https://doi.org/10.28976/1984-2686rbpec2024u297320

Submitted on 29 march 2023
Accepted on 10 january 2024
Published on 29 march 2024

Science Popularization in the Science, Technology and Society Perspective: A Literature Review

Popularização da Ciência na Perspectiva CTS: Uma Revisão de Literatura

Divulgación Científica Desde la Perspectiva CTS: Revisión de la Literatura

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Abstract

This study presents some of the current discussions and research on the topic of science popularization from the perspective of Science, Technology, and Society (STS), based on a systematic review of the literature. The systematization focuses on 53 articles published in the last decades in four databases (*Scielo, Scopus, Web of Science* and *DOAJ*). Methodologically, the parameters and procedures of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) are used, seeking to identify issues and debates around the popularization of science and also practical investigations regarding the issue. The descriptors used in the searches took the STS approach centrally into account. The results indicate the need to develop public policies to train and encourage students and researchers to get involved in popularizing science. Furthermore, considering the epistemic role of asymmetries in scientific communication can help to overcome the shallow discussion around deficit models and the development of deliberative participatory models. There is still a need for more studies on the development of participatory communication models that emphasize social justice by valuing the diversity of knowledge, methods, and communication practices.

Keywords: science popularization, STS, systematic review

Resumo

Este estudo relata algumas das atuais discussões e investigações acerca da popularização da ciência pela perspectiva Ciência, Tecnologia e Sociedade (CTS), a partir de uma revisão sistemática de literatura. A sistematização foca em 53 artigos publicados na última década em quatro bases de dados (Scielo, Scopus, Web of Science e DOAJ). Metodologicamente, foram utilizados parâmetros e procedimentos do Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), buscando identificar, por um lado, temas e debates em torno da popularização da ciência e, por outro, investigações práticas a respeito da questão. Os descritores utilizados nas buscas levaram em conta, centralmente, a abordagem CTS. Os resultados apontam para a necessidade de desenvolver políticas públicas de formação e incentivo para estudantes e pesquisadores se envolverem em ações de popularização da ciência. Além disso, a consideração do papel epistêmico das assimetrias na comunicação científica pode ajudar a superar a discussão rasa em torno de modelos deficitários e o desenvolvimento de modelos participativos deliberativos. Ainda mostra-se necessário maior número de estudos em torno do desenvolvimento de modelos de comunicação participativa que enfatizem a justiça social pela valorização da diversidade de conhecimentos, métodos e práticas comunicativas.

Palavras-chave: popularização da ciência, CTS, revisão sistemática

Resumen

Este estudio presenta algunas de las discusiones e investigaciones actuales sobre la divulgación de la ciencia desde la perspectiva de Ciencia, Tecnología y Sociedad (CTS), a partir de una revisión sistemática de la literatura. La sistematización se centra en 53 artículos publicados en la última década en cuatro bases de datos (Scielo, Scopus, Web of Science y DOAJ). Metodológicamente, se utilizan los parámetros y procedimientos de Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), buscando identificar, por un lado, cuestiones y debates en torno a la divulgación científica y, por otro, investigaciones prácticas en torno de la temática. Los descriptores utilizados en las búsquedas tendrán en cuenta, de forma centralizada, el enfoque CTS. Los resultados indican la necesidad de desarrollar políticas públicas de formación e incentivos para estudiantes e investigadores que se involucren en los esfuerzos de divulgación científica. Además, considerar el papel epistémico de las asimetrías en la comunicación científica puede ayudar a superar la discusión rasa en torno a modelos deficientes y el desarrollo de modelos participativos deliberativos. Aún muestra que se necesita un mayor número de estudios en torno al desarrollo de modelos de comunicación participativa que enfaticen la justicia social para la valorización de la diversidad de saberes, métodos y prácticas comunicativas.

