SERIOUS DIGITAL GAMES CREATED FOR SCIENCE COMMUNICATION: a scoping review[1]

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Abstract: *Purpose: To map the state of the art on serious digital games used for science communication. Methodology: A PRISMA-ScR scoping review searched SciELO, ScienceDirect, Web of Science and Scopus with Portuguese/English strings. From 341 records, 34 studies (1993-2023) in Portuguese, English or Spanish were included. Data were charted and synthesized narratively with descriptive statistics. Findings: Most studies were conducted in schools or universities. Games covered 29 themes (notably health, sustainability and STEM) and diverse genres; iterative and collaborative design were common. Evaluation remains dominated by short-term questionnaires, often with small convenience samples and limited attention to accessibility or long-term outcomes. Conclusion: The review outlines priorities for theory-informed design, clearer reporting and mixed-method, longitudinal and inclusive evaluations, and highlights narrative as a promising lever for future public engagement.*

Keywords: *Science communication, Digital games, Serious games.*

1. Introduction

Science communication involves sharing scientific content with different audiences; reflecting on different ways to promote discussions in society about how science works, its processes, products and implications; fostering social inclusion and public participation in science, and raising awareness amongst society and governments about the importance of investing in research (MASSARANI, 2022). Science communication activities can involve games to diversify them and reach new audiences.

Games have emerged as innovative tools in science communication, with potential for engaging diverse audiences with complex content in a playful and interactive way. They not only convey information but also facilitate the construction of meaning, experimentation, and

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reflection on scientific topics. A study (PAULA; VALENTE, 2016) highlights that digital games promote active learning, allowing players to explore scientific concepts in interactive contexts and receive immediate feedback on their actions. Furthermore, games have been identified as effective in stimulating critical thinking and problem-solving, essential skills in scientific learning (MATTAR; SOUZA; BEDUSCHI, 2017). In comparison, analog games, such as board and card games, offer a more collaborative and practical experience, allowing the simulation of scientific processes and teamwork to solve challenges (ILLINGWORTH; WAKE, 2021).

While both types of games provide an immersive way to learn, they also face specific challenges, such as the excessive use of multiple-choice tests, inclusion of activities not directly related to the objective of the game, balance between fun and education, and failures in the interface and mechanics (MATTAR; SOUZA; BEDUSCHI, 2017), in addition to the limited scalability and accessibility of analog games due to logistical and production issues.

However, the use of games in science communication still presents several gaps that need to be addressed to maximize its potential, such as the scarcity of longitudinal studies which investigate lasting changes in players' attitudes and scientific understanding (PROKOP; ILLINGWORTH, 2016; VOLK; SCHÄFER, 2024), and accessibility and inclusion (CAGNOLI, 2024; HASSAN; BALTZAR, 2022).

For this article, we decided to focus on digital games. Thus, adopting the terminology of games as a synonym for digital games, it is defined that:

> A game is a play activity comprised of a series of actions and decisions, constrained by rules and the game world, moving toward an end condition. The rules and the game world are delivered by electronic media and controlled by a digital program. The rules and game world exist to provide a framework and context for a player's actions. The rules also exist to create interesting situations to challenge and oppose the player. The player's actions, his decisions, choices, and chances, really, his journey, all comprise the "soul of play". It is the richness of context, the challenge, excitement, and fun of a player's journey, and not simply the attainment of the end condition, that determines the success of the game (SCHUYTEMA, 2007, p. 7).

Selecting these types of games was due to the relevance of this media, which rapidly grows in Brazil and gives rise to various types of research (PESQUISA GAME BRASIL, 2024).

Recent studies explore digital games created specifically for science communication. Digital games were used, for example, to communicate scientific content to motivate positive attitudes and perceptions about climate change and other aspects of the natural sciences (PICÓ; GALÁN-CUBILLO; SÁEZ-SORO, 2021). Games like these may be considered

serious games, as they are designed and used not only to entertain, but also to address issues that are important to people and bring about changes in real life (RAESSENS, 2010, p. 95). The author points out that the term serious games originally referred to digital games, sometimes used in educational, corporate, or political contexts, where fun took second place to planned outcomes (RAESSENS, 2010). In recent years, that concept has come to include digital, analog and hybrid games, and related terms such as applied games have emerged, reflecting a broader understanding of the nuances and practical applications of games as communication and educational devices (VASCONCELLOS; CARVALHO; ARAÚJO, 2018).

