Revista Brasileira de Ensino de Ciência e Tecnologia
ISSN: 1982-873X

https://periodicos.utfpr.edu.br/rbect

Virtual reality in physics education: dissemination, trends, and usability

Jeirla Alves Monteiro
jeirla@gmail.com
0000-0002-9329-5930
Universidade Federal do Pará, Belém, Pará, Brasil.

Antonio de Lisboa Coutinho Junior
lisboajr@gmail.com
0000-0001-7270-7759
Instituto Federal do Ceará, Fortaleza, Ceará, Brasil.

Isabel Cristina Rodrigues de Lucena
ilucena@ufpa.br
0000-0001-9515-101X
Universidade Federal do Pará, Belém, Pará, Brasil.

Gilvandenys Leite Sales
denyssales@ifce.edu.br
0000-0002-6060-2535
Instituto Federal do Ceará, Fortaleza, Ceará, Brasil.

ABSTRACT

This study aimed to analyze the use of Virtual Reality (VR) in Physics education within the Brazilian context through a systematic literature review. National databases were consulted, including the CAPES Portal, the Digital Library of the Brazilian Computer Society (BDSBC), and the proceedings of the Brazilian Congress on Informatics in Education (CBIE), resulting in a final sample of 22 studies. The results indicate that Mechanics is the most frequently addressed area in the analyzed research, with a growing use of mobile devices as access platforms. Among the main potential benefits of VR, increased student engagement and the facilitation of understanding abstract concepts through immersive visualizations stand out. On the other hand, the main challenges include limitations in the fidelity of simulations to physical laws, especially in generic environments, as well as the lack of more robust pedagogical evaluation models.

KEYWORDS: Virtual Reality. Augmented Reality. Physics Education.

1 INTRODUCTION

The use of Virtual Reality (VR) in educational processes has gained increasing attention in recent years (Prahani *et al.*, 2022). This trend is evidenced by the growing number of international studies examining the integration of VR into education (Budi *et al.*, 2021; Diziz; Pastorio, 2023; Koumpouros, 2024; Lampropoulos *et al*., 2024).

The term *Virtual Reality* was coined in the 1980s by researcher Jaron Lanier. However, the development of this technology dates back to earlier milestones, such as Ivan Sutherland's Head-Mounted Display (HMD) in the 1960s. Since then, VR has undergone several stages of development, including the commercialization of devices such as data gloves in the 1980s and, more recently, its widespread accessibility through smartphones and low-cost devices such as Google Cardboard (Netto *et al*., 2002).

As a broad concept, VR has been defined in various ways by scholars, developers, and researchers, resulting in multiple definitions throughout the literature (Netto *et al*., 2002). In general, VR can be understood as a technology that enables the creation of simulated virtual environments in which users can interact in immersion. These computer-generated environments may either replicate the real world or represent fictional scenarios (Lampropoulos *et al*., 2024).

With technological advancements, VR has become applicable across numerous fields, including economics, architecture, tourism, urban planning, dentistry, anatomy, education, and engineering (Prahani *et al*., 2022). In education, its applications encompass a wide range of learning contexts, including intercultural learning, three-dimensional laboratories, immersive learning experiences, and the promotion of meaningful learning.

Specifically in physics education, VR offers significant potential by enabling students to interact with simulated environments and explore physical phenomena in an immersive manner (Budi *et al*., 2021). Consequently, abstract concepts are no longer limited to theoretical descriptions but can be visualized and experienced directly by learners.

Internationally, review studies such as Merchant *et al*. (2014) have already reported improvements in the effectiveness of VR applications in STEM education. In Brazil, the use of Information and Communication Technologies (ICT) in physics education has likewise evolved, progressing from two-dimensional simulations, such as those developed in Flash, to more sophisticated three-dimensional virtual environments.

According to Diziz and Pastorio (2023), research on the use of VR in physics education has grown steadily. Nevertheless, despite this increase, the emerging trends in this field have not yet been clearly established. Therefore, this study aims to investigate how Brazilian researchers have been employing VR in physics education.

2 METHODOLOGY

The methodology adopted in this study followed the Systematic Literature Review (SLR) protocol, which consists of identifying, evaluating, and interpreting all available research relevant to a specific research question, topic, or phenomenon of interest (Kitchenham, 2004). This article is structured in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher *et al*., 2009), which outline the essential steps to conduct systematic reviews. These guidelines have been widely adopted in studies that seek to investigate a topic comprehensively by examining previously developed and published research (Grant; Booth, 2009).

The objective of this review was to analyze three aspects of the use of Virtual Reality (VR) in physics education: publication trends, research trends, and usability. To achieve this objective, specific research questions were devised for each aspect (Table 1).

Table 1 – Research Questions

Aspect	Research Questions
Publication	RQ1. Who are the most prominent authors? RQ2. Which institutions are the most active? RQ3. In which journals and conference proceedings have the studies been published?
Research Trends	RQ4. Which areas of physics are addressed? RQ5. Which educational levels are targeted by the studies? RQ6. Which software applications are used or mentioned in the studies? RQ7. Which development tools and operating systems are used to develop virtual reality applications for physics education?
Usability	RQ8. Which evaluation instruments are employed in the studies? RQ9. How do the studies evaluate the use of VR in physics education?

Source: Prepared by the authors (2024).

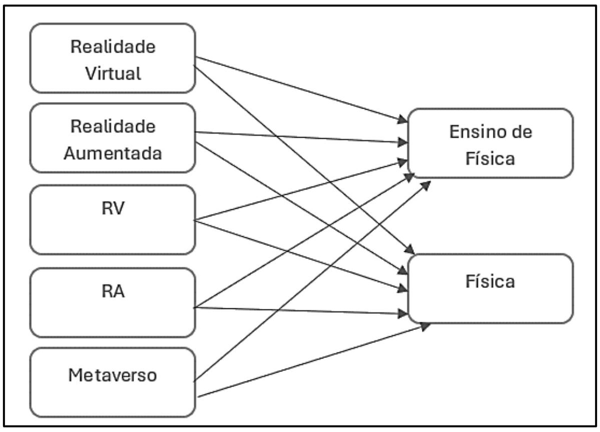
The databases used to identify relevant studies were the Portal CAPES [CAPES Journal Portal], the Biblioteca Digital da Sociedade Brasileira de Computação (BDSBC), [Digital Library of the Brazilian Computer Society] and the Anais dos Workshops do Congresso Brasileiro de Informática na Educação (WCBIE) [Proceedings of the Workshops of the Brazilian Congress on Informatics in Education].

