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Scientific Literacy Contributions at the Galileo Museum (Florence): Integration between Historical Heritage and Contemporary Education

Contributos da Alfabetização Científica no Museo Galileo (Florença): Integração entre Patrimônio Histórico e Educação Contemporânea

Contribuciones de la Alfabetización Científica en el Museo Galileo (Florencia): Integración entre Patrimonio Histórico y Educación Contemporánea

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Abstract

The *Museo Galileo*, in Florence, Italy, stands out as a non-formal education settings (NFES) of great historical and scientific significance and has undeniable potential to contribute to the scientific literacy of its visitors. Based on this specific perspective, the research reported in this article seeks to highlight communication strategies between the NFES and the contemporary public. Applied in nature and with a qualitative approach, the study had exploratory, descriptive, and explanatory objectives, involving bibliographic procedures, document review, survey, case study, and participant observation. Given the museum's diverse resources, a specific approach was chosen: a self-guided tour. Given the museum's diverse resources, a specific approach was chosen: a self-guided tour, focusing on information about Galileo's telescopes and the inclined plane, and a guided tour aimed at students aged 8 to 11, led by a facilitator who portrays Galileo Galilei. Referring to the specialized literature on scientific literacy, attributes related to the indicators were observed: (1) *scientific*, evidenced by the presentation of the apparatus, the scientific method, and science as a human construction; (2) *social interface*, when addressing the impacts of science on society and its relationships with economic and political factors; and (3) *interaction*, which is expressed physically, in the aesthetic-affective and cognitive dimensions. The conclusion is that the *Museo Galileo* exemplifies an NFES that combines the preservation of its historical heritage with contemporary educational demands.

Keywords: Scientific Literacy, science, education, non-formal education settings, Museo Galileo

Resumo

O *Museo Galileo*, em Florença, Itália, destaca-se como espaço não-formal de educação (ENFE) de grande relevância histórica e científica e inegável potencial para contribuir com aspectos de alfabetização científica de seus frequentadores. A partir desse recorte, a pesquisa relatada neste artigo buscou evidenciar estratégias de comunicação entre os ENFE e o público contemporâneo. De natureza aplicada e abordagem qualitativa, o estudo teve objetivos exploratórios, descritivos e explicativos, com procedimentos bibliográficos, revisão documental, levantamento, estudo de caso e observação participante. Dada a diversidade e a variedade de recursos do museu, optou-se por uma visita livre, com foco em elementos informativos acerca dos telescópios de Galileo e do plano inclinado, e o acompanhamento de uma visita guiada voltada para estudantes de 8 a 11 anos, conduzida por um mediador que interpreta a figura de Galileo Galilei. Com referência na literatura especializada sobre alfabetização científica, observaram-se atributos relacionados aos indicadores: (1) científico, evidenciado pela apresentação dos aparatos, do método científico e da ciência como construção humana; (2) interface social, ao abordar os impactos da ciência na sociedade e suas relações com fatores econômicos e políticos; e (3) interação, que se expressa fisicamente e nas dimensões estético-afetiva e cognitiva. Conclui-se, ademais, que o *Museo Galileo* exemplifica um ENFE que articula preservação de seu patrimônio histórico com as demandas do educacionais contemporâneas.

Palavras-chave: Alfabetização Científica, ciência, ensino, espaço não-formal de educação, Museo Galileo

Resumen

El *Museo Galileo*, en Florencia, Italia, se destaca como un espacio de educación no formal (ENF) de gran importancia histórica y científica y tiene un potencial innegable para contribuir a la alfabetización científica de sus visitantes. Con base en esta perspectiva específica, la investigación reportada en este artículo busca destacar las estrategias de comunicación entre los ENF y el público contemporáneo. De naturaleza aplicada y con un enfoque cualitativo, el estudio tuvo objetivos exploratorios, descriptivos y explicativos, involucrando procedimientos bibliográficos, revisión de documentos, encuesta, estudio de caso y observación participante. Dados los diversos recursos del museo, se optó por un enfoque específico: una visita autoguiada, centrada en información sobre los telescopios de Galileo y el plano inclinado, y una visita guiada dirigida a estudiantes de 8 a 11 años, dirigida por un facilitador que representa a Galileo Galilei. En referencia a la literatura especializada sobre alfabetización científica, se observaron atributos relacionados con los indicadores: (1) *científico*, evidenciado en la presentación del aparato, el método científico y la ciencia como construcción humana; (2) *interfaz social*, al abordar los impactos de la ciencia en la sociedad y sus relaciones con factores económicos y políticos; y (3) *interacción*, que se expresa físicamente y en las dimensiones estético-afectiva y cognitiva. La conclusión es que el *Museo Galileo* ejemplifica una ENFE que combina la preservación de su patrimonio histórico con las demandas educativas contemporáneas.

Palabras clave: Alfabetización Científica, ciencia, enseñanza, espacio no formal de educación, Museo Galileo

Introduction

Science centers and museums, as examples of non-formal education settings (NFES)[1], provide diverse audiences with access to knowledge through multifaceted resources and strategies, such as: guided tours; experimental apparatus; simulations and immersive experiences (modeling, representation, visual, tactile, olfactory, and gustatory—interactive or not); historical records (texts, audiovisual content, and artifacts); scientific dissemination, etc. To engage and captivate audiences, these spaces play a fundamental historical, socio-scientific, cultural, and educational role, offering visitors access to scientific knowledge, encouraging understanding of the world, and stimulating questions and curiosity (Marques & Marandino, 2017; Neves & Silva,

1 Other examples of NFES include: toy libraries, waterfalls, centers, cinemas, collections, experiment libraries, exhibitions, fairs, industries, herbariums, churches, botanical gardens, shows, observatories, parks, planetariums, squares, beaches, rivers, concerts, theaters, zoos, among others.

2023). In addition, they play a fundamental role in scientific dissemination and the popularization of science and influence children's interest in science and its practices (Coimbra-Araújo et al., 2020; Friedman, 2010).

In the NFES category, museums have the potential to contribute to scientific literacy (SL) processes[2], as they connect content of this nature to visitors' everyday experiences or *expressed* interests (Cerati, 2014; Marandino et al., 2018; Marques & Marandino, 2017; Norberto Rocha, 2018; Palmieri et al., 2017). By enabling understandings of the world, albeit angular ones, the sciences have the power to broaden individuals' reflective, creative, and critical views of their surroundings, contributing to the formulation of conscious decisions on the topics they deal with and a commitment to social change (Ferreira et al., 2022a; Silva et al., 2024).

The *Museo Galileo*[3], located in Florence, Italy, is an example of an NFES in science that is recognized and relevant worldwide. One of its main missions involves collecting, curating, preserving, and exhibiting historical collections related to the studies and developments of Galileo Galilei — Italian physicist, astronomer, mathematician, philosopher, and engineer responsible for a unique breakthrough and paradigm shift in the scientific field. Considered one of the greatest scientists of all time, he stood out for his rigorous, useful, courageous, and consistent contributions to the study of natural phenomena, as well as for (as attributed to him) founding modern Western science (Bassalo, 1995; Naess, 2015).

As a historical museum of fundamental and marked relevance within the complex of which it forms part, and due to its strong inclination toward education and dissemination, the *Museo Galileo* is emblematic for the study of similar NFES museums. It is precisely this combination of invaluable historical and scientific value, of protruding material and immaterial dimensions (architectural, cultural, preservation, curation, and scientific dissemination of its artifacts and conceptual objects), and the socio-educational character of its existence and mission that justifies it as a fruitful example for analyzing its communication strategies with its contemporary audience. These strategies are examined in light of the scientific literacy indicators (SLIs) proposed by Marandino et al. (2018) — namely: scientific; social interface; institutional; and interaction — and their respective attributes.

2 The concept of Scientific Literacy (SL) will be carefully developed in the section of this paper that addresses its theoretical framework. At this point, however, with a view to standardizing the idea with the reader in the rest of the text, we will assume SL as the process of understanding: (1) essential scientific knowledge; (2) the nature and practice of science and its ethical and political factors; and (3) the interrelationships between science, technology, society, and the environment. In a more up-to-date and contemplative notion for the scientific literacy (SL) perspective, SL is taken as the ability to: (1) recognize, evaluate, and explain phenomena scientifically; (2) evaluate and plan scientific investigations around a problem of epistemological relevance and theoretical-methodological framework; and (3) interpret scientific data and evidence. Although this discussion does not address the polysemy and epistemological and theoretical delimitations of SL, those interested are encouraged to see Ferreira et al. (2023), Ferreira et al. (2024), and Ferreira et al. (2025).

3 The Galileo Museum, or *Museo Galileo* (its Italian name, as we will use it in this article), can be visited virtually on its website: https://www.museogalileo.it/it/.

The applied research with a qualitative approach had exploratory, descriptive, and explanatory objectives. In addition, it was conducted using multiple technical procedures (bibliographic, review of documentary sources, survey and case study, and participant observation). Based on immersion in the space, and with the aim of incorporating inputs into the understanding of the *Museo Galileo* as a historical and cultural heritage site and an illustrious example of NFES, independent observations were carried out alongside guided/accompanied visits, solo visits, complementary readings of bibliographic references, general records about the architecture, infrastructure, collection, and historical, scientific, and educational conditions and possibilities, sample analyses of subspaces, apparatus, and knowledge addressed, as well as dialogues with members of the museum's administrative and scientific staff.

Theoretical Framework

Science Museums and Their Objectives

Preferably non-profit and with a deep devotion to the citizens who use them, science centers and museums are permanent institutions that "[...] research, collect, preserve, interpret, and exhibit tangible and intangible heritage." Seeking inclusion, accessibility, diversity, and sustainability corresponds to a mode of operation and communication "[...] in an ethical and professional manner, providing diverse experiences for education, enjoyment, reflection, and knowledge sharing" (ICOM, 2025, p. 1). These are institutionalized NFESs that stimulate and amplify access to epistemological, historical, and scientific knowledge and that contribute diversified strategies aimed at engaging, captivating, and stimulating curiosity in order to produce meaning (Marques & Marandino, 2017).

The definition of these spaces by ICOM (2007) moves toward that of ICOM (2022), which essentially diverges (or becomes rarer) in the order in which museum activities are considered (in that one, from the acquisition of artifacts to the communication of the knowledge they deal with; in this one, starting from research to the communication of knowledge); in the central objectives for the public (in that one, education, study, and enjoyment; in the latter, educational, enjoyable, reflective, and knowledge-sharing experiences); and, finally, in the perspective of users (from a position of openness to the public, like an oracle, to another of promoting interactions and integrations with sectors of society in strict observance of diversity and sustainability). From a mission perspective, these spaces have gradually sought to break away from exclusive scholarship, interacting more organically with broader and less homogeneous groups and adapting to new social needs and expectations (Friedman, 2010; Queiroz & Costa, 2024; Valente et al., 2005).