The number of review articles that present an overview of that scenario is limited. For instance, there is a systematic review on user needs in environmental digital citizen science (SKARLATIDOU *et al.*, 2019); a narrative review of public interest in human anatomy (TAYLOR; WESSELS, 2024); and an umbrella review on the application of game elements in education (METWALLY *et al.*, 2021). These studies include, among other approaches, digital games and gamified activities as a theme and as a research tool. However, we did not find reviews of digital games as a science communication format.

Therefore, this article brings a review of studies involving serious digital games created for science communication. This research might give us insights on how these games are developed, what topics they address and the methods used to evaluate these games.

2. Methodology

For this review, we followed the steps of a scoping review, in order to map the state of the art of research on the creation and development of serious digital games for science communication. A review protocol was not registered for this study. However, the review process was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist (TRICCO *et al.*, 2018) to ensure methodological rigor and transparency.

For their quality, relevance, and broad scopes, we consulted the SciELO, ScienceDirect, Web of Science and Scopus databases in search of studies relevant to this research. On each database, we applied Boolean search strings using combinations in Portuguese and English of the following terms: science communication, science museum, science centre, science center, video game, video gaming, digital game, digital gaming, electronic game, computer game,

serious game, serious play, educational game, persuasive game, applied game, learning game, simulation game, games for change, impact game, purposeful game and interactive model. Table 1 presents examples of Boolean strings, filters, databases and search dates.

TABLE 1
Examples of boolean search strings used for data charting

Search date	Database	Search strategy	Filter
04/09/2023	Scopus	("science communication" OR "scientific dissemination" OR "science museum" OR "science centre" OR "science center") AND ("video game" OR "video gaming" OR "digital game" OR "eletronic game" OR "computer game") AND ("serious game" OR "educational game" OR "persuasive game" OR "applied game" OR "learning game" OR "simulation game" OR "games for change" OR "impact game" OR "purposeful game" OR "interactive model" OR "serious play")	None
04/09/2023	Web of Science	(“science communication" OR "scientific dissemination" OR "science museum" OR "science centre" OR "science center”) AND (“video game" OR "video gaming" OR "digital game" OR "eletronic game" OR "computer game”)	None
07/09/2023	Scielo	(“comunicação científica" OR "comunicação pública da ciência" OR "divulgação científica" OR "museu de ciência" OR "centro de ciência" OR "popularização da ciência”) AND ("jogo")	"Brazil" location filter removed
09/09/2023	ScienceDirect	("jogo sério" OR "jogos digitais" OR "game”) AND (“divulgação científica" OR "museu de ciência" OR "comunicação pública da ciência" OR "centro de ciência" OR "popularização da ciência”)	Filter for Portuguese and Spanish languages

SOURCE – The authors.

We did not use content search filters, except for the removal of the Brazil location filter from the Scielo platform, which is Brazilian; and the application of filters to remove results in French and include results in Portuguese and Spanish in ScienceDirect. This served as an attempt to identify new trends among searches over time and to find the maximum number of results relevant to the objectives of this project. Although searches yielded results in several languages, only works in Portuguese, English, and Spanish were included, as these are the languages that are familiar to the authors. Similarly, we did not use publication year filters. The inclusion and exclusion criteria are listed below.

Inclusion criteria:

a) Research that fits the adopted definition of science communication (sharing scientific content; identifying reliable sources and information; promoting popular participation in science and raising awareness in society about the importance of science and investing in research);

b) Research on games that promote science communication, even if they were not created expressly for this purpose nor use the term science communication or equivalents;
c) Research on digital games applied in science museums;
d) Research on the use of games for science education, inside and outside school and academic environments, due to their proximity to science communication;
e) Research on serious digital games;
f) Articles in Portuguese, English and Spanish.

Exclusion criteria:

a) Analog games (boardgames, cards, etc.);
b) Commercial games, initially created only for entertainment;
c) Research that uses games that have already been created, without considering their design and development;
d) Games focused on training (for engineering, medical and nursing school, etc.), in the context of professional training;
e) Results with the term "game" in a figurative sense;
f) Articles on Game Theory;
g) Review articles (meta-analysis, integrative or systematic review etc.);
h) Unavailable full article file.