Palabras clave: popularización de la ciencia, CTS, revisión sistemática

Introduction

The examination of public science communication[1] can be approached from various perspectives and for different purposes (Lewenstein, 2022). Among the possible approaches, based on the understanding of the coexistence of communicative models, studies in the field[2] of Science, Technology, and Society (STS) have contributed to a critical perspective on the role of the public knowledge and participation in the construction of Science and Technology (SciTech) in modern life, helping to question simplistic conceptions. This is because the STS field offers a vision that all research is a political and contextualized practice, and that science is a public value that should contribute to democracy (Davies, 2022). According to the foundational understanding of the scientific process from the STS perspective, it is always necessary to consider who has access to science and what values are at stake. This conception allows breaking away from scientistic epistemological positions that accept the neutrality of science as a universal value. One can assume the premise that science is a public good that should be widely distributed and democratically governed (Davies, 2022), and public communication of SciTech plays a vital role in constructing this reality.

1 In Spanish (Escobar, 2018) and Portuguese, the most commonly used term is "divulgação científica"; meanwhile in English it is quite common to use "science communication" or "public science communication" (Davie, 2022; Lewenstein, 2022).

2 As Pelissari (2023) points out, there are different terminologies to refer to STS, such as: approach, vision, studies, focus, area, field, movement, among others. It is important to acknowledge that this is a controversial issue and demands in-depth discussion. Although STS is not a stable discipline, it is a meeting point for research from different traditions, looking into how knowledge is constructed and shaped by various contexts.

Considering the contributions of the STS field to an understanding of the interactions and intentions that lead to different models of public science communication, a search was conducted looking for studies that have developed this perspective. The premise is that there is a need to bring visibility and continuity to STS studies on the popularization of science, as well as to foster interactions with other perspectives and fields of study. In this regard, literature review studies can contribute to these interactions, as well as identifying the main themes, debates, and practical studies being developed, prompting future researches. In the search for literature reviews, two papers were found and taken as the starting point for this study: Tinker (2013) and Alcíbar (2015). These authors synthesize discussions about the popularization of science into three main models of Public Communication of Science and Technology (PCST), namely: (1) Public Appreciation of Science and Technology (PAST), (2) Public Engagement with Science and Technology (PEST), and (3) Critical Understanding of Science in Public (CUSP).

In broad terms, the PAST model is unidirectional, viewing science as unquestionable, scientists as authorities, and the public as lacking of scientific knowledge. The PEST model surpasses the idea of deficiency, but still separates science and society, assuming science as a fixed entity. The CUSP model emphasizes the interactive relationship of science in society and recognizes the value of all forms of knowledge. It proposes a dual obligation for science-society communication: to inform and educate the public while exploring and critiquing science (Alcíbar, 2015; Tinker, 2013). These models of public communication coexist and are employed in different circumstances.

The date of publication of these works, around ten years ago, require a systematic literature review study focused on the period 2013-2023. To this end, a search for articles within this timeframe was carried out in recognized databases, in order to understand how investigations have evolved and what future perspectives for continuity are indicated. For this review, some parameters from the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) were used as a methodological guide, and the following research questions were posed:

1) In the selected articles, what themes and debates surrounding the popularization of science are being promoted?
2) In the selected articles, what investigations of science popularization practices are being carried out?

Methodology

The PRISMA guidelines (Galvão et al., 2015; Page et al., 2021) were used as a reference of basic parameters regarding the methodological quality and data analysis of this study. Although PRISMA was specifically developed for systematic reviews and meta-analyses in the health field, its guidelines and checklist have been adapted and used in various knowledge areas. The PRISMA guide is divided into three phases: (1) planning, (2) conducting, and (3) reporting the systematic review. In the planning phase, the research questions, search strategies and inclusion/exclusion criteria for

studies are defined. During the conducting phase, relevant studies must be selected and assessed, data are collected and analyzed. In the reporting phase, the review results of the review are presented, including a full description of the selection process, assessment of methodological quality and data analysis (Page et al., 2021).