2.1 Protocol

To construct the search string, several terms related to Virtual Reality (VR) in the context of physics education were combined. Three reference articles were selected to identify relevant keywords and formulate the search terms. These studies employed descriptors such as *virtual reality*, *augmented reality*, *AR*, and *VR*. Based on this analysis, the term *metaverse* was also incorporated. All these terms were then combined with the expressions *physics education* and *physics* (Figure 1).

RBECT
Revista Brasileira de Ensino de Ciência e Tecnologia

Figure 1 – Combination of Search Terms (Search String)



Source: Prepared by the authors (2024).

Since each database requires a specific search syntax, the search terms were adapted accordingly for each source (Table 2) to maximize the retrieval of relevant studies. In the CAPES Journal Portal, two filters were applied: language and material type. For the language filter, the option "Any Language" was selected, while for the material type, the option "Article" was chosen, as the analysis of theses and dissertations was beyond the scope of this study.

Table 2 – Search Strategy

Database	Search Modeling
Portal CAPES	Any field → realidade virtual AND Any field → contains → ensino de física Language: any language. Type of material: Article
BDSBC - Biblioteca Digital da Sociedade Brasileira de Computação	Sources: conference proceedings and journals Any field: realidade virtual OR realidade aumentada OR metaverse OR AR OR VR AND ensino de física OR física Languages: English, Spanish, and Portuguese
WCBIE – Anais dos Workshops do Congresso Brasileiro de Informática na Educação	Search in all categories: realidade virtual OR realidade aumentada OR metaverso OR AR OR VR AND ensino de física OR física

Source: Prepared by the authors (2024).

To ensure that only studies capable of addressing the research questions were included, a set of inclusion and exclusion criteria was established. These criteria are presented in Table 3.

Table 3 – Inclusion and Exclusion Criteria

Nº	Description	Criterion
1	Studies addressing the use of Virtual Reality (VR) in physics education	Inclusion
2	Studies describing the development of VR-based software or games for physics education	Inclusion
3	Both empirical and theoretical studies	Inclusion
4	Studies not focused on physics education in Brazil	Exclusion
5	Studies on Virtual Reality applied to disciplines other than physics	Exclusion
6	Duplicate studies	Exclusion
7	Systematic literature reviews	Exclusion

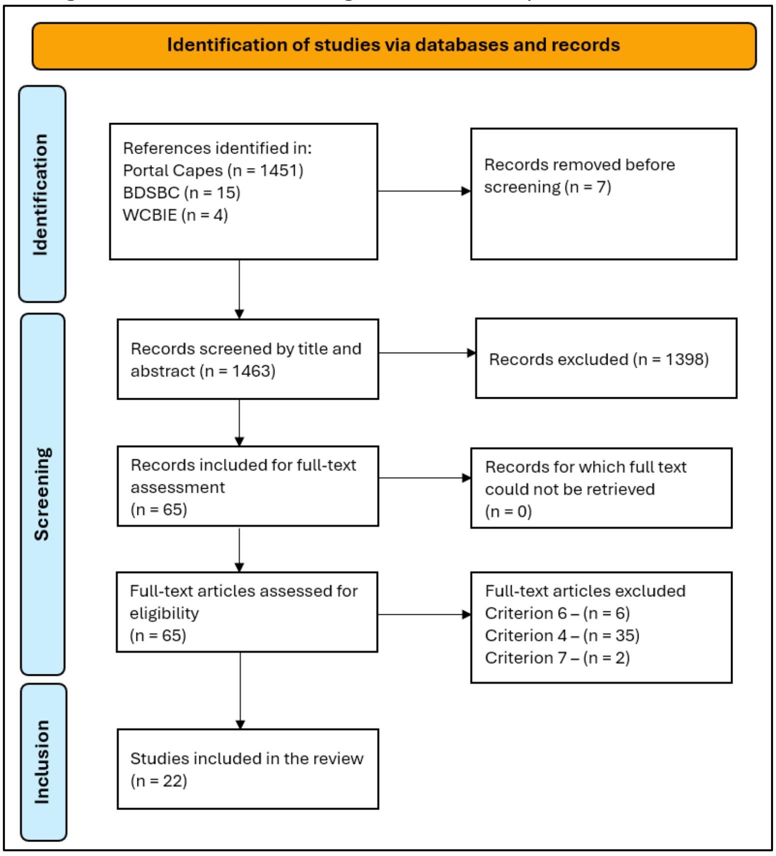
Source: Prepared by the authors (2024)

3 EXECUTION AND RESULTS

Initially, the search string was executed across the selected databases. A total of 1,451 records were retrieved from the CAPES Journal Portal, of which seven were excluded because they were dissertations. The BDSBC yielded 15 studies, while four studies were identified in the Proceedings of the WCBIE. All retrieved records were imported into Mendeley for organization and for the application of the screening criteria.

The screening process was conducted in two stages. The first stage involved reviewing the titles and abstracts to identify studies that met the established eligibility criteria. At the end of this stage, 65 articles were selected for full-text review. In the second stage, following the full-text assessment and the application of the inclusion and exclusion criteria, the final sample comprised 22 studies. The study selection and inclusion process is illustrated in Figure 2.

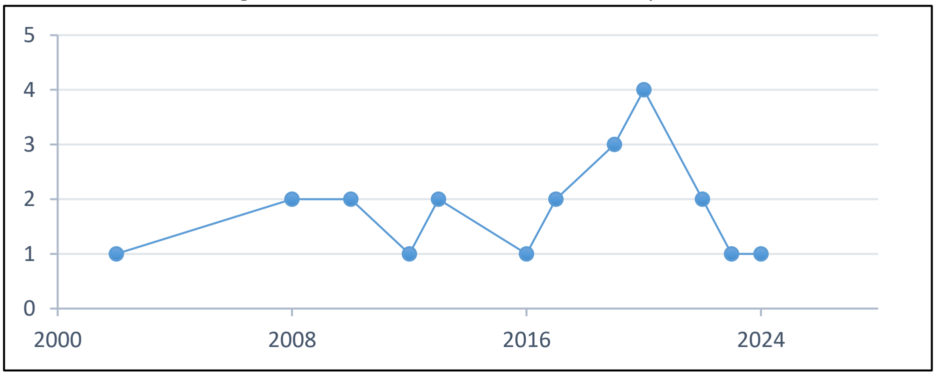
Figure 2 – PRISMA Flow Diagram of the Study Selection Process



Source: Prepared by the authors (2024).