Adapting the proposal by Tricco et al. (2018), we also created the diagram in Figure 1 below to better visualize the process.

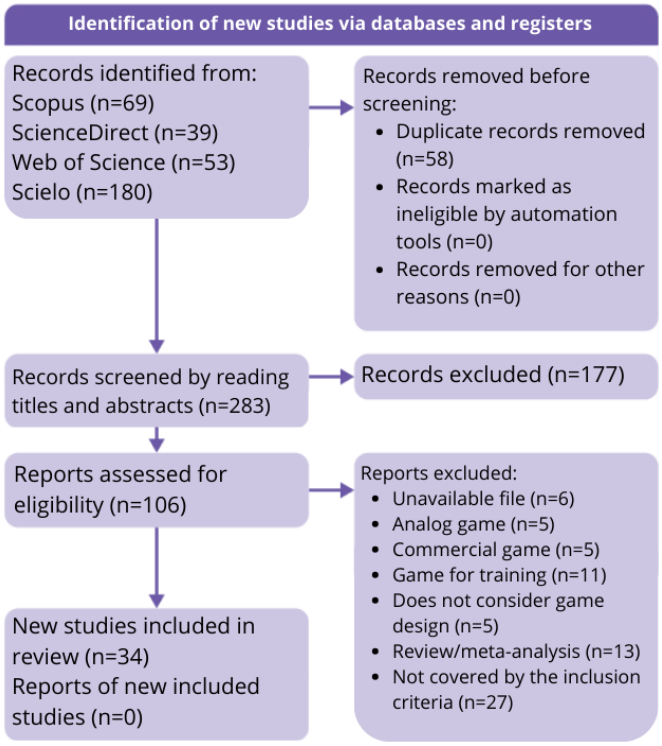

FIGURE 1 – Diagram of the research selection process for this review
SOURCE – Adapted from TRICCO et al., 2018.

We accessed the databases between September 4th and 9th, 2023, yielding 341 results, of which 58 duplicates were removed. The primary data extraction was conducted by one reviewer using a Google Sheets spreadsheet. To ensure accuracy and reliability, a second reviewer audited the extracted data for all included studies. Any uncertainties were discussed until a consensus was reached. In the first tab of the spreadsheet, we counted the number of articles found in each database. In the second tab, we entered the link and title of the papers we found and then read their titles and abstracts, indicating the removal of those that did not fit the scope of the project according to the inclusion and exclusion criteria, reducing the sample to 106 papers. We then passed these publications to the third tab, in which we marked the reading of the full texts and, also based on the inclusion and exclusion criteria, closed the sample at 34 papers. In the fourth tab, we entered the data collected from the sample and organized it around different categories and characteristics for later analysis.

The analyzed articles were organized into categories that indicate the level of education of the target audience (Early Childhood Education, Elementary Education, High School, Higher Education, Postgraduate Education or, if no education level was reported, General Public); if the projects were applied in museums; and their results, including the

country/location of the study, type of study (qualitative, quantitative or mixed methods), sample (number of participants) and sampling method (probabilistic or non probabilistic methods). Based on the work of Gil (2002), we charted the methods used by the original authors to assess the games (interviews, questionnaires, forms, field diary/observation, participant observation/ethnography, tests, documentary records, focus groups) and for analysis (statistics, content analysis, personas, affinity diagrams, content validation, experience report, open and axial coding, thematic analysis, or unspecified qualitative analysis), in order to understand how the impact and effectiveness of science communication games are currently being measured and validated in the literature. Then, we included a creation methodology category, to list information about the game development process and three other classification categories to understand game rules, ways in which the players interact with the game, and aesthetics adopted by those studies.

The data were summarized using a narrative synthesis approach combined with descriptive statistics for quantitative variables (such as target audience). The thematic categorization of game topics and mechanics was initially performed by the lead researcher. To ensure reliability, a second researcher audited the categorization process. Disagreements regarding the classification of specific studies were resolved through discussion until consensus was reached.

Consistent with the guidelines for scoping reviews (PETERS *et al.*, 2020), a formal assessment of methodological quality of the included studies was not made. However, limitations of specific studies (such as small sample sizes or lack of control groups) were described in the results when relevant to the discussion of research gaps.