In this study, during the planning and conducting phases, once the research questions related to the science popularization from the STS perspective had been defined, the following procedures were adopted:

1) Selection of relevant databases related to the fields of social sciences and humanities:

The search was carried out on four databases that published in the educational, social and interdisciplinary fields: *Scielo*, *Scopus*, *Web of Science*, and *Directory of Open Access Journals* (DOAJ).

2) Keyword search in digital tools in the selected databases:

The literature review took place at two different times. Initially, in December 2022, searches were conducted using the keywords '*popularização*', '*divulgação*', and '*disseminação*'. The preference for these Portuguese terms, more common in the Brazilian context, is due to our position as researchers based in Brazil. Although this study does not intend to confine itself regionally, avoiding being an exhaustive mapping or a quantitative analysis tied to numbers from specific institutions, researchers, or regions, we recognize the relevance of prioritizing discussions related to the Brazilian context.

However, we also understand that many developments, especially theoretical and conceptual ones, emanate from broader contextual interactions. Therefore, we value knowing international perspectives and remain open to the complexity of the dialogue with different views and contexts. Furthermore, given the global nature of the STS movement, we chose to include equivalent terms in English ('popularization', 'divulgation', and 'dissemination'), recognizing that a significant part of academic production, regardless of the country of origin, includes titles and abstracts in English. Following this logic, after obtaining the results, they were then refined considering the presence of terms such as '*CTS*', 'STS', '*Ciência, Tecnologia e Sociedade*' and/or 'Science, Technology, and Society' in the articles found.

In a second stage, in January 2023, a search was conducted using the term 'Public Communication of Science and Technology'[3] in the same databases. We chose to complement the first stage of the review with this second search, understanding that this term is an umbrella concept for various terms related to the popularization of science from the STS perspective (Alcíbar, 2015), mainly encompassing studies in English. This decision aims to broaden the range of results, going beyond Brazilian articles, which, although of particular interest to us, do not limit the approach to current discussions on science popularization from the STS perspective intended by this study.

3 "Science Communication" or "Public Science Communication" can be considered more common terms in English. However, due to the large number of articles and possible theoretical perspectives, the term "Public Communication of Science and Technology" was chosen, understanding it as an intersection between science communication/popularization and STS studies.

3) Reading of titles and abstracts to identify whether the article corresponds to the intended topic of discussion, followed by the exclusion of duplicated works:

The following were taken as exclusion criteria: (a) publications prior to 2013[4]; (b) publications that address the inclusion of public science communication materials in Basic Education[5]; (c) publications from the fields of Medicine, Health, Nutrition, and Urbanism[6]; (d) publications that are not research articles (book chapters, conference or editorials)[7].

During the conducting phase of the study, we carried out detailed readings of the selected articles, categorizing them based on their nature (theoretical or practical studies regarding science popularization) and identifying the main lines of discussions developed by the authors.

This systematic review has limitations primarily related to the variety of terms used to refer to public science communication and the areas that approach this subject as an object of research. Thus, it is understood that the aim of this study is not to provide an exhaustive literature review covering all the work in the area, but rather to contribute to the construction of a landscape regarding the theoretical understandings and practical investigations that the field of public science communication articulated with the STS perspective has developed in recent years.

Results

Table 1 organizes the quantities corresponding to the results obtained through database searches.

4 To report more recent works and, consequently, current developments in science popularization within the STS field.

5 Studies in Basic Education involve a variety of complex discussions (pedagogical issues, curriculum, educational policies, teacher training, etc.) that go beyond the scope of this study. We pretend to focus on discussions promoted in science popularization articulated with the STS perspective, rather than on transformations, contributions or limitations of these practices in formal education, and vice versa.

6 We understand that some studies presented more specific contributions to the fields of Medicine, Health, Nutrition, and Urbanism, not aligning with the general discussions reported in this study.

7 To focus on more robust studies, as research articles are typically more detailed and undergo a more rigorous review process.