The analysis of the 22 selected studies showed that 2020 recorded the highest number of publications on the use of Virtual Reality (VR) in physics education. The earliest study identified was published in 2002, as shown in Figure 3.

Figure 3 – Distribution of Publications by Year



Source: Research data (2024).

The selected studies are listed in Table 4, which includes the title, year of publication, and the identification code assigned to each study. These codes are used as references throughout the subsequent analyses.

Table 4 – List of Selected Studies

COD	Reference	Title
T01	Trentim e Tarouco (2002)	Proposta de utilização de um laboratório virtual de física na melhoria do processo de ensino-aprendizagem
T02	Forte *et al*. (2008)	Implementação de Laboratórios Virtuais em Realidade Aumentada para Educação à Distância
T03	Santos (2008)	Virtual, Real ou Surreal? A Física do Second Life
T04	Greis e Reategui (2010)	Um Simulador Educacional para Disciplina de Física em Mundos Virtuais
T05	Falcão e Machado (2010)	Um Laboratório Virtual Tridimensional e Interativo para Suporte ao Ensino de Física
T06	Viegas *et al.* (2012)	Ferramenta de Apoio ao ensino de Física utilizando Realidade Aumentada
T07	Silva e Sousa (2013)	O uso da realidade virtual para o ensino de física quântica
T08	Ribeiro *et al*. (2013)	Realidade Aumentada Aplicada ao Ensino e Aprendizagem do Campo Magnético de um Ímã em Forma de Ferradura
T09	Oliveira e Manzano (2016)	Aplicações de realidade aumentada no ensino de Física a partir do software LAYAR
T10	Gonçalves *et al*. (2017)	Avaliação do desenvolvimento de ambientes de Realidade Aumentada elaborados por alunos do ensino médio em aulas de física
T11	Oliveira e Manzano (2017)	Desenvolvimento, utilização e avaliação da realidade aumentada em aulas de física
T12	Melendez *et al*. (2019)	Lançamento Horizontal Com Realidade Virtual: Jogo Educativo para Smartphones Desenvolvido por Estudantes da Educação Profissional
T13	Gonçalves e Oliveira (2019)	Elaboração de Materiais de Realidade Aumentada por Estudantes de Ensino Médio: Impactos e Possibilidades
T14	Nicolete *et al*. (2019)	Estudo exploratório sobre realidade aumentada e laboratório remoto no ensino de física.
T15	França e Silva (2020)	A realidade virtual e aumentada dedicada ao processo ensino-aprendizagem de física: socialização da concepção e validação do aplicativo RVA_360 – Momento Angular
T16	Herpich *et al*. (2020)	Atividade educacional utilizando Realidade Aumentada para o Ensino de Física no Ensino Superior
T17	Kagimura e Kalaki (2020)	Aplicativo móvel de realidade virtual para o ensino multidisciplinar de conteúdos de Óptica
T18	Panke e Góes (2020)	Realidade Aumentada como Recurso Didático para o Ensino e Aprendizado de Escalas Planetárias e Estelares
T19	Tito e Moraes (2022)	Realidade Virtual para Ensino da Física: análise do engajamento e presença de uma experiência imersiva no aprendizado da Cinemática
T20	Vahldick e Vieira (2022)	Um Jogo Sério em Dispositivos Móveis para o Aprendizado de Física utilizando Realidade Aumentada
T21	Santos *et al*. (2023)	AURORA: Protótipo de Aprendizagem no Ensino de Física Integrando Mapas Conceituais e Tecnologia Computacional
T22	Neto *et al*. (2024)	Aplicabilidade da realidade aumentada no ensino de física

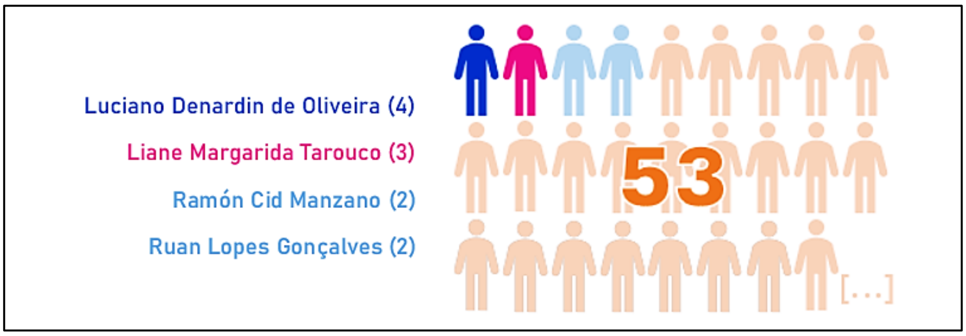
Source: Prepared by the authors (2024).

3.1 Publication

RQ1. Who are the most prominent authors?

A total of 57 researchers were identified as contributors to studies on the use of Virtual Reality (VR) in physics education. Two authors stood out, each contributing three or more publications (Figure 4), while two additional authors were associated with two publications each. The remaining 53 researchers each contributed to only one study in the sample.

Figure 4 – Most Prolific Authors



Source: Research data (2024).

RQ2. Which are institutions are the most active?

Regarding the institutions involved in the selected studies, a total of 24 organizations were identified. Of these, 17 were public universities and seven were private institutions, including one secondary school, Colégio Marista Assunção, located in Porto Alegre. Among the mapped institutions, two stood out with more than four publications each, three contributed two publications, and the remaining institutions were represented by a single publication. Figure 5 presents the institutions with the greatest research output on the use of VR in physics education.

Figure 5 – Most Active Institutions

Source: Research data (2024).

RQ3. In which journals and conference proceedings have the studies been published?