Going beyond the semantic dimension, these transformations are plastic to social change and emerging museological manifestations. Different models of museums and science centers have emerged throughout history, constituting three generations based on their objectives: (1) conservation, collection, research, and training; (2) education, conservation, collection, and research; and (3) education (Friedman, 2010). They originated from private collections in the early 19th century, such as the *Conservatoire National des Arts et Métiers* in Paris, which opened in 1794. At that time, the main objective of the first generation was to meet academic and industrial needs by promoting and using their collections as teaching materials (Friedman, 2010). According to Cazelli et al. (2002), these collections originated mainly from individual collections belonging to influential figures in society. A notable example is that of the Medici family in Tuscany (Italy), a region historically linked to the development of science (Miniati, 2017).

At the beginning of the 20th century, the second generation was fundamentally driven by public funding with the aim of collecting artifacts, preserving collections, and offering exhibitions of historical objects in order to popularize culture and knowledge, such as the *German Museum in Munich and the Museum of Science and Industry in Chicago* (Nascimento & Ventura, 2001). Its main feature is its emphasis on the preservation and accessibility of collections, keeping them untouchably on display. Many of these spaces originated from private collections, as is the case with the *Museo Galileo* (Camerota, 2012). In this context, we see the transition from a first-generation museum to a second-generation museum, incorporating the purpose of democratizing access to the collection — previously restricted to a few — and thus promoting cultural and scientific dissemination to society. Private collections, therefore, became accessible to wider audiences (Nascimento & Ventura, 2001).

Unlike the previous generation, which mainly targeted a privileged group of individuals, the second generation aims to democratize access to culture and contribute to the education of the general population (Friedman, 2010). From its predecessor, it preserves the impossibility of audience interaction, corresponding to the traditional educational model and one-way communication to passive users of museum resources (Cazelli et al., 1999).

The first third-generation science museum, the *Palais de la Découverte*, also in Paris, was founded in 1937, inspired by Einstein's visit to the French capital in the previous decade. Avoiding the term "museum," it aimed to stimulate scientific education, although it dispensed with permanent artifacts, collection, and conservation, an important distinction from the previous generation. The Cold War space race, major international industry exhibitions, and science fairs contributed to the growth of similar spaces (called science and technology centers). The distinction lies precisely in the fact that third-generation science museums do not focus on exhibitions of historical objects, but rather on scientific concepts and ideas with an emphasis on contemporary science and technology (Cazelli et al., 1999; Friedman, 2010; McManus, 1992). The numbers and overall distribution rate of this type of museum are growing every year. Among the spaces that stand out for their interactive approach with audiences around the world, we can mention, for example, but not exhaustively, the *Cité des Sciences et de l'Industrie* (Paris/France), MUSE (Trento, Italy), the Catavento Museum (São Paulo, Brazil), the PUCRS Science and Technology Museum (Porto Alegre, Brazil), and the *Museo Interactivo Mirador* (Santiago, Chile).

It is worth emphasizing that the third generation of museums has education as its fundamental objective. The exhibitions prioritize the animation and interactivity of objects, influenced by learning theories, such as those of Piaget in his studies dedicated to human genetic epistemology, which emphasize the importance of experience (Friedman, 2010). The members of this group do not seek mere contemplation of historical scientific apparatus, but rather the manipulation of new objects, with physical and sensory interaction. These activities are based on a combination of the positivist perspective of knowledge and discovery learning. In all science museums, regardless of generation, "[...] the communicative model of transmission predominates, in which the focus is on the transfer of ideas without social contextualization" (Hein, 1995, cited in Ribeiro & Soares, 2019, p. 4). Presenting intrinsic characteristics and distinct approaches, they seek to reflect diverse mediations in relation to the sciences.

Second-generation museums are based on historicity through intangible materials, while third-generation museums are based on interaction with a broad and unspecified audience. Nevertheless, both face criticism. The first is considered unattractive because its static configuration, based on a traditional teaching approach, subjects visitors to a passive position, as mere observers. On the other hand, the second model, by prioritizing interaction with visitors, dilutes the historical and cultural aspects of science (Valente, 2005). This state of affairs suggests that the most effective alternative for preserving scientific, technological, and historical content, in accordance with original intentions, as well as for ensuring inclusion, accessibility, diversity, and sustainability, would be to combine characteristics of the second and third generations. This could offer historical perspectives and present the sciences as products of human transformations, while the latter should link their presentations to contemporary scientific and technological aspects (Valente, 2005).

Scientific Literacy (SL)

Reflection on how understanding and mastery of scientific knowledge can facilitate conscious decision-making and drive social development is not new. As early as the 17th and 14th centuries, respectively, Francis Bacon and Herbert Spencer addressed different aspects of this topic. Additionally, in 1978, Thomas Jefferson, then Vice President of the United States, noted the need for a more pragmatic approach to science education (Hurd, 1998) — outlining what would later be coined SL. Throughout history, the concept has been interpreted in different ways, depending on the authors and multiple factors (Laugksch, 2000). Originating from the English term *scientific literacy*, it can be translated in different ways into Portuguese, such as "letramento científico" and "enculturação científica" in Brazil, or "literacia científica" in Portugal (Ferreira et al., 2023; Ferreira et al., 2024; Silva & Sasseron, 2021).

Gérard Fourez (1994) contributed significantly to the field of science education by formulating essential elements for classifying an individual as scientifically literate. Among these criteria, the following stand out: knowledge of key concepts, hypotheses, and scientific theories; the ability to apply them; their use in making responsible decisions; understanding the interrelationship between society, science, and technology; recognition that scientific knowledge is subject to change throughout history; understanding the use of technologies and their implications, and the ability to differentiate a scientific result from a mere opinion, etc. (Sasseron & Carvalho, 2011).

Sasseron and Carvalho (2008), when analyzing the concepts and objectives of SL in the literature, identified three structural axes to be considered: (1) a fundamental understanding of essential scientific terms, knowledge, and concepts; (2) an understanding of the nature of science and the ethical and political factors involved in its practice; and (3) an understanding of the interrelationships between science, technology, society, and the environment. In the educational context, this occurs when science education trains students to "[..] make decisions and understand both the countless uses of science and its applications in improving quality of life, as well as the limitations and negative consequences of its development" (Chassot, 2003, p. 99), thus promoting socio-environmental transformation and contributing to the improvement of living conditions. However, SL is not restricted to the school environment, nor does it end at a specific moment. It is a continuous journey that develops throughout life, just like science, and extends to various contexts and everyday experiences. In this perspective, several studies have emerged on the possibilities of relationships between SL and NFESs.

For example, Dawson (2019) investigated strategies to promote equity and inclusion in SL, based on findings that describe the experience of minority groups in the scientific learning process in NFES. Bevan and Penuel (2017) discuss the importance of dissociability between research and practice for improving science education in those spaces, with a focus on ethics and equity. The work of Falk and Storksdieck (2005), in turn, discusses how NFESs contribute to learning and how this occurs in different ways for different contexts and is influenced by eleven fundamental factors in three dimensions — personal, sociocultural, and physical ones. Finally, Allen and Gutwill (2009) discuss how evidence-based instructional design can improve adult scientific learning in museums, offering practical strategies for promoting SL.

Still seeking to understand how NFESs contribute to promoting SL, Norberto Rocha (2018) investigated the potential of museums and science centers. Supported by the assumptions of SL and based on the work of Cerati (2014), it expanded the so-called Scientific Literacy Indicators (SLIs), developing a model to identify the intensities of the indicators and attributes present in the exhibitions (Marandino et al., 2018). Four indicators were included as follows: scientific; social interface; institutional; and interaction. The scientific indicator addresses aspects that are substantially of this nature, such as scientific processes and products: epistemologies, ideas, concepts, theories, methods, etc. The social interface indicator deals with the relationship between science and society, economics, and politics. The institutional indicator refers to the roles of institutions in the formulation, development, and dissemination of science, as well as their social functions. Finally, the interaction indicator evaluates the ways in which visitors participate in activities in the respective spaces.

A Brief Overview of the *Museo Galileo*

The *Museo Galileo* — Institute and Museum of the History of Science located in Florence, Italy — was founded in 1927. Among its main objectives are the collection and preservation of historical collections, the promotion of scientific research, and the dissemination of knowledge, which typically positions it as a second-generation museum. The space is responsible for preserving one of the most important collections of scientific instruments in the world and is recognized as one of the leading centers for scientific dissemination, in addition to standing out in scientific museography, documentation, and research. Its statute4 defines its objective as follows:

> [...] safeguard and enhance its collection and promote, also in collaboration with other entities, activities of research, advanced training, teaching, exhibition, dissemination, coordination, and services related to the history of science and technology, to technical-scientific heritage, and to the dissemination of technical-scientific culture (*Museo Galileo*, 2021, p. 1, translated by the author).

The lower floor of Palazzo Castellani, where the museum is located, houses temporary exhibitions and a space for conferences and workshops. On the ground floor are the ticket office, the introductory room, the bookshop, and spaces dedicated to physical and virtual interactions, where replicas and models are available for practical use (Camerota, 2012). The first and second floors house the permanent exhibitions, while the top floor contains offices and the museum's impressive library, a source of research for visitors from all over the world.

One of the main attractions of the *Museo Galileo* is the permanent exhibition of the collections of the Medici and Lorraine families, with over instruments and devices of great scientific, historical, and aesthetic importance. The organization of the objects seeks to narrate the history of the scientists' work through the collections. The first floor houses a room dedicated to this remarkable scientist, entitled "The New World of Galileo." It displays instruments designed and built by Galileo that are still useful and used today, such as telescopes and the objective lens of the telescope with which he first observed Jupiter's moons.

Due to preservation requirements, the original devices are not available for practical demonstration. In the interactive room, on the other hand, visitors have the opportunity to handle replicas of the instruments, view the movement of the sphere on the replica of the inclined plane, and perform their own analyses, in a way attempting to emulate the work that historical scientists, such as Galileo, did in their research (Mello et al., 2022). As a result, museums now offer activities that aim to allow visitors to abandon their position as mere spectators and become part of the process of knowledge construction (Nascimento & Ventura, 2001).

The museum offers great support to researchers through its extensive library, which houses around 170,000 works of historical and scientific relevance. In addition to the physical versions, since 2014 the collection has been available remotely through the

4 Available at: https://www2.museogalileo.it/it/chi-siamo/794-natura-e-finalita.html.

digital library[5] (Casati, 2015). It allows users to access, from anywhere, copies of works such as Galileo's *Siderius Nuncius* (1610), with its famous drawings of the lunar relief.