Table 1

Number of Articles Found and Selected for Analysis

Database	Keywords	RT	AE	AEL	S
Scielo	("popularização" OR "divulgação" OR "disseminação" OR "popularization" OR "divulgation" OR "dissemination") AND (("STS") OR ("Science, Technology and Society") OR ("CTS") OR ("Ciência, Tecnologia e Sociedade"))	20	12	2	4
Scopus	("popularização" OR "divulgação" OR "disseminação" OR "popularization" OR "divulgation" OR "dissemination") AND ("STS") OR ("Science, Technology and Society") OR ("CTS") OR ("Ciência, Tecnologia e Sociedade")	505	495	—	10
Web of Science	("popularização" OR "divulgação" OR "dissemination" OR "popularization" OR "divulgation" OR "dissemination") AND (("STS") OR ("Science, Technology and Society") OR ("CTS") OR ("Ciência, Tecnologia e Sociedade"))	663	6418	21	1
DOAJ	(popularização OR divulgação OR popularization OR divulgation) AND ((STS) OR (Science, Technology and Society) OR (CTS) OR (Ciência, Tecnologia e Sociedade))	209	200	3	6
Scielo	"Public Communication of Science and Technology"	7	4	—	3
Scopus	"Public Communication of Science and Technology"	73	46	13	14
Web of Science	"Public Communication of Science and Technology"	59	42	10	7
DOAJ	"Public Communication of Science and Technology"	15	5	2	8
TOTAL					**53**

Note. RT – Total results; AE - Excluded Articles (year, focus, and/or duplicate); AEL - Articles Excluded after Reading; S - Selected.

Source: Setlik & Pelissari, 2023.

Initially, the selected publications were classified as theoretical or practical studies. Theoretical studies encompass literature reviews, works, or document analysis. On the other hand, practical studies involve the development and/or analysis of science popularization practices, such as interactions of subjects in the field or interviews with scientists. Through the reading and analysis of the 53 selected articles, 27 were classified as theoretical and 26 as practical. Within this classification, studies were further sub-classified. The theoretical articles were categorized into *Historical and public policy discussion* and *Theoretical understanding*. The practical studies were categorized into

8 The term "dissemination" is adopted in various research fields, as a result, most of the studies found are not related to discussions about the science popularization.

Analysis of interviews with scientists, professionals, and science communicators; *Analysis of science journalism and digital media*; *Analysis of interactions in scientific cultural institutions*; and *Other*. A summary of this classification, with the respective selected articles and the number of publications in each group can be found in Table 2.

Table 2

Possible Classification for Selected Studies

Main Classification	Focus	Articles	Number
Theorical (Research question 1)	Historical and Public Policy Discussion	Massarani (2022) Jia (2022) Ishihara-Shineha (2021) Baram-Tsabari et al. (2017) Falla, el al. (2016) Lock (2016) Massarani & Moreira (2016) Massarani (2014)	8
	Theoretical Understanding	Dawson et al. (2022) García-Guerrero & Lewenstein (2022) Lewenstein (2022) Metcalfe et al. (2022) Formenton et al. (2021) Noga et al. (2021) Jensen & Gerber (2020) Santos & Bazzo (2019) Escobar (2018) Escobar (2017) Hermelin (2017) Cortassa (2016) Melo et al. (2016) Meyer (2016) Suldorsky (2016) Alcíbar (2015) Giraldo (2015) Nowotny (2014) Merejo (2013)	19

Table 2

Possible Classification for Selected Studies (continuation)