3. Results

3.1 General characteristics

We selected 34 articles for this review, which date from 1993 to 2023. Most of them are from the Scielo database (n=21), while the Scopus (n=8), ScienceDirect (n=3) and Web of Science (n=2) databases are in second, third and fourth places. The largest number of publications occurs in the period between 2015 and 2023, with particular emphasis on the years 2021 (n=7), 2019 (n=4) and 2020 (n=4).

Regarding the geographic distribution of the studies, there was a predominance of research conducted in Latin America, particularly in Brazil, which accounted for more than

one-third of the included articles (n=13). Other Latin American countries represented were Mexico (n=4) and Colombia (n=3), in addition to one multi-centric study involving Chile, Australia, and New Zealand. The United States was the second most frequent location (n=5). European studies were represented by Spain (n=3), Portugal (n=2), Italy (n=1), and the United Kingdom (n=1). One study did not report its location.

Eight studies were conducted in museums or science centers, and 26 studies were conducted in universities, schools and other institutions. In terms of content, we identified 29 different themes addressed by the games.

In regard to the participants, the sample sizes varied significantly across the included studies, ranging from 3 to 238 people. The majority of studies employed small convenience samples, typically with fewer than 50 participants, aimed at usability testing or preliminary validation. Only three studies reported samples larger than 100 participants. But reporting standards varied: 5 studies did not disclose the number of participants, and for 3 studies, this category was not applicable as they were essentially descriptive of the development process.

3.2 Target audience and educational level

Regarding the level of education, we assigned the category “general public” to 13 studies because the participants had different levels of education, origins, identities, ages and socioeconomic profiles. Other studies were aimed at children and young people in elementary school (n=11), high school (n=7), higher education (n=7) and early childhood education (n=5).

3.3 Game information

A wide variety of game engines (development platforms) was used to create those games. Six studies adopted Unity, popular for its three-dimensional element creation capabilities. Two studies used more than two game engines, and another 15 did not reveal the platform they used. The remaining games were created by Adobe Flash CS3, Adobe XD, BabylonJS, Blockly, Cocos2d-x, Figma, Game Make Studio 1.4, Integrated Development Environment (IDE), Node.js, Scratch 2.0, Turbo Pascal 5.5 (from 1989), Twine 2, Unreal Engine 4, Macromedia Flash 8, Adobe Dreamweaver CS3 and WampServer.

3.4 Game topics

Based on the selected works, the review was organized into four main areas: “health-related topics”, “science education”, “science museums” and “various themes”.

3.4.1 Health-related topics

Health-related topics (n=13) involves games created to share knowledge about one’s own health, symptoms and treatment of diseases, or other aspects related to health with students, researchers and families. Obesity and nutrition were addressed by Dias et al. (2016; 2021) with DigesTower, a strategy game for children which showed high acceptance but was limited by small convenience samples. Similarly, Oliveira et al. (2020) evaluated Healthy Running for adolescents, reporting positive outcomes in physical activity levels, though noting design limitations such as the lack of a control group.

Regarding chronic conditions and patient care, D'Agostini et al. (2020) and Fonseca et al. (2015) explored the e-Baby and e-Baby Família games for premature infant care, highlighting the benefits of participatory design for parents and nursing students. Serafim et al. (2019) detailed the user-centered design of Batalha do Didi, a game for Type 1 Diabetes, while Diehl et al. (2015) found the InsuOnline game effective for insulin therapy training. Fernández Benítez et al. (2017) focused on the design of DietaDialisisQuiz, a multiplayer game for hemodialysis patients, although lacking empirical validation.

Infectious diseases and public health were also represented. Maciel et al. (2022) validated the Roleta Digital for human papillomavirus (HPV) prevention with experts. Santos et al. (2021) and Monteiro et al. (2018) applied Paulo Freirean pedagogy to health education: the former regarding leprosy awareness through participatory storyboarding, and the latter evaluating the DECIDIX game as a tool for dialogue.

Other specific applications included physiotherapy assessment (WEINTRAUB; HAWLITSCHEK; JOÃO, 2011) and anti-doping education, where Silva et al. (2019) reported immediate knowledge gains with Heart at Risk. Across these studies, while visual representations were noted to generate emotional impact (D’AGOSTINI *et al.*, 2020), a recurring limitation was the reliance on small convenience samples and evaluations focused on immediate satisfaction rather than long-term behavioral change.

3.4.2 Science museums

Science museums (n=8) include studies that address the creation and application of digital games within these institutions, covering diverse scientific disciplines ranging from environmental science to sociology.