The *Museo Galileo* has also incorporated digital technologies to enrich the experience of its visitors as they explore the exhibitions. A free app, available for smartphones and tablets, offers a range of features, including detailed descriptions of all the objects on display, as well as over four hours of videos demonstrating how the scientific instruments work and providing historical context for their design and use. To ensure greater accessibility, the information is available in Italian and English. This shows that the museum is keeping pace with the changes that these spaces have been undergoing in recent years, such as the introduction of new technologies and changes in the language used to communicate with the public (Nascimento & Ventura, 2001).

Among the many aspects that make the *Museo Galileo* one of the most important museums in the world, its dedication to providing enriching experiences for visitors stands out, with an emphasis on school groups by appointment. It has a team specialized in educational activities, offering a wide range of experiences for different levels. Among the activities available, they have the opportunity to interact with history and science through strategies such as puppet theaters, guided tours, and handling scientific instruments. Some of them take place in the dedicated space in the museum's basement.

Thus, the *Museo Galileo* highlights Galileo Galilei's importance to socio-scientific development, focusing on him for two main reasons: first, because the Grand Dukes' collections exemplify the scientific culture of the era in which he lived; second, because they reflect his profound influence on advances in the physical and mathematical sciences of the Modern Age (Camerota, 2012).

Methodology

This research is applied in nature, with a qualitative approach, exploratory, descriptive, and explanatory objectives, and multiple technical procedures—bibliographic, review of primary and secondary documentary sources, survey, and case study. The aim was to explore, in detail, activities developed at the *Museo Galileo* such as NFES, with a view to understanding, describing, and formulating models associated with the educational practices of the space in its context, allowing for an in-depth analysis of the fundamentals, processes, and interactions that occur there.

The data was collected *on site* between August 2024 and January 2025 as part of postdoctoral research. The museum formally authorized access to the space, which allowed for direct immersion in the exhibitions and activities offered by the institution. It is important to highlight that this role allowed for participant observation, interaction with the available equipment and documents, and observation of guided tours, in which an active and interactive position was taken with different aspects of the observed phenomenon (Fontana & Rosa, 2021) by participating in guided and interactive activities, recording dynamics linked to possible associated teaching-learning processes.

5 Museo Galileo. *Catalogo della biblioteca digitale* (Digital library catalog.) Available at: https://www2.museogalileo.it/it/biblioteca-e-istituto-di-ricerca/biblioteca-digitale/catalogo-biblioteca-digitale.html.

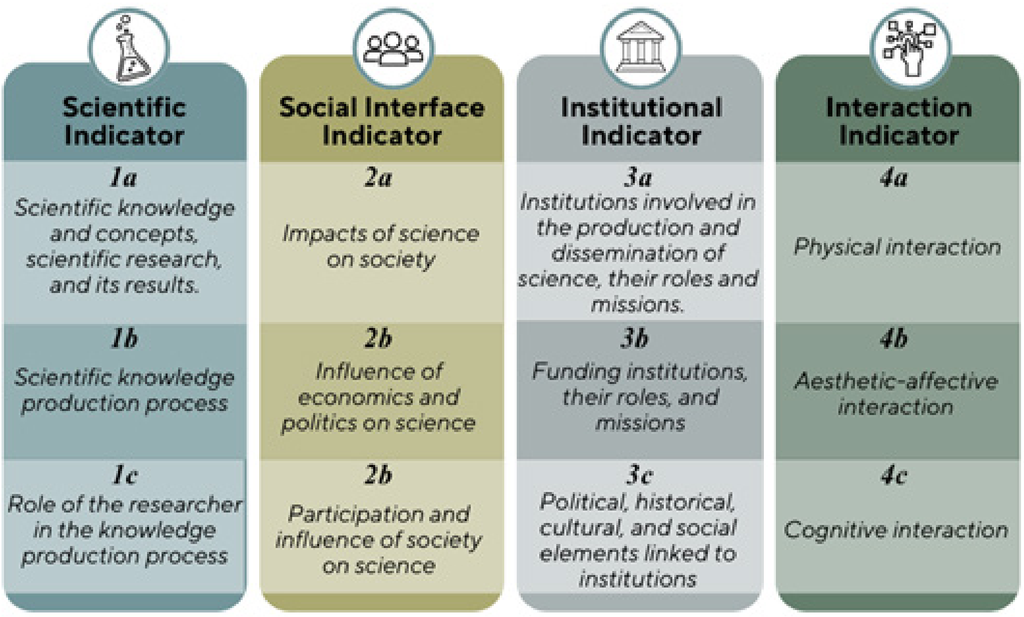
The guided tour is one of the museum's activities aimed at schoolchildren aged between 8 and 11 (the age group corresponding to the last three years of Italian primary education) and lasts one hour. The activity guide is an illustrious figure: Galileo Galilei himself (played by a museum employee), who leads participants on a tour of the scientific apparatus on display on one of the floors of the space, while presenting the history of science and its main discoveries. The records were made through notes taken by the researcher, since capturing images or audio during the activities was not permitted.

The documentary analysis consisted of examining the educational and exhibition materials available, including texts, videos, and interactive applications present in the exhibition. Given the vast size of the collection and the resources offered by the museum, we opted for a thematic approach to the research, focusing on two key instruments associated with Galileo: the telescope and the inclined plane. The descriptive plaques and materials available on the museum's official app were analyzed, totaling one text and eight videos.

Data analysis followed a deductive process, using SLIs as a theoretical-methodological tool (Figure 1) to identify and categorize visitor evidence (Cerati, 2014; Marandino et al., 2018; Norberto Rocha, 2018). This research tool has proven to be an important resource for analyzing scientific and educational practices (in some cases, dissemination) in NFES, and in this study, it has allowed for a structured understanding of the possibilities for the Museo Galileo to promote dimensions or traits of SL in its visitors (Ferreira et al., 2025b).

Figure 1

Scientific literacy indicators used for data analysis

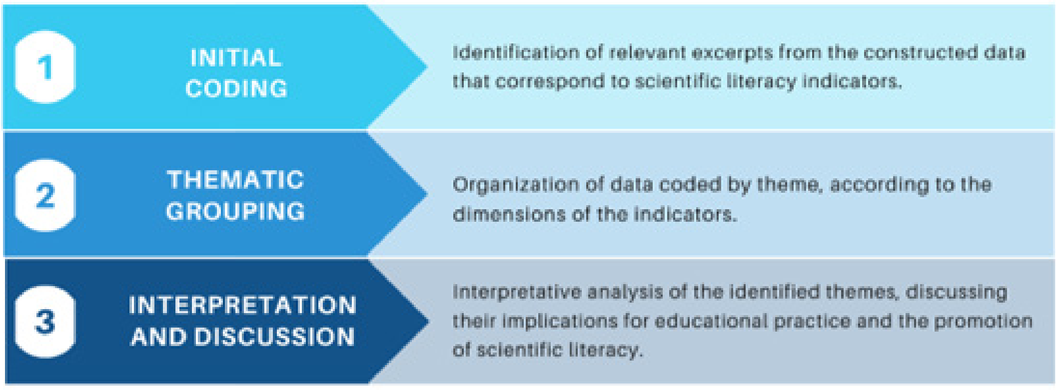


Source: Adapted from Marandino et al. (2018).

The analysis was conducted in stages, as described in Figure 2.

Figure 2

Steps followed for data analysis



The methodological approach adopted in this study allows for a detailed and contextualized analysis of the activities of the *Museo Galileo*, providing the conditions for understanding the complexity and richness of the educational practices developed. The adoption of the SLI tool aims to highlight the potential of the space to articulate its activities with socio-scientific and cultural dimensions, seeking to offer possibilities for an enriching and meaningful experience (Silva Filho & Ferreira, 2022).

Results and Analysis

The *Museo Galileo* has a large physical extension and many devices. In addition, it carries out scientific dissemination in various ways, in face-to-face or remote activities. To enable a quality analysis, it was decided to make selections. First, an analysis of the free visit using the museum's app as a guide to two types of instruments on display in the "Galileo's New World" room: telescopes and inclined planes. Then, an activity guided by instructors in the rooms on the first floor, called "A stroll with Galileo." The description of the space, the activity, and the choices is presented below, as well as the analyses of the related SLIs.

The Free Visit to the Room Galileo's New World

On the first floor, in the seventh of nine rooms, is the space dedicated especially to Galileo Galilei: Galileo's New World. It features 31 objects displayed inside or outside the showcases6 . In addition, there are three textual engravings and two screens showing explanatory videos about some of the devices on display. Upon entering, the first thing you see is an image of Galileo—a marble bust sculpted by Carlo Marcellini (1674–1677). Inside, you can immediately see the text engraving on the wall entitled "*Il nuovo mondo de Galileo*". The text presents the scientist and some of his contributions to astronomy:

6 The list of objects in each room can be accessed at: https://catalogo.museogalileo.it/indice/IndiceOggettiSalaIndiceStrumentiSala.html#s16732.

> [...] the Moon had a surface crossed by mountains and valleys like the Earth; the constellations displayed a number of stars vastly superior to those observable with the naked eye; Jupiter was surrounded by satellites (which Galileo named "Medici planets"); in its cycle, Venus had phases like the Moon; the surface of the Sun was dotted with dark spots; Saturn showed strange lateral protuberances (translated by the author).

The room largely displays scientific products such as the jovialab, Galileo's telescopes, the thermoscope, and the military compass. Usually, these scientific advances are known through photographs. However, visitors can get up close to instruments that were part of the development of science, such as Galileo's telescopes, which are located at the top of the first display case (Figure 3).

Figure 3

Display case 1 of the New World of Galileo space

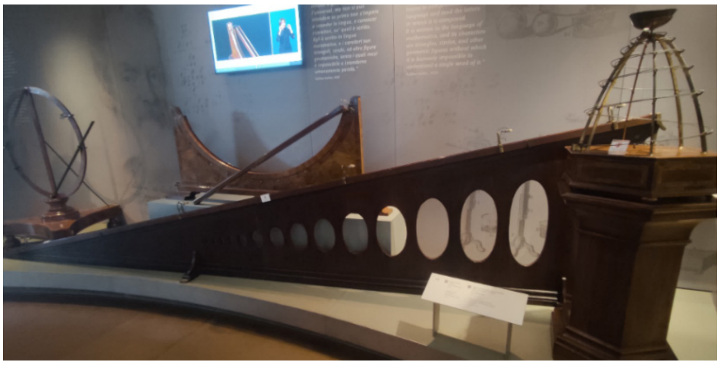
Source: authors' collection.

This first display case also contains an item of extreme importance to Galileo's studies: the objective lens (in Figure 3, in the center, below the telescopes). It was with this lens that Galileo made many of his astronomical observations and discoveries. Below it is a copy of *Siderius Nuncius* (1610), a work published by Galileo, which presents his drawings of the lunar relief. Next to it is another important text he authored: *Dialogo sopra i due massimi sistemi del mondo* (1632).