Main Classification	Focus	Articles	Number
Practical (Research question 2)	Analysis of interviews with scientists, professionals, and science communicators	Sanz & Tarhuni (2019)	5
		Rocamora et al. (2019)	
		Loroño-Leturiondo & Davies (2018)	
		Massarani & Peters (2016)	
		Kahlor et al. (2015)	
	Analysis of science journalism and digital media	Neves & Massarani (2022)	6
		Massarani & Neves (2021)	
		Silva & Ovigli (2021)	
		Massarani et al. (2020)	
		Sousa et al. (2014)	
		Palma (2013)	
	Analysis of interactions in scientific cultural institutions	Coelho et al. (2022)	6
		Massarani et al. (2022)	
		Scalfi et al. (2022)	
		Spada (2022)**	
		Massarani et al. (2021)	
		Lima & Rocha (2021)	
	Other	Sotério & Queiroz (2023)	9
		Krebs (2022)	
		García-Guerrero & Lewenstein (2020)	
		Vázquez Guerrero (2019)	
		Armon & Baram-Tsabari (2017)	
		Rodrigues et al. (2016)	
		Nielsen et al. (2015)	
		Delicado et al. (2014)	
		Possik et al. (2013)	

Note. ** Although it is a study classified as theoretical—meaning it is grounded in a literature review—we prefer to discuss it alongside practical studies involving museums.

Source: Setlik & Pelissari (2023).

Next, based on the classification proposed in Table 2, we discuss the results.

Discussion of the Results Based on the Proposed Questions

1) In the selected articles, what themes and debates surrounding the popularization of science are being promoted?

a) In publications of historical analysis and public policies regarding science popularization

This sub-item comprises publications that investigate the history of the constitution of science popularization practices, as well as the public policies developed in different contexts (Baram-Tsabari et al., 2017; Falla et al., 2016; Ishihara-Shineha, 2021; Jia, 2022; Lock, 2016; Massarani & Moreira, 2016; Massarani, 2014; Massarani, 2022). In general, these publications suggest that different regions have distinct histories in their practices and policies of science popularization development, which brings specific challenges and demands in each context (Massarani, 2014). Nevertheless, an effort is made to identify some discussions that may be common, i.e., that are emerging in different objects of these studies, as outlined below:

1) The lack of development of public science communication in undergraduate and postgraduate policies, despite the governmental emphasis in this area (Ishihara-Shineha, 2021; Massarani & Moreira, 2016; Massarani, 2022).
2) The persistence of public policies oriented towards a deficit model of understanding public science communication (Falla et al., 2016; Jia, 2022; Lock, 2016).

Regarding 1) the lack of attention given to public science communication in undergraduate and postgraduate policies, this has been identified as a problem in Latin America and Japan. Massarani (2014, 2022), a researcher and journalist, has published on the historical context of science popularization in the Latin American region, as well as specific demands and challenges. Massarani and Moreira (2016) emphasize the need to increase social engagement using mass media (internet and social networks) and the expansion of science communication on public channels and within research institutions. They indicate that it is important to value activities related to knowledge popularization within the university, creating public policies in this direction to increase student engagement in SciTech public communication actions. This gap between science policy and postgraduate policy in the development of human resources for experts is also pointed out by Ishihara-Shineha (2021) in the context of Japan.

When it comes to training programs for scientists in public science communication, there are still some gaps to be filled. According to Baram-Tsabari et al. (2017), who analyzed the learning objectives in training programs, the gaps mainly appear in the areas of affective learning and identity formation. In public science communication, this means acquiring an identity as a science communicator, which, when explored, allows many experts to discover their ability to communicate with different audiences. Undergraduate and postgraduate students are potential future SciTech public science communicators and seek this training to explore a new professional identity. However, as the authors point out, many training courses do not address this aspect in the available syllabuses.

Regarding 2) the persistence of the deficit model in public policies, Lock's study (2016) historically contextualizes the existing debates in the UK about the position of science and scientists in society at the end of the 20th century. Lock considers the impact of the *Two Cultures*[9] (Snow) and *Science Wars*[10] theses in reflecting on tensions and stressors in science as an institution of power, questioning who is allowed to speak on its behalf. As a result, notions of a deficit of understanding or an attitude of support for a certain type of science and/or government are indicated as historically constructed and linked to the exercise of power. Therefore, it is important to recognize the historical-social construction of the deficit, its epistemic role, and develop ways to avoid its perpetuation in public policies. Although there are theoretical and empirical advances in understanding these practices, the idea of a public cognitive deficit persists in the agenda of public science communication studies, as discussed by Cortassa (2016), Meyer (2016) and Suldorsky (2016). In the next subitem, we present studies that discuss theoretical understandings of science popularization involving possible understandings for the persistence of the deficit model.

