE/ACIS 17th International Conference on Computer and Information Science (ICIS)*, pages 142–147. DOI: https://doi.org/10.1109/ICIS.2018.8466457.

Radianti, J., Majchrzak, T. A., Fromm, J., and Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Comput. Educ.*, 147(C). DOI: https://doi.org/10.1016/j.compedu.2019.103778.

Samala, A., Rawas, S., Rahmadika, S., Criollo-C, S., Fikri, R., and Sandra, R. (2025). Virtual reality in edu-

cation: global trends, challenges, and impacts—game changer or passing trend? *Discover Education*, 4. DOI: https://doi.org/10.1007/s44217-025-00650-z.

Serafin, S., Adjorlu, A., Nilsson, N., Thomsen, L., and Nordahl, R. (2017). Considerations on the use of virtual and augmented reality technologies in music education. In *2017 IEEE Virtual Reality Workshop on K-12 Embodied Learning through Virtual Augmented Reality (KELVAR)*, pages 1–4. DOI: https://doi.org/10.1109/KELVAR.2017.7961562.

Sharaf, N., Ahmed, G., and Ihab, S. (2020). Virtual/mixed reality control of a game through scratch. In *2020 24th International Conference Information Visualisation (IV)*, pages 689–693. DOI: https://doi.org/10.1109/IV51561.2020.00119.

Southgate, E. (2018). Immersive virtual reality, children and school education: A literature review for teachers. *DICE report series*, 6:1–18. Available at: `https://ericasouthgateonline.files.wordpress.com/2018/06/southgate_2018_immersive_vr_literature_review_for_teachers.pdf`, Accessed on 27 July 2026.

Souza, A. M. d. C., Aureliano, T., Ghilardi, A. M., Ramos, E. A., Bessa, O. F. M., and Rennó-Costa, C. (2023). Dinosaurvr: Using virtual reality to enhance a museum exhibition. *Journal on Interactive Systems*, 14(1):363–370. DOI: https://doi.org/10.5753/jis.2023.3464.

SUL, R. G. D. (2018). Referencial Curricular Gaúcho: Humanas. Available at: `https://portal.educacao.rs.gov.br/Portals/1/Files/1529.pdf`. Accessed on 27 July 2026.

van Limpt - Broers, H., Louwerse, M., and Postma, M. (2020). Awe yields learning: A virtual reality study. CogSci 2020 ; Conference date: 30-07-2020 Through 01-08-2020. Available at: `https://cognitivesciencesociety.org/cogsci20/papers/0088/0088.pdf`, Accessed on 27 July 2026.

Viol, R. S., Fernandes, P. C., Lacerda, I. I., Melo, K. G. F., Nunes, A. J. d. A., Pimenta, A. S. G. M., Carneiro, C. M., Silva, M. C., and Delabrida, S. (2025). EduVR Collab: A tool for management immersive collaborative learning. *Journal on Interactive Systems*, 16(1):120–136. DOI: https://doi.org/10.5753/jis.2025.4276.

Wang, Q. (2021). The creation of multi intelligence music classroom in children's enlightenment stage based on virtual reality technology*. In *2021 2nd International Conference on Education, Knowledge and Information Management (ICEKIM)*, pages 431–434. DOI: https://doi.org/10.1109/ICEKIM52309.2021.00100.

Zhang, Y., Huang, Z., Quigley, K., Sankar, R., and Yang, A. (2019). A user experience study of locomotion design in virtual reality between adult and minor users. In *2019 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, pages 47–51. DOI: https://doi.org/10.1109/ISMAR-Adjunct.2019.00027.