Regarding publication venues, the selected studies were published across 10 academic journals and five conference proceedings, as presented in Table 5.

Table 5 – Journals and Conference Proceedings

Journals	Conference Proceedings
RENOTE – Revista Novas Tecnologias na Educação	Congresso Brasileiro de Informática na Educação
ENCITEC – Ensino de Ciências e Tecnologia em Revista	Simpósio de Realidade Virtual e Aumentada
RBECT – Revista Brasileira de Ensino de Ciência e Tecnologia	ENPEC - Encontro Nacional de Pesquisa em Educação em Ciências
RVC – Revista Vitruvian Cogitationes	Workshop de Realidade Virtual e Aumentada
BJD – Brazilian Journal of Development	Workshop de Informática Na Escola
REnCiMa – Revista de Ensino de Ciências e Matemática	
EENCI – Revista Experiências em Ensino de Ciências	
Revista Brasileira de Informática na Educação	
Informática na educação: teoria & prática	
Revista Iberoamericana de Tecnología en Educación y Educación en Tecnología	

Source: Research data (2024).

The journal with the highest number of publications on the use of Virtual Reality (VR) in physics education was RENOTE – *Revista Novas Tecnologias na Educação*, with six articles. This was followed by ENCITEC – *Ensino de Ciências e Tecnologia em Revista*, with two publications, while each of the remaining journals published one article.

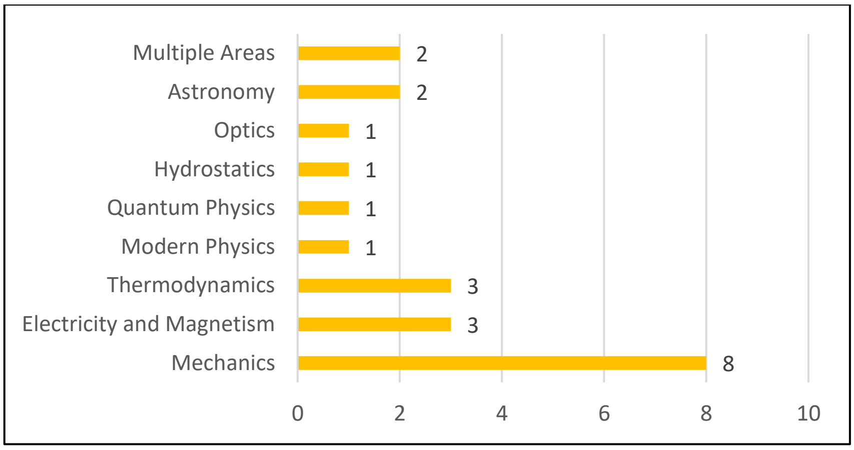
Among the conference proceedings, the Brazilian Congress on Informatics in Education (CBIE) accounted for the largest number of publications, with two studies, whereas each of the remaining conferences contributed one study.

3.2 Research Trends

RQ4. Which are areas of physics are addressed?

To answer this research question, the physics content addressed in each study was extracted and analyzed. Figure 6 presents the areas of physics identified in the selected studies.

Figure 6 – Physics Topics Addressed



Source: Research data (2024).

The analysis of Figure 6 shows that Mechanics is the most frequently addressed area of physics, serving as the focus of eight studies. In addition, two studies (T01 and T20) encompass multiple areas of physics. Study T01 proposes the implementation of virtual physics laboratories. As a pioneering and broad-scope study, the authors do not focus on a specific physics topic but instead emphasize the technical feasibility of developing such environments. Study T20, in turn, describes the development of a quiz-based educational game inspired by the board game *Conhecendo a Física* ("Getting to Know Physics"), covering a wide range of physics topics. The detailed classification of each study by physics topic is presented in Table 6.

Table 6 – Classification of Studies by Physics Topic

Area	Study
Mechanics	T02, T03, T04, T05, T06, T12, T15, T19
Electricity and Magnetism	T08, T11, T14
Thermodynamics	T10, T13, T16
Modern Physics	T21
Quantum Physics	T07
Hydrostatics	T09
Optics	T17
Astronomy	T18, T22
Multiple Areas	T01, T20

Source: Research data (2024).

RQ5. Which are educational levels are targeted by the studies?

To address this research question, the studies were classified into three categories: application development, application use, and application analysis/theoretical studies. Table 7 presents the category assigned to each study.

Table 7 – Classification of Studies by Research Category

Category	Studies
Application Development	T02, T05, T06, T07, T08, T12, T14, T15, T17, T20, T21
Application Use	T10, T11, T13, T16, T18, T22
Application Analysis/Theoretical Studies	T01, T03, T04, T09, T19

Source: Research data (2024).

This classification made it possible to identify the primary focus of each study. The results indicate that 50% of the studies focused primarily on the development of VR applications. In contrast, 23% consisted of theoretical or review studies, whereas 27% investigated the use of existing VR applications.

In addition, the studies were classified according to whether they involved practical implementation with students or teachers or did not include an educational intervention (Table 8). This analysis revealed that some of the application development studies were implemented with the target audience, whereas others were limited to usability testing aimed at evaluating the functionality of the developed applications.

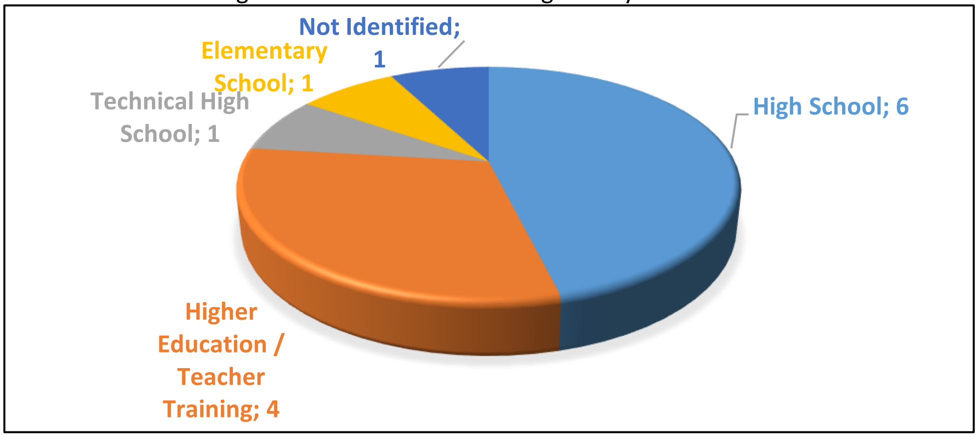
Table 8 – Studies Involving Practical Implementation

Tipe	Studies
Implemented	T05, T07, T08, T10, T11, T13, T14, T16, T18, T22
Not Implemented	T01, T02, T03, T04, T06, T09, T12, T17, T19
Usability Tested	T15, T20, T21

Source: Research data (2024).