b) In publications on theoretical understandings

Several of the studies selected use literature reviews to discuss different aspects related to science popularization. Briefly, these studies address topics ranging from public science communication training (Jensen & Gerber, 2020; Hermelin, 2017), investigations into scientific culture (Melo et al., 2016), scientific writing (Giraldo, 2015), philosophical discussions about cyberculture and technoscience (Merejo, 2013) to possibilities of articulating the STS field with Math Fairs held in Brazil (Santos & Bazzo, 2019) or with Scientific Recreation Workshops (SRW) (García-Guerrero & Lewenstein, 2022).

Other studies, for their part, develop the discussion around the meaning of public science communication and possible communication models, pointing to:

1) The essence of scientific communication practices (Lewenstein, 2022; Nowotny, 2014), which highlight the public value of science and the epistemological role of public communication.
2) The meanings and advances regarding public science communication models (Cortassa, 2016; Dawson et al., 2022; Escobar, 2017; Escobar, 2018; Formenton et al., 2021; Giraldo, 2015; Melo et al., 2016; Meyer, 2016; Merejo, 2013; Metcalfe et al., 2022; Noga et al., 2021; Suldorsky, 2016); which point to:
    a. The false dichotomy between deficit and democratic models.
    b. Reasons for the persistence of the deficit model.
    c. Development of new democratic models of public participation.

Regarding 1) the essence of public science communication practices, Lewenstein (2022) emphasizes that the knowledge that is considered secure about the natural world is not formed without social interactions, meaning it is the result of a complex network of communication that presupposes public participation. Therefore, there is

9 The thesis highlights the division between humanistic and scientific cultures and argues that the lack of mutual understanding between these cultures can impact the approach to complex societal problems.

10 It refers to debates between scientists and scholars in the Social Sciences in the late 20th century, addressing epistemological and philosophical questions about the nature of science, objectivity, and its interactions with society.

an epistemological role also played by SciTech public communication. Moreover, there are contradictions and complexities in the relationship between science and society that need to be studied in conjunction with science popularization practices, such as interests related to the scientific process, its objectives, purposes, the exclusion or inclusion of methods. These webs of relationships can be constantly evaluated by society, allowing more people to become aware of the complexity of the scientific process, its uncertainties and the public value of science, even within its limitations. In order to highlighting the discussion about the interest and public value of science, Nowotny (2014) suggests that the STS field can be enriched by future investigations into the collective imaginaries that arise from citizens' interactions with the new media that circulate knowledge. The author suggests that these imaginaries, if considered as necessary fictions about scientific practice, may contain surprising answers for the field of public communication research.

Regarding 2) the models of public communication of SciTech, there is, in recent literature, an intense debate about the construction and perception of the existence of different possibilities for social interactions, as well as the persistence of old models of interaction. Escobar (2017, 2018) points out that often STS studies contrast deficit and democratic models of public science communication. For this author, this contrast comes from the new social agreement of SciTech, which replaced the old pact advocating for a deficient form of dissemination, presenting a more democratic and effective model (Escobar, 2017). On the other hand, he argues that this opposition is a false dichotomy since the new social agreement is compatible with various supposedly democratic models that can also be classified as deficit.

For a better understanding of this theoretical proposition, in Figure 1, based on Escobar (2017), four major groups of scientific communication models have been schematized.