On the other side of the room, the inclined plane (Figure 4), over 5.4 m long, does not go unnoticed, along with other devices related to the movement of bodies, such as devices for demonstrating the parabolic trajectory of projectiles, the isochronism of falls along a spiral, the experiment of pendulum movements, and the brachistochrone descent.

Figure 4

Inclined plane and other instruments for studying motion displayed in the room Galileo's New World



Source: authors' collection.

Due to the size of the museum and the number of scientific objects it contains, we chose to analyze the room "Galileo's New World," which is representative of the collection of historical artifacts on display and is considered its main space. As the others (except the interactive one) follow a similar pattern, the analysis of one part of the permanent exhibition can reflect the general characteristics of the museum, especially in the historical artifacts section.

In "Galileo's New World," due to the number of devices and resources, a selection was made to evaluate two key instruments associated with Galileo: the telescope, which he perfected and used to observe the lunar surface, sunspots, and Jupiter's satellites, contributing to the collapse of Aristotelian theory; and the inclined plane, which reflects his studies on the movement of bodies and the acceleration of free fall. These instruments are related to his main works *Sidereus Nuncius* (1610) and *Dialogo sopra i due massimi sistemi del mondo* (1632).

For this analysis, all information present in the physical space was considered, such as the objects on display, the descriptive plaques, and the materials available in the museum's app, which any visitor can explore from their own smartphone. They are listed in Figure 5 as objects (O), videos (V), and texts (T).

Figure 5

Elements associated with the objects selected for analysis

Telescopes		Inclined plane	
Related item	**Code**	**Related item**	**Code**
Telescopes	O_1	Inclined plane	O_2
Galileo Galilei	T_1	Galileo Galilei	T_1
Telescope	V_1	Inclined plane	V_5
Galileo's Astronomy	V_2	Galileo and mechanics	V_6
Galileo's micrometer	V_3	Galileo and the science of motion	V_7
Helioscope	V_4	Law and free-falling bodies	V_8

The following are the elements related to the selected objects, together with the analysis of the SL indicators and attributes that characterize them.

The Free Visit and Scientific Literacy Indicators

When accessing the application to follow the free visit, the interested party will always find, as the first option in all devices, a text about Galileo Galilei (T_1). It highlights at least four attributes of two SLIs. The scientific indicator is addressed in two aspects — 1a and 1c. Products of scientific advancement are presented, with an emphasis on instruments created, improved, or developed by the scientist, such as the thermometer, compass, water extraction machine, telescope, and microscope. The text also addresses scientific discoveries made with telescopes, such as Jupiter's satellites, the phases of Venus, and sunspots.

Scientific knowledge is the fundamental basis for SL. It is through contact with this knowledge that visitors can reformulate their ideas, establish connections with pre-existing knowledge, and thus build deeper understanding. By improving their scientific understanding, they expand the possibilities for developing SL-related skills, such as the ability to make conscious everyday decisions.

The role of the researcher in the process of knowledge production is clearly evidenced in the description of science as a product of human construction, related to attribute 1c. In this context, Galileo's name is related to the scientific products and concepts he developed. The text highlights his scientific contributions and personal characteristics, humanizing the researcher and demystifying his activity by presenting his life trajectory. The narrative includes professional aspects, such as his work at Italian universities, and significant personal events, such as his birth, the loss of his daughter, and his death. These elements help to construct a broader view of the scientist, highlighting the interaction between his personal life and his discoveries, presenting him as a person with dilemmas and problems, and not just apotheoses, in line with what is expected of an honest epistemological and historical approach to science (Matthews, 1995).

In resource T_1, attribute 2b is also identified with the influence of politics on science. The Catholic Church's reaction to Galileo's statements and his defense of the Copernican theory show how religious (and political) power affected scientific development. Galileo was isolated from society, forced to recant and disavow the results of his observations. As a consequence, science was directly impacted, since, like his ideas about heliocentrism, other related scientific proposals were prohibited, hindering scientific progress in this area.

The telescopes referring to element O_1 (seen in Figure 3) intrinsically possess attributes 1a and 1c, as they are products of scientific research explicitly attributed to Galileo. The information plaque in the display case indicates that:

> The oldest telescopes were manufactured in the Netherlands in the early 17th century, but it was Galileo who first intuited their astronomical potential. Thanks to remarkable improvements, his telescopes exceeded 20 magnifications. Galileo also transformed the telescope into a measuring instrument, thus managing to determine the periods of Jupiter's satellites [...] (room "The New World of Galileo," *Museo Galileo*, 2024, authors' records in free translation).

This element can also be attributed to the interaction indicator, since it is an original object belonging to Galileo, so that, symbolically, being so close to it can provide an affective interaction (4b). This stems from the importance of the intangible object to the observer and, clearly, the respective historical, philosophical, and sociological aspects that authorize such interaction.

> The history, philosophy, and sociology of science, in the context of difficulties in understanding science, bring together the ethical, cultural, and political interests of individuals, make their subjects more stimulating and reflective, and increase their critical thinking skills (Valente, 2005, p. 56).

Element O2 (Figure 4), a 5.44-meter-long inclined plane, according to the information plaque, was built in the 19th century and has unknown origins. It is important to note that there is no consensus among researchers as to whether he actually carried out the inclined plane experiment as presented, as well as the experiment of falling bodies in the Tower of Pisa (Neves et al., 2008). However, it is undisputed that Galileo contributed to the understanding of the movement of bodies by describing the proportionality between the distance traveled by a body and the square of the time required for this movement, as described in his work *Discorsi e dimostrazioni matematiche, intorno a due nuove scienze* (Galilei, 1638).

According to research published by *Physics World* (Crease, 2002), readers ranked the inclined plane experiment eighth among the most beautiful physics experiments in history. The space that houses the inclined plane is the point of greatest interest to visitors during a visit to the room "The New World of Galileo" (Mello, 2020). In other words, it exerts an emblematic fascination on those present, being considered an object of immense relevance in the history of science, mobilizing the interaction indicator through the aesthetic-affective attribute (4b).

There are four (4) video resources related to telescopes in total (V_1, V_2, V_3, and V_4); Figure 6 shows an example of how the scientific indicator is observed.

Figure 6

Resources associated with telescopes and attributes of the scientific indicator

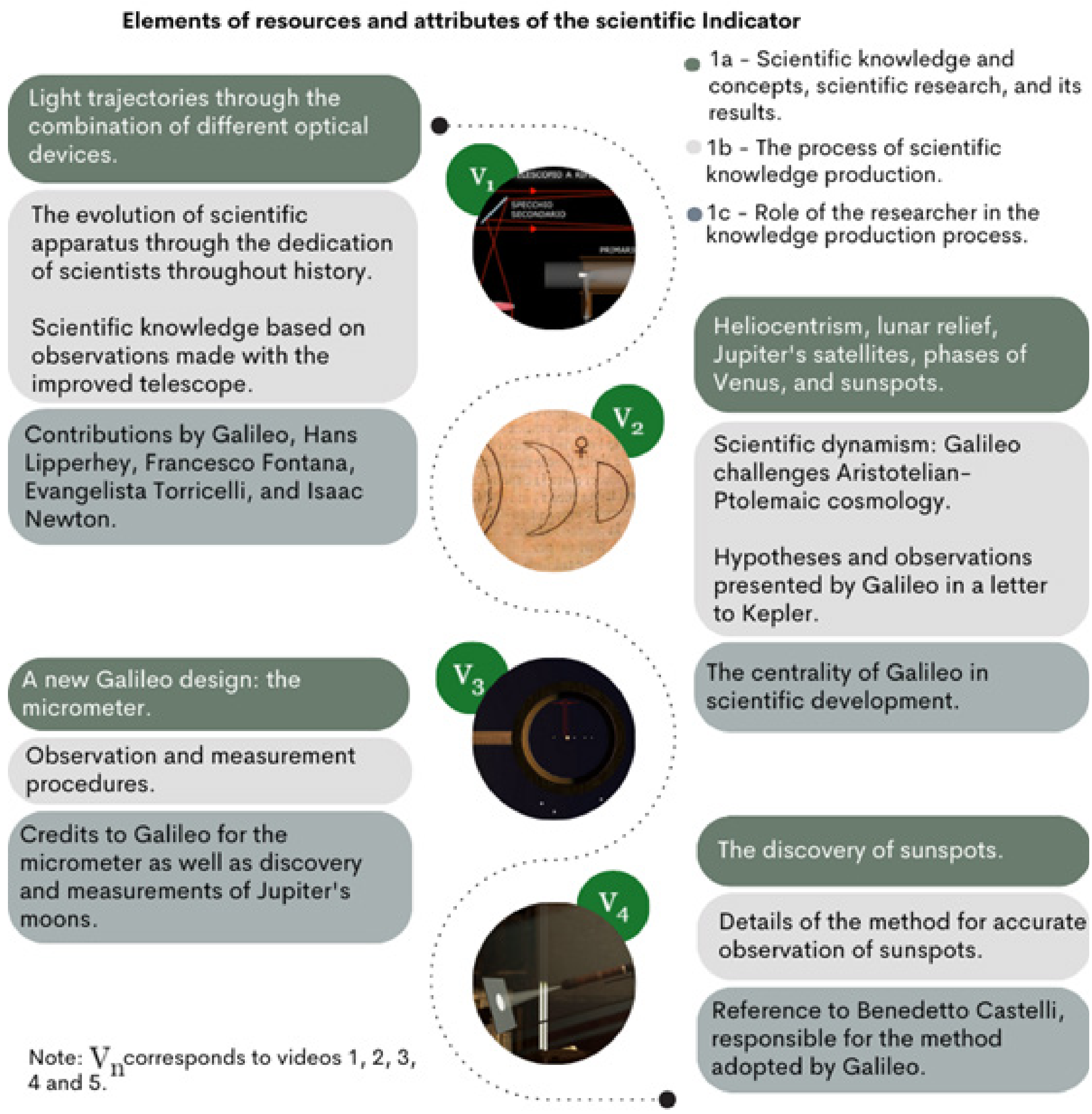
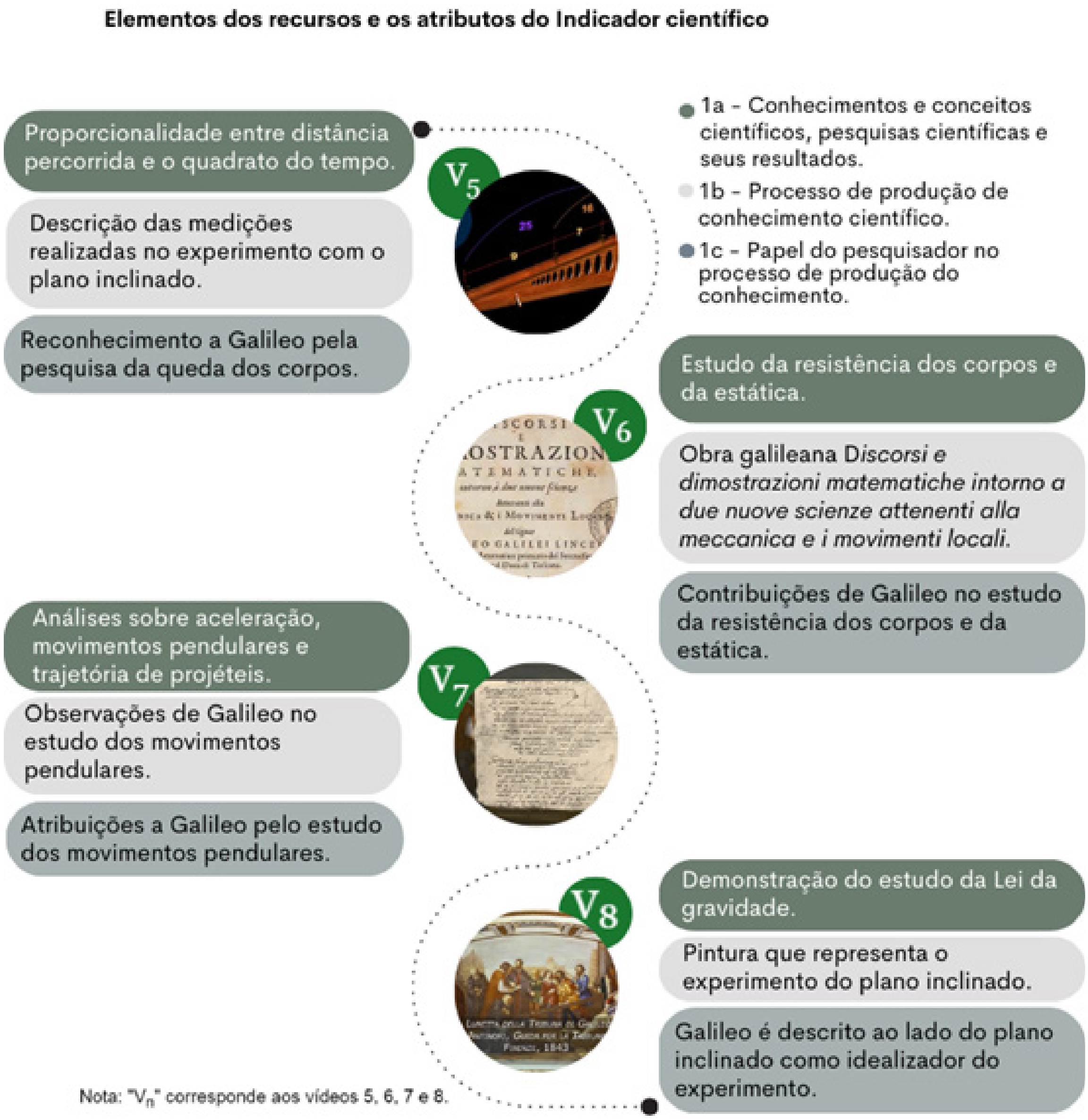