Considering the 10 implemented studies together with the three usability-tested studies, the education level targeted by each investigation was identified. The analysis showed that most interventions were conducted with high school students, as illustrated in Figure 7.

Figure 7 – Education Level Targeted by the Studies



Source: Research data (2024).

Study T05 was implemented with 33 first-year high school students; T07 involved two third-year high school classes; and T08 was conducted with 22 third-year high school students. Study T10 included two second-year high school classes, while T11 involved 66 students from three third-year high school classes. Similarly, T13 was implemented with 35 second-year high school students, and T14 targeted students enrolled in a technical high school program in Electromechanics.

Regarding usability testing and teacher training, T15 was evaluated by eight physics teachers, and T16 involved 22 undergraduate students enrolled in a Physics Teacher Education program. Study T18 was designed for elementary school students. Finally, T20 was tested by 40 participants aged 18 to 44 years, making it impossible to associate the study with a specific educational level. T21 was validated by polytechnic education instructors, while T22 involved 28 teachers participating in a professional development session.

RQ6. Which are the VR applications are used or mentioned in the studies?

A total of 16 VR-related applications were identified, of which eight were used in the selected studies and eight were only mentioned. Table 9 presents the complete list of these applications.

Table 9 – VR Applications Identified in the Studies

Used	Mentioned
1. Second life	1. Kaneva
2. Layar	2. HIPIHI
3. AvatAR UFRGS	3. Open Simulator
4. RVA_360	4. Habbo Hotel
5. SkyConquest	5. Club Penguin
6. AURORA	6. There.com
7. LabSEF	7. Meez
8. Zappar	8. Home

Source: Research data (2024).

The most frequently used application was Layar, which appeared in four studies (T09, T10, T11, and T13). Originally developed as an Augmented Reality (AR) platform for creating and editing digital content, Layar has been applied across various domains. In 2014, the company behind the platform was acquired by Blippar, while preserving its core functionality of overlaying digital elements onto the physical environment through mobile devices. In physics education, Layar is particularly valuable because it makes abstract concepts more tangible. For example, in T10, the application was used to demonstrate thermal energy transfer processes, whereas in T11 it supported the visualization of electrostatic shielding concepts, specifically the Faraday cage.

The second most frequently cited application was Second Life (SL), identified in two studies (T03 and T04). Released in 2003 by Linden Lab, Second Life is a three-dimensional virtual environment in which avatars interact within a persistent virtual world. Although it provides opportunities for simulation and remote collaboration, its use in physics education requires careful pedagogical consideration. Study T03 points out that the physics implemented in Second Life is only partially consistent with the real world. While variables such as time and length have direct real-world counterparts, quantities such as mass, acceleration, and energy are defined differently from those in classical Newtonian mechanics.

AvatAR UFRGS is an AR platform developed by the Federal University of Rio Grande do Sul (UFRGS) to support teaching and learning. The platform overlays digital elements—including images, videos, and three-dimensional models—onto the physical environment, providing users with an interactive and immersive learning experience.

The primary purpose of AvatAR UFRGS is to facilitate teaching and learning across multiple fields of knowledge, ranging from the natural sciences to the humanities. Through this platform, educators can create customized educational experiences, including experimental simulations and visualizations of abstract concepts, thereby making learning more dynamic and engaging. The platform was employed in T16, in which the authors used the Internal Combustion Engine and Gas Spectrometry simulations.

RVA_360 – Angular Momentum is an immersive application developed by França and Silva (2020) in T15. Initially designed to display 360-degree videos, it was later expanded into a platform capable of adapting VR experiences to a 360-degree panoramic format. The application features a motorcyclist as the main character, allowing users to select a motorcycle and perform maneuvers to explore concepts such as velocity, acceleration, kinetic energy, and potential energy.

SkyConquest is an AR educational application that enables users to compare the characteristics of planets and stars. It was developed by Panke and Goes (2019) and was used in T18.

AURORA is an interactive application designed for the creation of concept maps. It was developed by Santos *et al*. (2023) and employed in T21.

LabSEF is a three-dimensional virtual laboratory designed to support physics learning. It was developed by Falcão and Machado (2010) and implemented in T05. According to its developers, LabSEF enables users to perform and collect data from simulations of experiments that would be impossible to conduct in real-world settings. These experiments can be repeated with different data sets to reinforce learning. All simulations include three-dimensional graphical animations, allowing users to observe the experiments from multiple perspectives and freely explore the virtual environment.

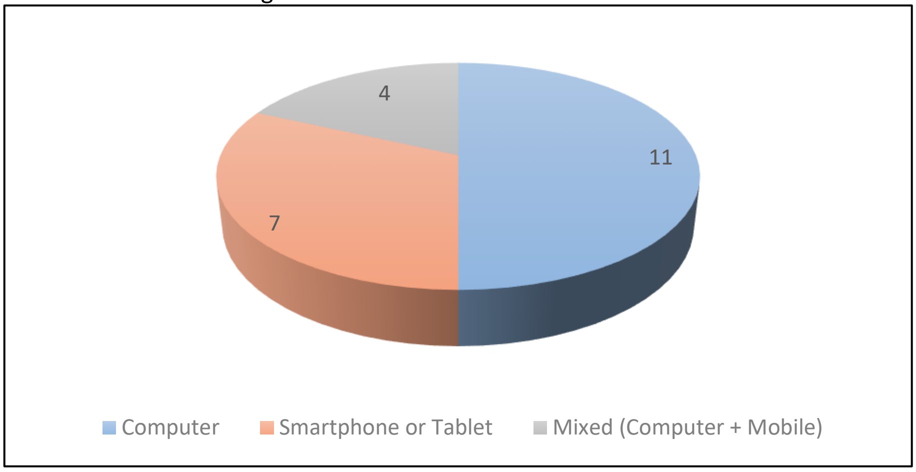
Zappar is an AR platform that enables users to create, share, and experience interactive digital content superimposed on the physical world. The platform supports the development of AR experiences using images, videos, three-dimensional models, games, and animations. It was used in T22.