Figure 1

Four Groups of Science Communication Models

Model	Characteristics	Dimension in focus
1. Deficit	The public lacks knowledge and needs SciTech knowledge.	*Epistemic*
2. Context	The public has a knowledge base and responds to scientific information contextually (influenced by social, cultural, political aspects, among others).	*Epistemic*
3. Lay Expert	Distinction between two types of knowledge: expert and lay. While experts have expertise in SciTech issues, laypeople have their own type of specialized knowledge, known as local knowledge, which is as important to society as SciTech knowledge.	*Political*
4. Public Participation	Actions to improve public participation and increase trust in SciTech, aiming for democratization, shifting from the control of an elite to society.	*Political*

Source: Setlik & Pelissari (2023). Figure constructed based on Escobar (2017).

According to Escobar (2017), Lewenstein classifies these models into two groups that face distinct challenges, depending on the dimension that is in focus. The first group (models 1 and 2) focuses on increasing public understanding of SciTech, emphasizing its benefits. The second group (models 3 and 4) is fundamentally concerned with STS equity in decision-making, seeking strategies to achieve equality among stakeholders. Based on this characterization, the author argues that the public science communication has two different and complementary dimensions: an *epistemic dimension* and a *political dimension*.

In the epistemic dimension, the central concern lies in the dissemination of the SciTech content and procedures, including theoretical, conceptual, historical, philosophical, sociological, religious, psychological aspects, among others. In the political dimension, the focus is on the desire for citizens to exert greater influence in SciTech, involving issues of power and authority. Consequently, there are corresponding types of deficits that should not be used interchangeably: cognitive deficit and political deficit. Recognizing the existence of the political dimension is essential for the developing an understanding about the popularization of science, as pointed out by Meyer (2016). The author also considers that scientists are often excluded from the public in SciTech communications and only the public is associated with knowledge deficiency. Hence the need to develop new understandings in which everyone can be perceived as both the public and as scientists, in relation to the various knowledges and communicative practices. This perspective aligns with discussions around the process of individuals forming their identity concerning their participation in SciTech.

Although the epistemic and political dimensions are deeply interconnected, emphasizing one of them can lead to different perspectives. Understanding them and finding points of dialogue can help reconcile existing conceptions of public science communication. According to Escobar (2017), depending on the type of deficit one has in mind, it is possible to classify different models as deficit, and there is not necessarily a direct correlation between types of deficits. Therefore, there are distinct versions of both the deficit model and the democratic model, some of which can themselves be classified as deficit. The reflections lead to the central conclusion that the notion of participation should not be taken as a necessary and sufficient condition to distinguish between deficit and democracy.

Regarding the persistence of deficit models, other authors discuss reasons for the fact that, despite the possibility of new understandings and modes of public science communication, the deficit model always seems to reappear (Cortassa, 2016; Meyer, 2016, Suldorsky, 2016). For example, Cortassa (2016) presents two types of explanations for this phenomenon: the practical and the epistemic. The study delves into the epistemic reason and identifies as a key factor the asymmetry between scientists and the public. The author suggests that recognizing this asymmetry as a basic condition for interaction can help overcome the deficit model debate (the simple answer of whether there is a deficit, yes or no) and open up new paths for the study of the popularization of science. In this

view, assuming that the existence of cognitive asymmetry between the agents (in their various directions) participating in the process of communication and construction of science is a presupposition, this disparity does not become an obstacle to be overcome (Cortassa, 2016). This can help to ensure that studies are not limited to a shallow analysis regarding the existence or the non-existence of a deficit in a communication model. For Suldorsky's (2016), absolute rejection of the deficit model is not appropriate, and studies focusing on the specific conditions under which different models of public communication emerge are needed. This author also points to the need to develop an epistemic gaze, with an in-depth assessment of the role of epistemic authority in research and in the practice of popularizing science.