Figure 7 below shows this indicator for the four videos related to the inclined plane (V_5, V_6, V_7 and V_8).

Figure 7

Resources associated with the inclined plane and attributes of the scientific indicator



It can be observed that the three attributes of the scientific indicator are identified in the resources. Attribute 1a is related to research results, concepts, theories, and scientific ideas. Resources V_1,V_2,V_3, and V_4 address knowledge of Galileo's heliocentric theory and his observations (sunspots, phases of Venus, satellites of Jupiter, and lunar relief) thanks to the advent and improvement of the telescope. In turn, V_5,V_6,V_7, and V_8 address concepts of motion, such as the relationship between time and distance and the acceleration of bodies.

Attribute 1b emphasizes the dynamism of science and scientific methods. It is essential that visitors understand that certain knowledge is neither absolute nor immutable, and it can be questioned and revised. However, questions and transformations in scientific knowledge are based on new research, which, in turn, is based on investigative methods. Scientific results can be modified as measurement and observation instruments evolve. Thus, scientific knowledge does not originate from simple conjecture, but it is supported by solid foundations and subject to continuous modification. This point is of great relevance, as science education often conveys a positivist view, which considers science to be objective and immutable (Souza & Chapani, 2013). Thus, it is important to recover the historical character of science, which contrasts with this conception and recognizes its dynamic and evolutionary nature.

Attribute 1c is identified mainly by the reference to various scientists who contributed to the development of science, whether in the formulation of concepts, the definition of methods, or the creation of scientific equipment. This reflects the tendency to highlight science as a product of human construction, the result of collective effort and the contribution of multiple individuals over time.

Figure 8 presents a summary of the IAC assessment.

Figure 8

The resources analyzed at the Museo Galileo and the respective attributes of the IACs

Resource	Scientific Indicator			Social Interface Indicator			Institutional Indicator			Interaction Indicator		
	1a	*1b*	*1c*	*2a*	*2b*	*2c*	*3a*	*3b*	*3c*	*4a*	*4b*	*4c*
O_1	✓		✓								✓	
T_1	✓	✓	✓	✓	✓							
V_1	✓	✓	✓									
V_2	✓	✓	✓									
V_3	✓	✓	✓									
V_4	✓	✓	✓									
O_2	✓		✓								✓	
V_5	✓	✓	✓									
V_6	✓	✓	✓									
V_7	✓	✓	✓									
V_8	✓	✓	✓									

It can be seen that the attributes of the scientific indicator are widely present in the analysis undertaken. In all the resources examined, attribute 1a is present, which, as a rule, manifests itself through the presentation of scientific concepts or products. This finding is predictable, given that the instruments occupy a central position in the exhibition, also reflecting the general structure of the museum.

In view of the Interaction Indicator, attribute 4a (as well as attributes 4c[7]) related to physical interaction is not observed. This absence is understandable, given that the artifacts in question are historical and their handling is restricted by preservation requirements. Similarly, other attributes were not identified in this analysis. At this point, it is important to note that this limitation is only a snapshot of the museum's proposal, since there are spaces dedicated to interactive rooms, guided activities, and other areas where such attributes could be found.

It should be noted that, during a free visit, the explanatory texts and resources available through the app or screens in the exhibition room contribute significantly to enhancing communication with the public, in addition to enabling the contemplation of the SLIs. The objects themselves have the power to immerse visitors in history, allowing them to feel closer to it and making it, presumably, more tangible than the representations seen in textbooks. In addition, the audiovisual resources offered deepen this immersive experience, allowing visitors to come into direct contact with the concepts associated with them, as well as with the relevant historical contexts. The museum thus provides resources that enable a more comprehensive visiting experience, transcending the images and objects exhibited within the institution's walls.

These new forms of interaction and communication by NFESs (particularly science museums) are central to maintaining and updating their nature, scope, characteristics, and functions, seeking assertive, effective, and high-quality dialogue with visitors.

The Guided Tour: Meet Galileo

The *Museo Galileo*, through its educational group, offers activities for students of various age groups, from childhood to adolescence, through the "Museum for Schools" program. Among these, the use of playfulness to teach children stands out, as in the puppet theater "Once upon a time... at the *Museo Galileo*: the story of puppets." For more advanced students, there are other activities, such as "Galileo, Bacon, and Kepler: a journey through science, reality, and imagination," which seeks to promote reflection on the exchange of knowledge and cooperation between notable researchers during the scientific revolution, beginning in the 16th century.

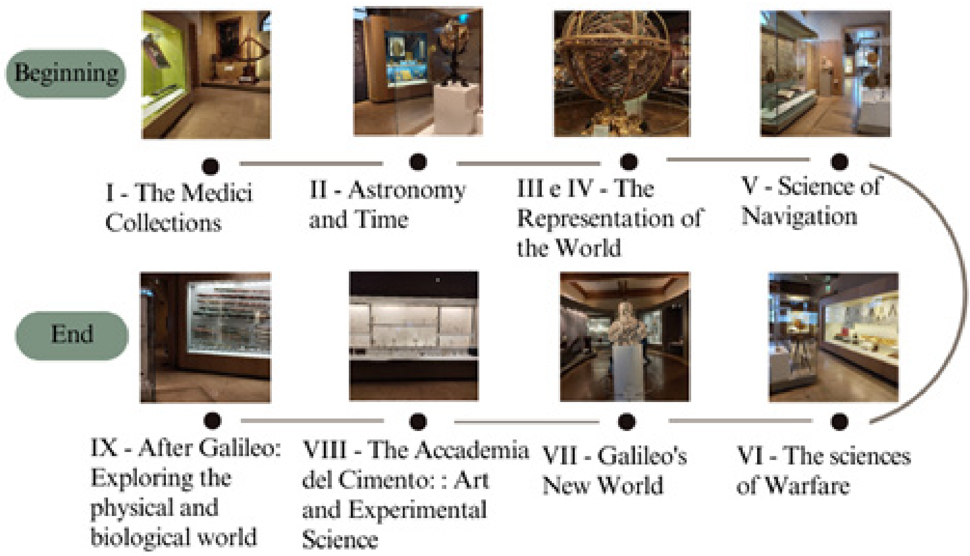
Among the proposed activities, the guided tour "Meet Galileo" was chosen because it is an activity that explores the museum environment in a dynamic way, combining elements of a free visit with a different approach to communication through a guide. In addition, the central theme of the visit is Galileo, who, as a historical figure, leads and presents the artifacts to visitors. Finally, the itinerary includes one of the museum's main attractions: the room "Galileo's New World," considered the heart of the exhibition.

7 Although attribute 4c (cognitive interaction) may be present, it was not feasible to observe it, since the researcher did not have full access to the interactions that took place during the guided tour and their possible consequences for the participants.

Lasting about an hour, the tour takes the public to the exhibitions on the first floor, where the Medici family collection is located. The space is divided into nine rooms arranged chronologically, and the tour follows this order (Figure 9), presenting the main scientific instruments on display.

Figure 9

Route of the guided tour "Meet Galileo"



As visitors, students have the opportunity to explore the museum's rooms and artifacts and encounter a key figure in the history of science: Galileo Galilei. This is how the guide introduces himself, wearing clothing appropriate to the scientist's historical period. The character leads visitors on the tour while presenting the scientific artifacts that preceded and followed his career, in addition to his own discoveries and original artifacts, such as the telescopes from 1609 and 1610.