Finally, Kaneva, HIPIHI, OpenSimulator, Habbo Hotel, Club Penguin, There.com, Meez, and Home are virtual worlds similar to Second Life. These platforms were not employed in the reviewed studies but were mentioned in T04 as examples of virtual environments.

RQ7. Which are the development tools and operating systems are used to develop virtual reality applications for physics education?

To identify the operating systems employed in the selected studies, the supporting platforms used or mentioned in each study were analyzed. The results showed that 50% of the studies relied exclusively on desktop or laptop computers, 32% used smartphones or tablets, and 18% adopted a hybrid approach, combining both types of devices (Figure 8).

Figure 8 – Platforms Used in the Studies



Source: Research data (2024).

Following this initial analysis, only the studies classified under the Application Development category were examined to identify the software platforms used during development. The results indicated that all applications developed for mobile devices were designed for the Android operating system.

According to Oliveira *et al*. (2014), Android is a software platform originally developed by Android Inc. and acquired by Google in 2005. Although initially designed for mobile devices such as smartphones and tablets, the platform has since been extended to support smartwatches, smart TVs, and automotive systems.

Based on the Linux kernel, Android has undergone continuous development and has become one of the world's most widely used operating systems (Oliveira *et al*., 2014). One of its main advantages is its open-source nature, which allows developers to access and modify the source code to create customized versions of the operating system.

This flexibility provides a wide range of possibilities for educational applications, facilitating the integration of both Virtual Reality (VR) and Augmented Reality (AR) technologies, whether immersive or non-immersive. In contrast, the studies that used desktop or laptop computers as their primary platform did not specify the operating system employed. The development platforms identified in the selected studies are summarized in Table 10.

Table 10 – Operating Systems Used

Operating System	Studies
Android	T08, T12, T14, T17, T20
Not specified	T02, T05, T06, T07, T15, T21

Source: Research data (2024).

Regarding the development tools, most studies involving the creation of applications employed Unity (T07, T12, T14, T15, T17, and T20). This can be attributed to the fact that Unity AR Foundation is a cross-platform framework that enables developers to create augmented reality experiences and subsequently deploy applications for both Android and iOS without requiring additional recoding. Furthermore, Unity is one of the leading platforms for developing real-time 3D content (Koumpouros, 2024).

Study T05 reported the use of the Java programming language to develop a virtual laboratory. According to Junior *et al*. (2012), one of Java's main advantages is its platform independence, allowing applications to run on different operating systems without recompilation. Java is widely used for developing desktop, web, server, and mobile applications. It is an interpreted language in which the source code is compiled into an intermediate format, known as bytecode, which is executed by the Java Virtual Machine (JVM).

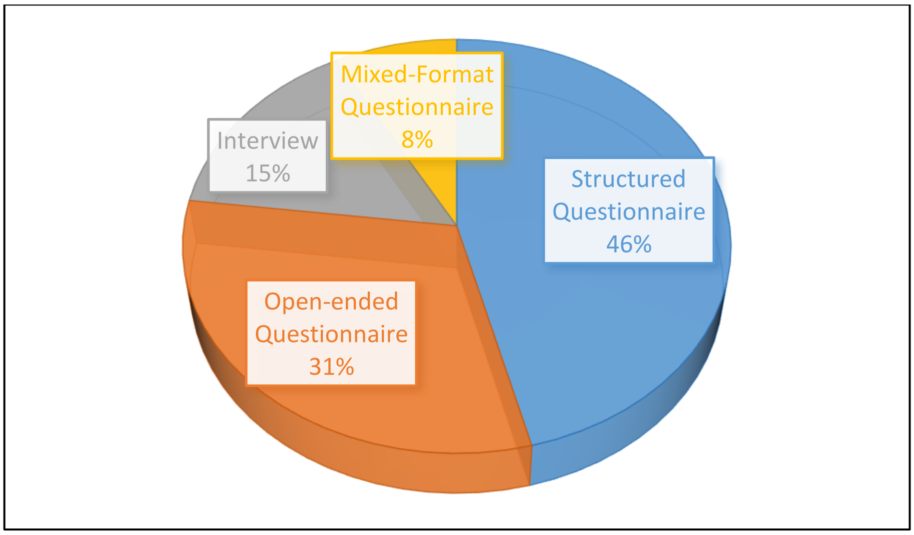
Study T21, in turn, reported the use of the C++ programming language to develop a concept mapping application. According to Junior *et al*. (2012), C++ was designed as an extension of the C programming language and is recognized for its efficiency and ability to support low-level programming. Consequently, it is widely used in the development of operating systems, video games, and other high-performance applications.

3.3 Usability

RQ8. Which are the evaluation instruments are employed in the studies?

As regards to the evaluation instruments, most studies involving either practical implementation or usability testing relied on structured questionnaires. These instruments were designed to assess aspects such as usability, ease of use, the relevance of the application for physics education, user satisfaction, and motivation. Figure 9 illustrates the distribution of the evaluation instruments, while Table 11 presents the relationship between each study and the evaluation methods employed.

Figure 9 – Evaluation Instruments Used in the Studies



Source: Research data (2024).

Table 11 – Evaluation Instruments Employed in Each Study

Evaluation Instrument	Studies
Structured Questionnaire	T05, T07, T08, T14, T16, T20
Open-Ended Questionnaire	T10, T11, T13, T22
Mixed-Format Questionnaire	T15
Interview	T18, T21

Source: Research data (2024).

Studies T14, T16, and T20 employed the MAREEA (Mobile Augmented Reality Educational Approaches Evaluation Model) questionnaire. This instrument was developed to address a gap in understanding the effectiveness of mobile Augmented Reality (AR) educational approaches. The model was designed based on the need to evaluate not only the technology itself but also its implementation and pedagogical impact within educational settings (Herpich *et al.*, 2019).