Most games in this category heavily focus on sustainability and ecology. In Mexico, Barcena-Vazquez et al. (2023) developed Reto Global to raise awareness about global warming, using quantitative pre- and post-tests, while Cordova-Rangel and Caro (2023) utilized Design Thinking to create Aventura Marina, a marine life escape room, though its evaluation was restricted by the COVID-19 pandemic. In the United States, Rowe et al. (2017) evaluated Future Worlds, a sustainability strategy game, noting significant knowledge gains and differences in engagement based on age and gender. In Colombia, Angrino et al. (2013) applied structured methodologies (TRIZ and ACT) to design a game about wetlands and migratory birds, although the study remained at the design phase without empirical implementation. Cignoni et al. (2015) reported on The Blob Game of Life regarding ecosystems in an Italian computing museum, relying on informal observations.

Other science fields were also represented. An early study by Lee et al. (1993) described Spectrum, a game about hydrogen atom physics in Mexico, which showed promise in knowledge retention despite the methodological limitations typical of the time. In the field of linguistics, Gokcen et al. (2018) presented Madly Ambiguous to teach natural language processing concepts; while successful in gathering user data, the study lacked a formal assessment of pedagogical impact. Finally, Andrade (2021) proposed a conceptual framework for "Sociological (Re)search Games" through The Mystery of The Missing Knowledge, focusing on the theoretical potential of games for social science communication rather than empirical validation.

While some studies performed robust evaluations (ROWE *et al.*, 2017; BARCENA-VAZQUEZ *et al.*, 2023), a recurring limitation across this subset, according to the authors, is the reliance on small, non-probabilistic samples or anecdotal evidence (CIGNONI; CAPPELLINI; MONGELLI, 2015; GOKCEN; HILL; WHITE, 2018). Furthermore, purely descriptive design studies (ANGRINO *et al.*, 2013; ANDRADE, 2021) highlight a gap between game conceptualization and the assessment of visitor learning outcomes.

3.4.3 Science education

Science education (n=12) includes research on how games can amplify knowledge and awareness of science in formal and informal science teaching settings, covering a wide range of disciplines and methodological approaches.

Several studies explored games to teach complex concepts in Science, Technology, Engineering, and Mathematics (STEM). Castrillón et al. (2019) integrated pedagogical theories with usability principles to design a prototype for Kinematic Physics, while Peng et al. (2017) utilized gamified Apollo missions to foster engagement in space exploration, though both studies were limited by a lack of learning quantification with end-users. Regarding Nanotechnology, Hudson-Smith et al. (2023) demonstrated that the text-based game NanoAdventure was as effective as traditional texts for knowledge acquisition. In the field of Computational Thinking, Ríos Félix et al. (2020) developed an Intelligent Learning Environment with emotion recognition; despite high engagement, the study found no statistically significant difference in learning gains compared to control groups.

Environmental issues were a prominent theme. Fox et al. (2020) employed an experimental design to show how reducing psychological distance in games can increase support for environmental policies. Collaborative design was a key methodology in this cluster: Picó et al. (2021) used a Living Lab approach for Planeta Debug (climate change), and Pollio et al. (2021) explored participatory design for Antarctic Futures to interface science with policy. In specific contexts, Jaramillo Reinel et al. (2021) focused on coffee cultivation using agile methodologies, while Ichiba and Bonzanini (2022) validated a game on vermicomposting to serve as a formative assessment tool in early childhood education.

A subset of studies prioritized accessibility and social themes. Oliveira et al. (2021) focused on inclusive design, evaluating Expedição Antártica for visually impaired users to teach Science and Math. In health education, Moura et al. (2019) validated the content and appearance of Healthy Adventure for adolescents with high expert consensus. Finally, Contreras-Espinosa et al. (2016) used Action Research to co-create Dolors Aleu with teachers, a game about the history of women in medicine.

Across these education-focused studies, a recurring challenge was the reliance on convenience sampling (JARAMILLO REINEL *et al.*, 2021; FOX *et al.*, 2020) and the frequent lack of mentions regarding adherence to ethical research principles (CASTRILLÓN *et al.*, 2019; OLIVEIRA *et al.*, 2021). While design processes were often well-documented,

rigorous validation of learning outcomes with the target audience remains a gap in several studies.