In accordance with the layout of the museum rooms, the presentation follows a chronological order that narrates the evolution of the history of science. The first two rooms display a vast collection of measuring instruments, such as quadrants, astrolabes, sundials, and night clocks. Next, in rooms III and IV, several terrestrial and celestial globes are displayed, notably an imposing armillary sphere (1588–1593) measuring 3.7 meters in height. It is an object of great visual impact, both for its grandiose dimensions and its beauty. It represents the "universal machine" of the world, according to Aristotelian-Ptolemaic conceptions. At this point in the visit, a brief explanation is given about the difficulties faced by those who opposed this system in the 16th and 17th centuries, with Giordano Bruno being an example of a historical figure who lost his life defending an alternative view to that represented by this apparatus.

The visit continues to the "Science of Navigation" room, displaying various instruments that illustrate the history of maritime science during the period of great navigations. Here, the guide also presents the bust of an important figure in the history of navigation: the cartographer Amerigo Vespucci, from whom the name "New World," America, originated.

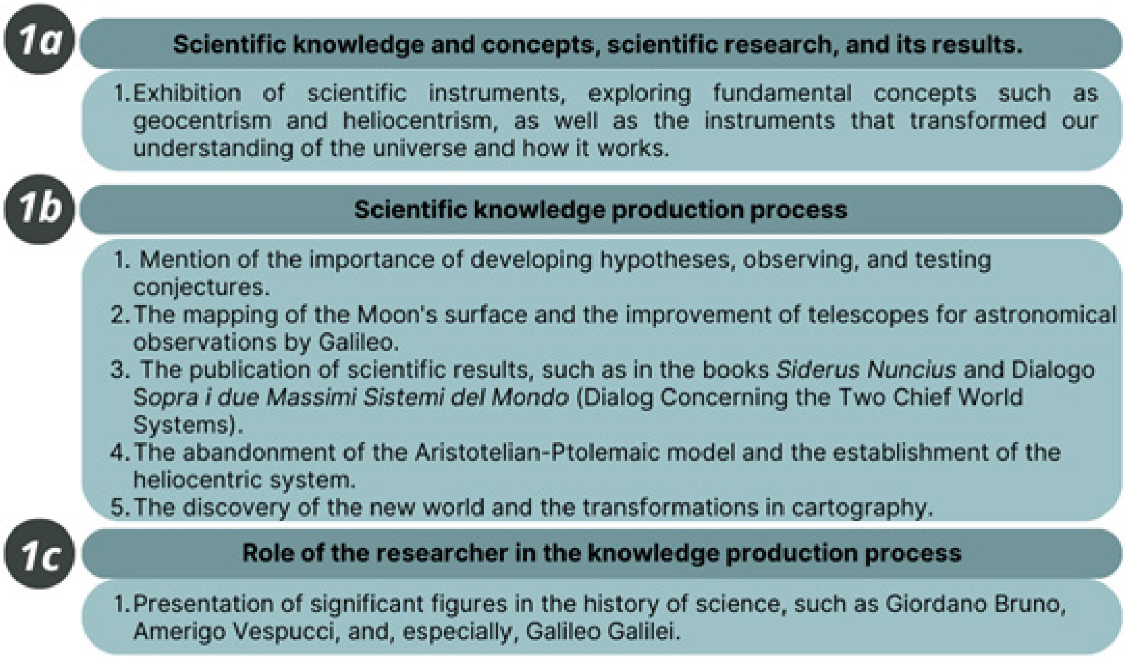
After the beginning of this journey, based on a universe still centered on the Earth, Galileo Galilei, the tour guide, begins the presentation of a period of history of which he became a fundamental part. As an introduction, to explain how his telescopes work, he presents and offers visitors two lenses with different focal lengths; thus, they can manipulate the lenses, adjusting the distance between them to find the best way to view distant objects through one of the museum's windows. With this activity, Galileo introduces two of his original instruments, which are in the room "Galileo's New World" and represent some of his most important innovations: telescopes. The guide, in the first person, explains his astronomical discoveries, such as the moons of Jupiter and the relief of the Moon, illustrated in his book on display, *Siderius Nuncius*, and discusses his renunciation of the Copernican theory in order to save his life in the face of conflict with the Catholic Church.

The visit continues with the observation of other objects related to Galileo, such as the thermoscope and the microscope, and culminates in the last two rooms (VIII and IX), which cover periods after his time. Room VIII displays instruments used in research conducted by members of *The Accademia del Cimento*, who followed in Galileo's footsteps in conducting experiments and studying the principles of natural philosophy. The visit ends in the last room, with instruments from the second half of the 17th century, such as more advanced microscopes and larger telescopes with more complex optical arrangements than those of Galileo.

During the guided tour, several SLIs are observed. This analysis focuses on evaluating the visit, not in the order in which it was conducted, but highlighting the SL indicators and attributes observed in the interaction between the guide and visitors. Figure 10 illustrates some points that exemplify the scientific indicator approach.

Figure 10

Scientific indicator in the guided tour "Meet Galileo"



The first scientific attribute is explored throughout the visit, both through the presentation of historical artifacts, considered scientific instruments, and through the concepts associated with them (1a.1). The visit highlights, in particular, the aspects of heliocentrism and geocentrism. This attribute is intrinsic to the activity and central to understanding the topics covered.

Attribute 1b addresses the scientific method (1b.1), linked to Galileo, as well as the presentation of his research results (1b.2) and scientific publications (1b.3). This indicator highlights the uncertain and provisional nature of science (1b.4), showing that science is not definitive, but is always open to questioning and reformulation based on new discoveries. Critical thinking is essential to drive new studies and promote the continuous development of science.

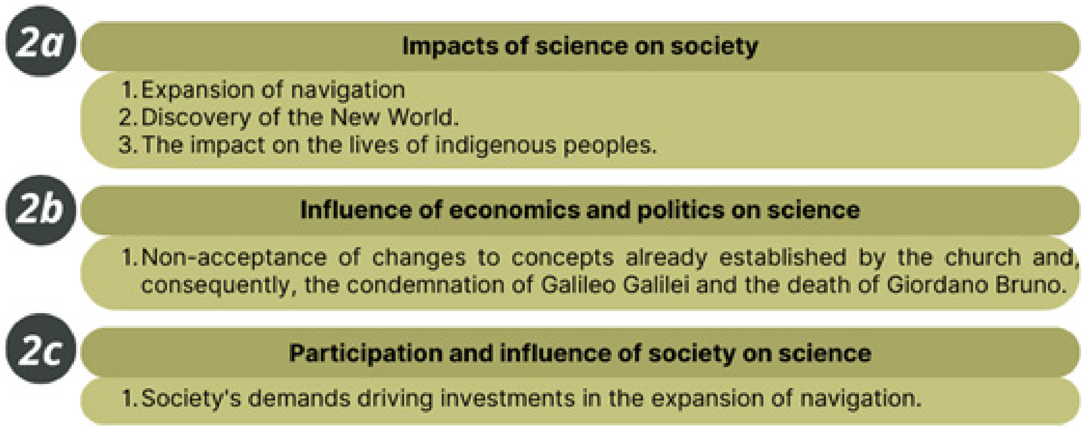
This favors the objective of SL, which aims to develop citizens' skills and abilities to contribute to society through debates and positions, with a view to improving the world in which they live. Controversies are often present in scientific and technological development (Colombo Jr. & Marandino, 2020; Matthews, 1995), developing skills related to SL.

The last attribute of this indicator (1c) is addressed by highlighting science as a product of human construction, developed by various scientists throughout history. According to Matthews (1995), the historical aspects of science can humanize it, which, in turn, can stimulate the learning of scientific concepts. The History of Science demonstrates that science is not something ready or definitive, but rather a field in constant transformation, shaped by the contributions of scientists over time.

The second indicator (social) is identified in all its attributes (Figure 11).

Figure 11

Social indicator in the guided tour "Meet Galileo"



The tour explores how the evolution of scientific instruments for location and measurement enabled the expansion of navigation (2b.1). This development had a major impact on society, allowing the discovery of unknown territories, called the "new world," now known as America. However, the indigenous peoples suffered dramatic consequences, with a large part of their populations decimated by the visitors. Thus, it is possible to show that science, in its development, can impact society in a positive or negative way. Understanding these situations contributes to the improvement of citizens' critical thinking, stimulating their critical sense and providing a better understanding of their daily lives. "This indicator promotes understanding of the social significance of science and explores the interrelationships between the scientific, technological, social, and environmental spheres" (Cerati, 2014, p. 82).

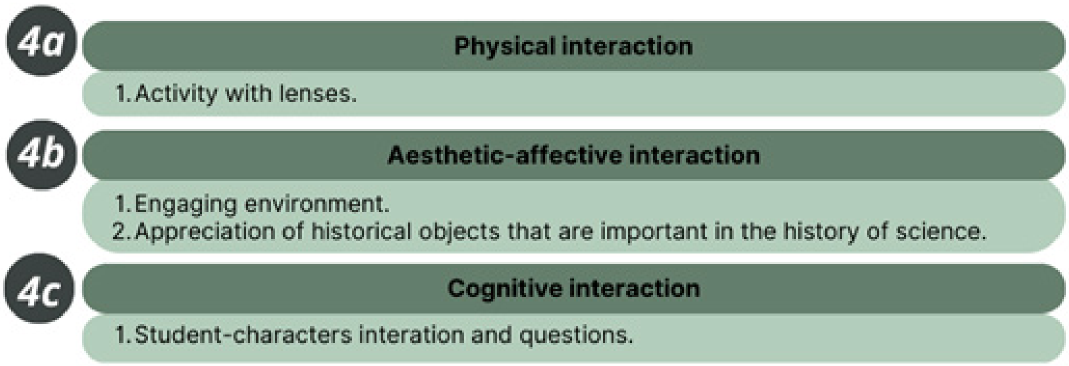
The negative influence of the Church on science is addressed during the visit, focusing mainly on two historical figures: Giordano Bruno and Galileo Galilei (2b.2). This attribute allows students to identify how science, economics, and politics, in this case represented by the Church, are interconnected and interdependent.

The Galileo guide explains how society's demands drove investment in the expansion of navigation, which led to the advancement and improvement of the measuring instruments used to guide ships (2b.3). The need for sea travel positively drove scientific progress in this area, in addition to highlighting the influence of science on human history.

The third indicator present in the visit is interaction, which is shown in Figure 12.

Figure 12

Interaction indicator in the guided tour "Meet Galileo"



Physical interaction with the objects on display is not permitted, as it is impossible to handle them due to their historical value. However, there is a moment of physical interaction (4a.1) during the visit, when Galileo Galilei presents his pair of lenses (similar to those that make up his telescopes), capable of allowing a clearer observation of distant objects through the museum window. Three pairs of lenses are made available to students, who individually position the lenses in front of each other, adjusting the distances to find the best configuration for observing a distant point.