A key feature of the MAREEA model is its multidimensional approach, which recognizes that the effectiveness of AR in education depends on the interaction of pedagogical, technological, and usability factors. The instrument comprises a set of interrelated components covering dimensions such as instructional design, engagement, motivation, active learning, and accessibility (Herpich *et al.*, 2019).

RQ9. How do the studies evaluate the use of Virtual Reality in physics education?

The studies that involved practical implementation consistently reported positive evaluations regarding the use of Virtual Reality (VR) in physics education. The main educational benefits identified across these studies are summarized in Table 12, providing a comprehensive overview of the potential of VR as an instructional tool.

Table 12 – Summary of the Educational Potential of VR in Physics Education

Educational Potential	Educational Impact	Related Studies
Visualization of Concepts	Facilitates the understanding of abstract and invisible phenomena (e.g., magnetic fields and kinematics) through three-dimensional models.	T05, T08
Gamification	Promotes critical thinking and student engagement through immersive narratives and progressive challenge-based activities.	T07
Experiential Learning	Enables *learning by doing* in virtual laboratories, fostering practical skills and problem-solving abilities.	T14
Immersion and Presence	Places learners in environments that are otherwise inaccessible (e.g., outer space or the subatomic world), encouraging active learning.	T18

Source: Research data (2024).

With respect to the visualization of complex concepts, study T05 demonstrated that the use of three-dimensional virtual laboratories made concepts in kinematics more tangible. By interacting with 3D models, students achieved a deeper understanding of phenomena that typically remain abstract in conventional classroom settings.

Regarding gamification, study T07 stands out for the complexity of its narrative and the progressive sequence of challenges incorporated into its Quantum Physics learning environment. According to Lampropoulos *et al*. (2024), the integration of VR into educational gamification promotes not only enjoyable learning experiences but also the development of collaborative skills and decision-making abilities in simulated environments.

Concerning engagement and experiential learning, studies T08 and T14 demonstrated that interaction with virtual objects—such as magnetic fields and electrical circuits—places students at the center of the learning process. This active role is fundamental to the construction of meaningful learning, enabling students to experience the scientific method in a safe and controlled environment.

A recurring finding across nearly all studies involving practical implementation was the role of motivation. In physics education, student motivation is frequently identified as one of the greatest challenges faced by teachers (Silva *et al*., 2018). The findings suggest that the introduction of VR initially acted as a source of extrinsic motivation, driven by the novelty of the technology. This initial engagement subsequently fostered intrinsic motivation and a genuine interest in learning physics. This motivational transition was particularly evident in studies T05, T07, T08, and T15.

4 CONCLUSION

The aim of this study was to analyze the application of Virtual Reality (VR) in physics education. To achieve this objective, three main aspects were investigated: publication trends, research trends, and usability. A Systematic Literature Review

(SLR) was conducted to address the research questions established for each of these aspects.

VR has the potential to facilitate the visualization of complex concepts, making abstract physical phenomena more comprehensible and concrete. Furthermore, it enables the creation of real-world simulations and gamified learning experiences, allowing students to explore and interact with instructional content in a more meaningful way. Based on the analysis of a final sample of 22 studies, it was possible to characterize the current state of VR research in physics education in Brazil.

Regarding publication trends, the review identified the contributions of 57 researchers affiliated with 24 institutions, the majority of which were public universities. The selected studies were published across 10 academic journals and five conference proceedings, indicating a research community that is still developing, although geographically diverse.

Concerning research trends, Mechanics emerged as the most frequently investigated area of physics, likely due to its inherently visual and vector-based nature, which benefits directly from three-dimensional representations. The review also distinguished studies focused on the development of proprietary applications from those employing existing software. Android and Unity were identified as the predominant operating system and development platform, respectively, for immersive educational applications. In addition, Layar (currently Blippar) and Second Life were the most frequently cited software platforms in the reviewed literature.

With respect to usability, VR was generally evaluated positively. The reported educational benefits converged around five major themes: the visualization of complex concepts, gamification, student engagement, experiential learning, and virtual exploration of otherwise inaccessible environments. However, an important gap was identified. None of the reviewed studies provided an in-depth discussion of implementation challenges, technical barriers, or unsuccessful pedagogical outcomes. The absence of such critical perspectives suggests that this field is still in a phase of technological optimism and would benefit from studies that more rigorously examine the practical challenges associated with implementing VR in educational settings.

Therefore, although the integration of VR into physics education appears highly promising, future research should move beyond descriptive investigations. Several important questions remain unanswered, including the time required for students and teachers to develop technological proficiency, the relationship between the initial motivation generated by technological novelty and long-term conceptual learning, and the comparative effectiveness of immersive versus non-immersive learning experiences.

In conclusion, the use of VR in physics education has significant practical implications and considerable potential to transform the teaching of abstract concepts into interactive and concrete learning experiences. To achieve greater pedagogical maturity, future research should investigate more thoroughly the relationship between implementation costs and actual learning outcomes, thereby providing stronger evidence to support the effective integration of VR into physics education.

REALIDADE VIRTUAL NO ENSINO DE FÍSICA: DIVULGAÇÃO, TENDÊNCIAS E USABILIDADE

RESUMO

O presente estudo buscou analisar a utilização da Realidade Virtual (RV) no ensino de Física no contexto brasileiro, a partir de uma revisão sistemática da literatura. Foram consultadas bases de dados nacionais, como o Portal Capes, a Biblioteca Digital da Sociedade Brasileira de Computação (BDSBC) e os anais do Congresso Brasileiro de Informática na Educação (CBIE), o que resultou na seleção de 22 trabalhos. Os resultados indicam que a área da Mecânica é a mais recorrente nas pesquisas analisadas, com crescente uso de dispositivos móveis como plataforma de acesso. Entre as principais potencialidades da RV, destacam-se o aumento do engajamento dos estudantes e a facilitação da compreensão de conceitos abstratos por meio de visualizações imersivas. Por outro lado, as dificuldades envolvem limitações na fidelidade das simulações às leis físicas, especialmente em ambientes genéricos, bem como a ausência de modelos de avaliação pedagógica mais consolidados.

PALAVRAS-CHAVE: Realidade Virtual. Realidade Aumentada. Ensino de Física.