3.4.4 Various themes

The review identified a distinct approach in the work of Curtis (2014), which analyzed the "Gamify Your PhD" initiative, a hackfest-style event where groups developed games based on doctoral research. Unlike studies focused on the validation of a single tool, this article offers a qualitative commentary on the collaborative dynamics of game creation. It highlights the inherent challenge of balancing scientific accuracy with the need for streamlined, fun gameplay mechanics. While the study underscores the potential of games to foster dialogue on complex ethical and social issues - such as food security and addiction - it relies on informal observation. The absence of formal evaluation of the games' impact or detailed documentation of the design methodologies was noted as a limitation, restricting the ability to draw generalizable conclusions about the effectiveness of such events for public engagement.

3.5 Game design elements

We found projects where collaborative design is present in several projects (n=13). For Planeta Debug (PICÓ; GALÁN-CUBILLO; SÁEZ-SORO, 2021), different research groups, including scientists, communicators, and designers, worked together to create nine interactive games. This type of multifaceted collaboration helps create more innovative and effective solutions for educational challenges.

The practice of iterative design, where games are continuously evaluated and refined based on user feedback, is a common feature (n=20). For example, the game Aventura Marina (CORDOVA-RANGEL; CARO, 2023), designed to promote visitor engagement in a museum, employed an iterative design process with prototypes and evaluation by museum staff before the final version was released.

Many games analyzed explore problem-solving and interactive mechanics. For example, the game DigesTower (DIAS *et al.*, 2021) uses tower defense mechanics where players control food variables and make strategic decisions to defend the digestive system from bacterial attacks, fostering critical thinking.

Healthy competitive dynamics are frequently explored. In the case of the game-based exhibition Future Worlds (ROWE *et al.*, 2017), there is a collaborative exploration of

complex sustainability systems, where players must work together to solve environmental issues. The multitouch interaction mechanism also allows multiple players to engage actively in the game, promoting group learning.

The style of these games can vary greatly depending on the target audience. Games aimed at children, like Aprendendo Vermicompostagem (ICHIBA; BONZANINI, 2022), have a simpler and more cartoonish visual style. The game involves players in a composting learning process through an interactive interface where children drag items into the compost bin. On the other hand, games like NanoAdventure (HUDSON-SMITH *et al.*, 2023), which deal with nanotechnology, adopt a more technical visual style, featuring images that mimic micrographs to help players visualize the concept of microscopic scales.

Across the reviewed works, we identified different genres and formats of games. Among narrative and choice-based games, interactive fiction/adventure games based on text (HUDSON-SMITH *et al.*, 2023) stand out, featuring decision structures and narrative branching, as well as games that combine role-playing, clue gathering, hypothesis building, and, in some cases, tests or supporting minigames (ANDRADE, 2021).

Digital escape room games (CORDOVA-RANGEL; CARO, 2023) incorporate minigames and puzzles as components of larger systems. Platform games are also present, including variations that function as metaphors for socio-environmental problems (FOX *et al.*, 2020), combinations of platforming and racing (OLIVEIRA *et al.*, 2020), and broader settings with elements of adventure, strategy, and tactics to the two-dimensional shoot 'em up subgenre (CURTIS, 2014).

There are turn-based strategy games, including those with multi-touch interface support and educational agents (ROWE *et al.*, 2017), and tower defense style games (DIAS *et al.*, 2021). Simulations address computational principles and machine interfaces, and ecological settings to observe how adjusting certain parameters affects species dynamics (CIGNONI; CAPPELLINI; MONGELLI, 2015); routine and self-care in health (SANTOS *et al.*, 2021), farming management (JARAMILLO REINEL *et al.*, 2021), clinical and hospital simulations oriented towards cases and decision-making (D'AGOSTINI *et al.*, 2020), as well as simulations of future scenarios and public policies related to climate change (POLLIO; MAGEE; SALAZAR, 2021).

Quizzes and question-and-answer games are also present, including those with competitive mechanics or digital roulette (MACIEL *et al.*, 2022) associated with multiple

choice. Instant messaging apps also emerge to promote discussion and collective decision-making (MONTEIRO *et al.*, 2018), in addition to mentions of competitive and multiplayer modes linked to educational and health objectives (FERNÁNDEZ BENÍTEZ; GONZÁLEZ PASCUAL; PUERTAS SANZ, 2017).