The visit is structured to tell the history of science through scientific instruments, providing an experience that engages visitors. The history and evolution of science become "tangible" as the evolution of historical instruments is explored (4b.2). Being so close to centuries-old artifacts that narrate the history of humanity through science can generate excitement in visitors, connecting them to historical events. This becomes even more impactful with Galileo's two telescopes, which were in the hands of one of the most important scientists in history and aided in research that profoundly influenced the development of science and society.

It is clear that visitors feel enthusiastic during the tour, as they frequently ask the guide questions, demonstrating interest and curiosity about the artifacts and the history of science. This engagement demonstrates a willingness to learn, which is an essential element in the pursuit of learning (Ausubel & Robinson, 1969; Falk & Storksdieck, 2005; Silva Filho & Ferreira, 2022). The atmosphere of the museum, Galileo himself as the tour guide, and the proximity to centuries-old objects that are part of the history of science favor aesthetic-affective interaction during the visit. Curiosity, manifested in the students' behavior, is an emotion that activates learning, stimulating energy and motivation, essential factors for the educational process (Agen & Ezquerra, 2021).

Throughout the visit, there is interaction between the guide and the visitors to ask them about their observations (4c.1). It is not, therefore, just a presentation, a monologue, but an activity with participation and freedom. One of the main objectives of museums is to encourage visitors to learn, making them leave the place with more questions and concerns than when they entered. Thus, "the museum is a tool for change, for individual change and, therefore, also for social change" (Wagensberg, 2005, p. 311). During the visit, social interaction between visitors, guides, and colleagues creates an environment conducive to the exchange of knowledge and reflection. The questions raised serve as stimuli for the active participation of visitors, who, through discussions, have the opportunity to review their conceptions and construct knowledge from a critical and reflective stance, in line with new learning theories (Silva Filho & Ferreira, 2018; Silva Filho & Ferreira, 2022).

The guided tour "A stroll with Galileo" presents all the attributes of the scientific indicator, in addition to those associated with social interface and interaction. A distinguishing feature of this experience in relation to the free visit of the adopted section is the possibility of manipulation at a certain point in the activity. Adopting the chronological order of events in the history of science contributes to understanding and favors the perception of the various factors that influence scientific development and its susceptibility to change (Valente, 2005). The intrinsic characteristic of the guided tour, which aims to guide its participants, is a factor that favors learning in museum spaces. Disorientation impairs the ability to concentrate on the exhibition and, consequently, learning (Falk & Storksdieck, 2005). It is highly likely that a free visit with large groups, such as a school class, will become chaotic. In contrast, during a guided tour, students are properly guided, which enhances their experience and facilitates learning.

Final Remarks

The research reported in this article sought to present a snapshot of the activities of the *Museo Galileo*, such as NFES, located in Florence, Italy. The historical objects in the exhibition can be considered its central part; however, several other sectors orbit this activity and could not be covered, due to limitations of scope and space, such as the research institute, the specialized library, the historical archive, and the photographic and multimedia laboratories (Casati, 2015). This is a second-generation science museum with significant historical weight and an impressive collection, whose analysis revealed enormous potential for promoting SL in its exhibition space.

As for SL, it can be observed that the museum, in the established context, covers the attributes of scientific, social, and interaction indicators. The scientific indicator is present in virtually all resources related to telescopes and the inclined plane, as well as in the guided tour. The preservation and dissemination of historical objects, especially scientific instruments, is intrinsic to the space. Many artifacts, such as quadrants, astrolabes, and telescopes, are products of science, created according to the knowledge and needs of each era. Scientific concepts are addressed mainly through the guides' explanations, as well as explanatory texts and videos available on the smartphone app and on the exhibition screens.

The *Museo Galileo* is a second-generation NFES that focuses on exploring the history of science through unique objects that, due to their importance and exclusivity, do not allow direct physical interaction. However, participation, public engagement, and the creation of an atmosphere for the discussion of scientific concepts are promoted by the possibilities of presentation, without losing the essential characteristics, in particular the priority given to the conservation and storage of historical artifacts. The interactive room, the smartphone, and the app for guided tours are valuable resources that the museum has developed to improve its communication with the public.

In this way, the *Museo Galileo* manages to balance its responsibility for the preservation of historical artifacts with that of responding to changes in educational formats and the demands of the contemporary public. This model allows it to remain relevant, providing dynamic and accessible educational experiences with high socio-scientific value, without compromising the preservation of heritage. This meets the need for museums to communicate effectively with increasingly broad, diverse, and *cyberculture-immersed audiences* (Ferreira et al., 2020; Ferreira et al., 2022b; Ferreira, Diniz & Mello, 2025a), which involves offering conceptual objects of science associated with the promotion of immersive experiences that connect the public with history and scientific processes (Valente, 2005).

Scheduled school visits offer experiences that are different from those experienced in the formal education environment, allowing interaction with historical artifacts and differentiated contact with knowledge, reflecting, in addition to school activities, different ways of learning (Marandino, 2001). In addition, they strengthen the connection between the school curriculum and museums, contributing to the consolidation of a scientific culture (Santos & Germano, 2020). By presenting science in an amplified way and promoting participatory dynamics, the collection and dynamics contained in the *Museo Galileo* have the potential to arouse the interest of students and contribute to the popularization of science and the formulation and enhancement of consistent public policies.

In addition to the theoretical and epistemological contributions related to the characteristics, possibilities, and limitations of a second-generation NFES for the development of SL, the study highlights the importance of the role and continuing education of the guide in mediating knowledge, enhancing the articulation of socio-scientific and cultural dimensions and providing opportunities for meaningful learning experiences (Ferreira et al., 2025b; Silva Filho & Ferreira, 2022). Thus, it offers practical support for the development of educational programs and communication strategies that make museums even more dynamic and attractive spaces for the contemporary public.

Second-generation museums have, in fact, been seeking to incorporate some aspects of the third generation, such as interaction with the public, without losing their characteristic functions, as observed in this research sample. Examples of this are the videos presented in exhibition rooms, in which digital technology is used to enhance communication with visitors, attracting attention and focusing on specific concepts or aspects of the history of science related to the artifacts on display (Friedman, 2010). The use of multimodal resources, including interactive elements and narratives that contextualize scientists as historical subjects, expands pedagogical possibilities, favoring more meaningful and engaged access to the knowledge it conveys.

The educational activities of the *Museo Galileo* demonstrate that (and how) it is possible, even in a space filled with intangible objects, to establish closer communication with school-age visitors and, from there, promote dimensions of SL. In Brazil and among Brazilians, where scientific culture is not yet a common social good, museums can be perceived as elitist, perfunctory, monotonous, and uninteresting environments; however, the example investigated demonstrates that these spaces have the potential to arouse interest and make the experience engaging, meeting contemporary demands for accessibility, quality, and versatility of scientific culture (Marandino, 2008). Such diversification, combining different procedures, contributes to the success of the exhibition. Furthermore, the heritage of the history of science is too vast and relevant to be limited to physical space, which restricts the possibilities of addressing various aspects of the historicity presented. By resorting to new means of communication, this obstacle is, to a certain extent, addressed and challenged.

References

Agen, F., & Ezquerra, Á. (2021). Análisis de las emociones en el trabajo de indagación: La Caja Negra. *Investigación en la Escuela*, (103), 125–138. https://doi.org/10.12795/IE.2021.i103.09

Allen, S., & Gutwill, J. P. (2009). Creating a program to deepen family inquiry at interactive science exhibits. *Curator: The Museum Journal*, *52*(3), 289–306. https://doi.org/10.1111/j.2151-6952.2009.tb00352.x

Bassalo, J. M. F. (1995). Nascimentos da Física: Idade Renascentista (4-95-2). *Revista Brasileira de Ensino de Física*, *17*(4), 337–354.

Bevan, B., & Penuel, W. R. (2017). *Connecting research and practice for educational improvement: Ethical and equitable approaches*. Routledge.

Camerota, F. (2012). A new name, a new look, a new way of communicating. In F. Camerota (Ed.), *Displaying Scientific Instruments: From the Medici Wardrobe to the Museo Galileo* (pp. 203–229). Goppion.

Casati, S. (2015). La Biblioteca digitale del Museo Galileo. *Biblioteche Oggi*, 33(1), 45–51. https://www.doi.org/10.3302/0392-8586-201501-045-1

Cazelli, S., Queiroz, G., Alves, F., Falcão, D., Valente, M. E., Gouvêa, G., & Colinvaux, D. (1–4 de setembro, 1999). *Tendências pedagógicas das exposições de um museu de ciência*. II Encontro Nacional de Pesquisa em Educação em Ciências (ENPEC), Valinhos, São Paulo.

Cerati, T. M. (2014). *Educação em jardins botânicos na perspectiva da alfabetização científica: Análise de uma exposição e público* (Tese de Doutorado, Universidade de São Paulo, São Paulo). Biblioteca Digital de Teses e Dissertações da USP. https://doi.org/10.11606/T.48.2014.tde-02042015-114915

Chassot, A. (2003). Alfabetização científica: Uma possibilidade para a inclusão social. *Revista Brasileira de Educação*, *26*, 89–100. https://doi.org/10.1590/S1413-24782003000100009

Coimbra-Araújo, C. H., Speck, R. A., Ferreira, G. K., Bartelmebs, R. C., Berticelli, D. G. D., Santos, G. R., Schreiner, M. A., Monte-Alto, H. H. L. C., Tonezer, C., Rosset, I. G., & Bergold, A. W. de B (2020). A pesquisa em ensino de CTEM e sua interação com aspectos da educação não formal e espaços não formais. *Caderno Brasileiro de Ensino de Física*, *37*(1), 315–331.

Colombo Júnior, P. D., & Marandino, M. (2020). Museus de ciências e controvérsias sociocientíficas: Reflexões necessárias. *Journal of Science Communication – América Latina*, *3*(1), A02. https://doi.org/10.22323/3.03010202

Crease, R. P. (2002). The most beautiful experiment. *Physics World*, *15*(9), 19–20.

Dawson, E. (2019). *Equity, exclusion and everyday science learning: The experiences of minoritised groups*. Routledge.