REFERENCES

BUDI, A. S.; SUMARDANI, D.; MULIYATI, D.; BAKRI, F.; CHIU, P. S.; MUTOHAROH; SIAHAAN, M. *Virtual reality technology in physics learning: Possibility, trend, and tools*. **Jurnal Penelitian & Pengembangan Pendidikan Fisika**, v. 7, n. 1, p. 23-34, 2021. Available at: https://journal.unj.ac.id/unj/index.php/jpppf/article/view/17578. Access on: Feb. 21st, 2024

DINIZ, V. S.; PASTORIO, D. P. *Uma revisão sistemática da literatura sobre a construção e uso dos mundos virtuais 3D no ensino de Física*. **Revista de Ensino de Ciências e Matemática**, v. 14, n. 2, p. 1-25, 2023. Available at: https://doi.org/10.26843/rencima.v14n2a06. Access on: Feb. 26th, 2024

GRANT, M. J.; BOOTH, A. *A typology of reviews: an analysis of 14 review types and associated methodologies*. **Health Information & Libraries Journal**, v. 26, n. 2, p. 91-108, 2009. Available at: https://doi.org/10.1111/j.1471-1842.2009.00848.x. Access on: Jul. 15th, 2026

HERPICH, F.; NUNES, F. B.; PETRI, G.; NICOLETE, P.; TAROUCO, L. M. R. *Modelo de avaliação de abordagens educacionais em Realidade Aumentada Móvel*. **RENOTE: revista novas tecnologias na educação**, Porto Alegre, v. 17, n. 1, p. 355-364, 2019. Available at: http://hdl.handle.net/10183/262898. Access on: Feb. 21st, 2024.

JUNIOR, M. A. C.; VIRTUOSO, G. H.; MARTINS, P. J. *Propriedades desejáveis a uma linguagem de programação: Uma análise comparativa entre as linguagens C, C++ e Java*. *In*: CONGRESSO SUL BRASILEIRO DE COMPUTAÇÃO, 2012, **Anais do Sulcomp**. Criciúma, v. 1, p. 1-3. Available at: https://d1wqtxts1xzle7.cloudfront.net/99247234/747-libre.pdf. Access on: Jul. 15th, 2026.

KITCHENHAM, B. ***Procedures for performing systematic reviews*.** Keele, UK: Keele University, v. 33, n. 2004, p. 1-26, 2004. Available at: https://www.researchgate.net/publication/228756057_Procedures_for_Performing_Systematic_Reviews. Access on: Jul. 15th, 2026.

KOUMPOUROS, Y. *Revealing the true potential and prospects of augmented reality in education*. **Smart Learning Environments**, v. 11, n. 1, p. 2, 2024. Available at: https://link.springer.com/article/10.1186/s40561-023-00288-0. Access on: May 3rd, 2024.

LAMPROPOULOS, G.; KINSHUK. *Virtual reality and gamification in education: a systematic review*. **Educational Technology Research and Development**, p. 1-95, 2024. Available at: https://doi.org/10.1007/s11423-024-10351-3. Access on: May 3rd, 2024.

MERCHANT, Z.; GOETZ, E. T.; CIFUENTES, L.; KEENEY-KENNICUTT, W.; DAVIS, T. J. *Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis*. **Computers & Education**, v. 70, p. 29-40, 2014. Available at: 10.1016/j.compedu.2013.07.033. Access on: May 3rd, 2024.

MOHER, D.; LIBERATI, A.; TETZLAFF, J.; ALTMAN, D. G. *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement*. **Annals of Internal Medicine**, v. 151, n. 4, p. 264-269. Available at: https://doi.org/10.7326/0003-4819-151-4-200908180-00135. Access on: Jul. 15th, 2025.

OLIVEIRA, A. L.; VIANNA, L. S.; NASCIMENTO, B. R.; VITA NETO, M. L.; SANTOS, M. G. *Um estudo sobre o sistema operacional Android*. **Revista de Trabalhos Acadêmicos - Campus Niterói**, n. 1, 2014. Available at: https://web.archive.org/web/20180512220632id_/http://www.revista.universo.edu.br/index.php?journal=1reta2&page=article&op=viewFile&path%5B%5D=1182&path%5B%5D=886. Access on: May 22nd, 2024.

NETTO, A. V.; MACHADO, L. S.; OLIVEIRA, M. C. F. *Realidade virtual: definições, dispositivos e aplicações*. Tutorial. **Revista Eletrônica de Iniciação Científica da SBC**, Porto Alegre, v. 2, n. 2, p. 1-33, 2002. Available at: http://www.de.ufpb.br/~labteve/publi/2002_reic.pdf. Access on: Apr. 26th, 2024.

PRAHANI, B. K.; SAPHIRA, H. V.; WIBOWO, F. C.; SULAEMAN, N. F. *Trend and Visualization of Virtual Reality & Augmented Reality in Physics Learning from 2002-2021*. **Journal of Turkish Science Education**, v. 19, n. 4, p. 1096-1118, 2022. Available at: https://files.eric.ed.gov/fulltext/EJ1377331.pdf. Access on: Feb. 21st, 2024.

SILVA, J.; SALES, G. L.; CASTRO, J. B. *Gamificação de uma sequência didática como estratégia para motivar a atitude potencialmente significativa dos alunos no ensino de óptica geométrica*. *In*: CONGRESSO BRASILEIRO DE INFORMÁTICA NA EDUCAÇÃO, 2018. **Anais dos Workshops do CBIE**, v. 1, p. 74. Available at: http://milanesa.ime.usp.br/rbie/index.php/wcbie/article/view/8213. Access on: Jul. 15th, 2026.

Received: Jul. 01st, 2024.
Approved: Jul. 17th, 2026.
DOI: 10.3895/rbect.v19n1.18786
How to cite: MONTEIRO, J. A.; COUTINHO, A. L.; LUCENA, I. C. R.; SALES, G. L. Virtual reality in physics education: dissemination, trends, and usability. **Brazilian Journal of Science Teaching and Technology**, Ponta Grossa, v.19, p. 1-21, 2026. Available at: <https://periodicos.utfpr.edu.br/rbect/article/view/18786>. Access on: XXX.
Mailing address: Jeirla Alves Monteiro - jeirla@gmail.com