3.6 Game design elements

The most common game evaluation method is the use of questionnaires (n=20), applied as a preliminary survey to representatives of the target audience, to both conduct pre- and post-tests and record experiences to evaluate game content and design, for example. In second and third places are observation with the support of a field diary (n=6) and interviews (5). Participant observation, focus groups, consultation of documental records (machine plans and old reports, for example) and data collected directly from the game (game completion time, answers to questions, errors and successes, etc.) are also used to a lesser extent.

Statistical data analysis is the most common method used (n=18), since many questionnaires focus on Likert scales. Next comes content validation (n=12), for which researchers invite experts from different fields to assess game content; and experience reports (n=12), in which the researcher describes their experience with the project. On a smaller scale, researchers also apply content analysis (n=3), affinity diagrams (n=2), personas (n=1), thematic analysis (n=1) and open/axial coding (n=1). Seven studies stated that they made a qualitative analysis but did not inform their analysis methodology.

4 Discussion

This scoping review mapped how serious digital games have been created and studied in the context of science communication, revealing a field that is growing but still fragmented. The literature concentrates largely on educational institutions (n=26), with fewer studies conducted in science museums and centers (n=8), suggesting that the design and evaluation of games for public-facing, non-formal environments remains underexplored. The geographic distribution also indicates a strong presence of Latin American research - probably influenced by the inclusion of SciELO, a Brazilian database, among the ones consulted. These patterns highlight a research landscape where serious digital games are frequently positioned at the intersection of science communication and science education, but where the contours of “science communication” as a distinct objective are not always made explicit.

These works are closely linked to the concept of science communication adopted in this article, whether they are applied in science museums, to inform about health care, in science education or academic events. These studies bring together concepts and practices used to expand the reach of their findings and promote popular participation in science (MASSARANI, 2022). The articles on science education analyzed in our study reinforce the link between science communication and science education, which aims to introduce students in schools, undergraduate and graduate programs to scientific concepts and practices used to study different aspects of existence (MARANDINO, 2002).

The reviewed studies show a diverse range of game designs, genres and mechanics - such as quizzes, simulations, puzzles, platform games, turn-based strategy, and tower defense - mobilized to translate scientific content into interactive experiences. Iterative (n=20) and collaborative processes (n=13) appear as recurring strengths, indicating an awareness of user-centered practices and the value of co-creation with educators, scientists, designers, and target audiences. It is important to note that iterative development and collaborative design were coded as non-exclusive categories, and several studies reported both approaches.

Twenty studies adopted an iterative process of game creation, at different stages of development. When some aspects needed to be revised, researchers could, for example, conduct pre-tests, interviews and/or apply questionnaires to a sample of the target audience to check whether the game prototype could be adapted to the final version and applied in the research. These studies follow the logic of iterative design, in which researchers brainstorm ideas, point toward a solution, develop prototypes to minimize problems and perform tests for refinement, returning to the beginning in a cyclical movement. With this method, creation occurs based on the experience of playing a game and, in parallel, developing it (SALEN; ZIMMERMAN, 2012, p. 27).

The articles in which different groups participated in stages of the research and creation of games (n=13) are close to the concept of design in partnership, as they adopt collective creativity practices and consider different points of view, such as the interests of students, players, designers, institutional managers and researchers, to act, learn, transform and dialogue with the reality of the groups involved, including in teaching-learning situations (PACHECO; TOLEDO, 2016, p. 15).

The articles we analyzed were mostly conducted with participants of different age groups and educational levels (13 studies); they mainly involved the application of

questionnaires (20), statistical data analysis (18), experience reports (12) and validation of the game's contents (12); and they covered 29 different topics, including obesity, climate change, physics, astronomy, computing, linguistics and several others. As for the game development platforms, the studies used a variety of tools, with Unity being the most common (six occurrences).

When it comes specifically to research in museums, authors mention the importance of creating the game for mobile devices, to facilitate access and use by the public; the need of a clear and concise transmission of the scientific message so as not to distract the visitor and avoid excessive use of screens; and adopting popular mechanics such as puzzles, memory and trivia games, due to their popularity. We also found comments of authors who started planning the communicational and educational objectives and, then, sought to improve the entertaining elements for research participants; reduced the amount of text on the screens; considered limitations of the museum's section in which the game would be made available; encouraged the player's curiosity and sense of exploration; offered immediate and eye-catching feedback to the participants, so that they could see the result of their actions on the screen; included different levels of difficulty in the games; and also used the game as an academic experiment, simulations and data collection instrument.