Falk, J. H., & Storksdieck, M. (2005). Learning science from museums. *História, Ciências, Saúde-Manguinhos*, *12*(suppl), 117–143. https://doi.org/10.1590/S0104-59702005000400007

Ferreira, M., Silva Filho, O. L., Costa, M. R. M., Portugal, K. O., Lima, L. M., Pera, G., Rocha, J. V. S., Alves, P. L., Zanetti, H. M., & Sacerdote, H. C. S. (2020). Ensaio sobre as inter-relações entre arquitetura escolar, cibercultura e ensino de Ciências: desafios e propostas para as juventudes da Geração Y. *Revista do Professor de Física*, *4*(3), 1–29. https://doi.org/10.26512/rpf.v4i3.35431

Ferreira, M., da Silva Filho, O. L., Portugal, K. O., de Araújo Bottechia, J. A., Lima, M. B., Costa, M. R. M., & Oliver, N. A. D. (2022a). Formação continuada de professores de Ciências em caráter investigativo, interdisciplinar e com mediação por tecnologias digitais. *Revista Brasileira da Pós-Graduação*, *18*(39), 1–39. https://doi.org/10.21713/rbpg.v18i39.1971

Ferreira, M., Portugal, K. O., Oliveira, A. A. D., Duarte, I. D. S. R., Ferreira, D. M. G., & Mill, D. (2022b). Jornadas formativas mediadas por tecnologias digitais na formação inicial do professor de Física: reflexões a partir da experiência em uma disciplina de Metodologia do Ensino. *Revista de Enseñanza de la Física*, *34*(1), 129–150. https://doi.org/10.55767/2451.6007.v34.n1.37939

Ferreira, M., Costa, M. R. M., & Demo, P. (2023). Perspectivas, contradições e crítica do letramento científico como dispositivo educacional: Entrevista com Pedro Demo. *Revista da FAEEBA – Educação e Contemporaneidade*, *32*(69), 292–312. https://doi.org/10.21879/faeeba2358-0194.2023.v32.n69.p292-312

Ferreira, M., Costa, M. R. M., Cerqueira, E. N. G. M., & da Silva Filho, O. L. (2024). Letramento científico no século XXI: definições, problemáticas, desafios e avanços na Educação Superior. *e-Boletim da Física*, *12*(1), 1–10. https://doi.org/10.26512/e-bfis.v12i1.53327

Ferreira, M., Diniz, D. S., & Mello, A. S. (2025a). Conectando Saberes: Tecnologias Digitais como Dispositivo no Projeto Horta Mágica e na Educação Sustentável em uma Escola Integral. *Dialogia*, (54), e28002. https://doi.org/10.5585/54.2025.28002

Ferreira, M., Schwerz, R. C., Batista, M. C., & da Silva Filho, O. L. (2025b). Panorama da Alfabetização Científica em Espaços Não-Formais de Educação no Brasil a partir de Publicações Científicas de Impacto. *Investigações em Ensino de Ciências*, *30*(2), 194–219. https://ienci.if.ufrgs.br/index.php/ienci/article/view/4143

Friedman, A. J. (2010). The evolution of the science museum. *Physics Today*, *63*(10), 45–51. https://doi.org/10.1063/1.3502548

Fontana, F., & Rosa, M. P. (2021). Observação, questionário, entrevista e grupo focal. In C. O. A. Magalhães Júnior, & M. C. Batista (Orgs.), *Metodologia da Pesquisa em Educação e Ensino de Ciências* (pp. 220–252). Massoni.

Fourez, G. (1994). *Alphabétisation scientifique et technique: Essai sur les finalités de l'enseignement des sciences*. De Boeck Université.

Galilei, G. (1610). *Sidereus Nuncius*. Tommaso Giunti.

Galilei, G. (1632). *Dialogo Sopra i Due Massimi Sistemi del Mondo*. Gian Battista Landini.

Hein, G. E. (1995). The Constructivist Museum. *Journal for Education in Museums*, *16*, 21–23.

Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. *Science Education*, *82*(3), 407–416. https://doi.org/10.1002/(SICI)1098-237X(199806)82:3%3C407::AID-SCE6%3E3.0.CO;2-G

ICOM. (2025). *Museum definition*. https://www.icom.org.br/nova-definicao-de-museu-2/

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education*, *84*(1), 71–94. https://doi.org/10.1002/(SICI)1098-237X(200001)84:1%3C71::AID-SCE6%3E3.0.CO;2-C

Miniati, M. (2017). Birth and life of Scientific Collections in Florence. *Museologia & Interdisciplinaridade*, *5*(9), 14–41. https://doi.org/10.26512/museologia.v5i9.17201

Marandino, M. (2001). Interfaces na relação museu-escola. *Caderno Brasileiro de Ensino de Física*, *18*(1), 85–100. https://periodicos.ufsc.br/index.php/fisica/article/view/6692

Marandino, M. (2008). *Educação em museus: A mediação em foco*. Geenf.

Marandino, M., Norberto Rocha, J., Cerati, T. M., Scalfi, G., de Oliveira, D., & Lourenço, M. F. (2018). Ferramenta teórico-metodológica para o estudo dos processos de alfabetização científica em ações de educação não formal e comunicação pública da ciência: Resultados e discussões. *Journal of Science Communication – América Latina*, *1*(1), A03. https://doi.org/10.22323/3.01010203

Marques, A. C. T. L., & Marandino, M. (2017). Alfabetização científica, criança e espaços de educação não formal: Diálogos possíveis. *Educação e Pesquisa*, 44, e170831. https://doi.org/10.1590/S1678-4634201712170831

Matthews, M. (1995). História, filosofia e ensino: A tendência atual de reaproximação. *Caderno Brasileiro de Ensino de Física*, *12*(3), 164–214. https://periodicos.ufsc.br/index.php/fisica/article/view/7084

Mello, D. A. T. (2020). *Design e ergonomia na divulgação da ciência e a questão dos museus para a alfabetização científica: O caso do Museo Galileo* (Tese de Doutorado, Universidade Tecnológica Federal do Paraná, Ponta Grossa, Paraná). Repositório Institucional da Universidade Tecnológica Federal do Paraná. http://repositorio.utfpr.edu.br/jspui/handle/1/24488

Mello, D. A. T., Neves, M. C. D., Mello, A. J. T. S., & dos Santos, G. B. S. (2022). A Model-Based Analysis of the Museo Galileo Interactive Area. *Science & Education*, *32*(4), 1197–1219. https://doi.org/10.1007/s11191-022-00360-0

McManus, P. M. (1992). Topics in Museums and Science Education. *Studies in Science Education*, *20*(1), 157–182. https://doi.org/10.1080/03057269208560007

Naess, A. (2015). *Galileo Galilei: Um revolucionário e seu tempo*. Zahar.

Nascimento, S. S., & Ventura, P. C. S. (2001). Mutações na construção dos museus de ciências. *Pro-posições*, *12*(1), 126–138. https://periodicos.sbu.unicamp.br/ojs/index.php/proposic/article/view/8644016

Neves, M. C. D., Batista, J. M., Costa, J. R., Gomes, L. C., Batista, M. C., Fusinato, P. A., Almeida, F. R., Silva, R. G. R., Savi, A. A., & Pereira, R. F. (2008). Galileo fez o experimento do plano inclinado. *Revista Electrónica de Enseñanza de las Ciencias*, *7*(1), 226–242.

Neves, M. C. D., & Silva, J. A. P. (2023). Ciência informal e o crossroad entre arte e ciência. *Revista em Extensão*, *22*(2), 68–81. https://doi.org/10.14393/REE-v22n22023-68116

Norberto Rocha, J. (2018). *Museus e centros de ciências itinerantes: Análise das exposições na perspectiva da Alfabetização Científica* (Tese de Doutorado, Universidade de São Paulo, São Paulo). Biblioteca Digital de Teses e Dissertações da USP. https://doi.org/10.11606/T.48.2018.tde-03122018-122740

Palmieri, L. J., Silva, C. S., & Lorenzetti, L. (2017). O enfoque Ciência, Tecnologia e Sociedade como promoção da Alfabetização Científica e Tecnológica em Museus de Ciências. *ACTIO*, *2*(2), 21–41. http://dx.doi.org/10.3895/actio.v2n2.6783

Queiroz, I. L. F. D., & Costa, L. F. D. (2024). Museus e entes parceiros: boas práticas de ações inclusivas. *Em Questão*, *30*, e-140006. https://doi.org/10.1590/1808-5245.30.140006

Ribeiro, A., & Soares, O. de J. (2019). *Educação, museus de ciência e museologia social: Aproximações possíveis*. XII Simpósio Pedagógico e Pesquisa em Educação.

Santos, T. S., & Germano, M. G. (2020). Relação museu-escola: Influências da escola nas abordagens museais. *Caderno Brasileiro de Ensino de Física*, *37*(2), 971–1003. https://doi.org/10.5007/2175-7941.2020v37n2p971

Sasseron, L. H., & Carvalho, A. M. P. (2008). Almejando a alfabetização científica no ensino fundamental: A proposição e a procura de indicadores do processo. *Investigações em Ensino de Ciências*, *13*(3), 333–352. https://ienci.if.ufrgs.br/index.php/ienci/article/view/445

Sasseron, L. H., & Carvalho, A. M. P. (2011). Alfabetização científica: Uma revisão bibliográfica. *Investigações em Ensino de Ciências*, *16*(1), 59–77. https://ienci.if.ufrgs.br/index.php/ienci/article/view/246

Silva, M. B., & Sasseron, L. H. (2021). Alfabetização científica e domínios do conhecimento científico: Proposições para uma perspectiva formativa comprometida com a transformação social. *Ensaio Pesquisa em Educação em Ciências*, *23*, e34674. https://doi.org/10.1590/1983-21172021230129

Silva, M. G. L., Marbà-Tallada, A., & Márquez Bargalló, C. (2024). Da leitura da realidade à ação problematizadora: Uma análise do nível de consciência no desenvolvimento do pensamento crítico. *Revista Brasileira de Pesquisa em Educação em Ciências*, e51094, 1–35. https://doi.org/10.28976/1984-2686rbpec2024u795829

Silva Filho, O. L., & Ferreira, M. (2018). Teorias da aprendizagem e da educação como referenciais em práticas de ensino: Ausubel e Lipman. *Revista do Professor de Física*, *2*(2), 104–125.

Silva Filho, O. L., & Ferreira, M. (2022). Modelo teórico para levantamento e organização de subsunçores no âmbito da Aprendizagem Significativa. *Revista Brasileira de Ensino de Física*, *44*, e20210339. https://doi.org/10.1590/1806-9126-RBEF-2021-0339

Souza, A. L. S., & Chapani, D. T. (2013). Teoria crítica de Paulo Freire, formação docente e o ensino de ciências nos anos iniciais de escolaridade. *Revista Lusófona de Educação*, *25*(25), 119–133. https://revistas.ulusofona.pt/index.php/rleducacao/article/view/4383

Valente, M. E. A. (2005). O Museu de Ciência: Espaço da história da ciência. *Ciência & Educação*, *11*(1), 53–62. https://doi.org/10.1590/S1516-73132005000100005

Valente, M. E., Cazelli, S., & Alves, F. (2005). Museus, ciência e educação: novos desafios. *História, Ciências, Saúde-Manguinhos*, *12*(suppl), 183–203. https://doi.org/10.1590/S0104-59702005000400010

Wagensberg, J. (2005). The "total" museum, a tool for social change. *História, Ciências, Saúde-Manguinhos*, *12*(suppl), 309–321. https://doi.org/10.1590/S0104-59702005000400015

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