The overlap between science education and science communication is conceptually productive for understanding where and how these games are applied; however, it also creates a risk of conceptual dilution if the specific aims of public science communication - such as dialogue, participation, trust building, and engagement with science-in-society issues - are not clearly stated.

They may also be close to the exercise of citizen science, based on collaboration between citizens and scientists in scientific work, whether in the process of collecting and analyzing data or in practices such as raising hypotheses and inferring results (PARRA, 2015). Skarlatidou et al. (2019, p. 15), although they do not specifically address digital games, have already shown in a review how research seeks to improve the experience of citizens in scientific activities and increase their contributions by using game elements such as badges, prizes, competitions or leaderboards in activities that are not games, a practice called gamification. In this context, Metwally et al. (2021), although they also do not work with games, explore in an umbrella review how gamification is growing in popularity in

educational research, highlighting the need to follow the rigor of methods in validating the advantages of using gamification.

This review has limitations that should be acknowledged. First, the search strategy was restricted to four specific databases and articles published in English, Spanish or Portuguese. Consequently, relevant studies indexed in other repositories or published in other languages may have been missed. Second, by focusing on peer-reviewed academic literature, this review potentially excludes a significant number of serious games developed by private companies, museums, or independent developers who do not publish their work in scientific journals. Therefore, our results reflect the academic state of the art regarding science communication games, which may differ from the trends observed in the commercial game market. Finally, consistent with the methodological framework of a scoping review, we did not perform a formal critical appraisal of the methodological quality of the included studies. As such, while we report on the evaluation methods used by authors, we cannot verify the robustness or risk of bias of the reported findings regarding the effectiveness of these games.

The prevalence of questionnaires (n=20) and statistical analyses (n=18), coupled with a strong emphasis on immediate learning outcomes, indicates that the field still relies heavily on short-term, predominantly quantitative validations. While such approaches are useful for early-stage testing, they offer limited insight into sustained engagement, long-term knowledge retention, attitude change, or behavioral outcomes. Future studies would benefit from more frequent use of mixed-method designs, triangulation of data sources (including in-game analytics and qualitative accounts), and clearer reporting of ethical procedures - especially in studies involving children or the collection of behavioral gameplay data.

Yet, the limited use of robust theoretical frameworks for game design in science communication, combined with inconsistent reporting of development platforms and design rationales, suggests a need for greater methodological transparency. Strengthening the articulation between mechanics, intended dynamics, and desired aesthetic experiences could help future projects better align entertainment value with communicational and educational objectives, especially in museum contexts where time, attention, and device constraints shape visitor engagement.

A key insight emerging from this review is the central role of narrative in structuring science communication experiences within games. Therefore, our future studies might investigate how different story-driven mechanisms can enhance engagement, comprehension,

and dialogue within science communication initiatives, whether mediated by digital or analog games.

5 Conclusion

This scoping review mapped the state of the art in research on the creation and development of serious digital games for science communication, revealing a field that is expanding but still characterized by conceptual, methodological and practical fragmentation. By examining 34 studies conducted across educational institutions, science museums, community contexts and diverse disciplinary areas, we identified how these games have been designed, evaluated and positioned within broader efforts to communicate scientific knowledge to the public.

Our analysis highlights gaps for future research: most studies use short-term, questionnaire-based assessments, so longitudinal work is needed to test retention, sustained engagement, and attitudinal or behavioral change. Few studies consider diverse publics, accessibility, cultural perspectives, or disability needs. Clearer links among rules, responses to player input, and aesthetics would better connect design to communication goals. This should be matched by transparent reporting on platforms, prototyping, ethics, and mixed-method evaluation with in-game analytics. Science museums remain understudied as public-facing sites for serious digital games.

Building on these findings, future research includes: exploring motivational factors that sustain player engagement; conducting comparative studies between digital, analog and hybrid game formats; expanding research in museums and other informal learning contexts; and examining how serious games can promote dialogue, trust-building and public participation in science. Additional opportunities lie in studying co-creation practices with scientists, designers, educators and target communities, as well as investigating how games produced in game jams or participatory workshops can effectively translate scientific content.

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