Escobar (2017) classifies democratic models of public participation into three basic types: *direct*, *representative*, and *deliberative* participation. The difference between these models lies in their divergent conceptions of citizen participation and how it should occur in decision-making processes. For Escobar, the *direct participation* of citizens in a research laboratory, choosing which methods and procedures to develop and use is not always feasible, and the justification lies precisely in the supposed cognitive deficit. In other words, it is expected that people who will be making decisions about methods, criteria for empirical evidence, and developing a certain type of scientific knowledge, in certain situations, are expected to have some kind of background and expertise in that area. The *representative participation*, on the other hand, can be considered democratic, but it happens through the election of representatives with the necessary specialized knowledge for decision-making that take into account the needs of the public. For Escobar (2017), these two types of direct and representative participation, in their current state, fail to prevent certain forms of deficit. Thus, a possible path is drawn with *deliberative participation*. In this model of public participation, citizens are seen as self-governed subjects capable of developing intelligent habits of investigation. However, these habits are not acquired in isolation, but rather through integration into deliberative processes with others. This deliberation requires freedom, understood as moral self-direction, considering the impact of individual actions on others (Escobar, 2017). From this perspective, the development of SciTech should not only serve specific interests of experts and/or the rest of society, but should demand the collaboration of both groups. For Escobar (2017), although these models are more successful, they still leave open questions about the epistemic and political asymmetries that sustain them. In this sense, there is much to be discussed and developed in terms of democratic models, starting from the consensus that this is the direction to be taken (Formenton et al., 2021; Noga et al., 2021; Dawson et al., 2022; Metcalfe et al., 2022): participatory models that are democratic and not deficit, which increasingly highlight the epistemic and political dimensions of SciTech public communication.

Studies such as those by Formenton et al. (2021) and Metcalfe et al. (2022) argue in favor of popularizing science from a participatory perspective. According to Metcalfe et al. (2022), participatory science communication recognizes various publics as equals

in terms of power and knowledge compared to scientists and policymakers. These authors point out that *citizen science* can be a type of participatory model, requiring active involvement of the public in defining problems, collecting, and analyzing data. According to the authors, citizen science has been characterized in three practices: *contributive*, *collaborative* or *co-created*. In the contributive practice, community members provide useful information to scientists and researchers more passively. In the collaborative practice, scientists and community members work together on a research project more actively. In the co-created practice, scientists and community members work together from the beginning of the scientific process, allowing for more intense and equal collaboration. Co-creative initiatives are the most participatory, where citizens not only collect data but can also help in the project's design, data analysis or results dissemination. This is a relatively recent field of study that is increasingly discussed and highlighted in scientific research.

Still when it comes to developing participatory models, Dawson et al. (2022) offer a critique of the *status quo* of science communication research, especially over the past twenty years in the UK, and reflect on the importance of equity, diversity, and inclusion in this context. The study argues that narrow epistemic parameters of science communication research restrict the work on social justice and equity, and it is important to recognize that science communication research is a part of societies and has policies that can be implicit or explicit. Epistemic asymmetry can create significant epistemic violence (by excluding other knowledges, feelings, practices and people), and more visibility needs to be given to this dimension. For Dawson et al. (2022), significantly inclusive science communication research requires questioning and challenging established norms in the field, seeking to understand the inequalities and exclusions present in the process of public science communication. This means valuing other sources of knowledge and recognizing the importance of feelings and emotions in the construction of broader and more inclusive narratives. Also in this direction, in the context of Brazil, Noga et al. (2021) argue for science popularization as a valuable tool for social inclusion and advocate for policies to encourage public participation in decision-making, reduce social inequality and fight structural racism. The field of STS in Latin America has developed in connection with specific contextual issues in the social formations of this region and, in this sense, can contribute to an understanding and development of the science popularization aimed at social justice.

In summary, recent advances in the theoretical debate on public science communication allow us to put the deficit model analyses into perspective. A common conclusion seems to be that there are limitations in this model's critical conclusions, and it is no longer sufficient to identify its unidirectional nature. New perspectives on the problem have emerged, incorporating and surpassing the criticisms elaborated so far and consequently developing the research field of science communication from the STS perspective. In this sense, it would be possible to hypothesize that this perspective itself has significantly aided in broadening views on the subject.

2) In the selected articles, what investigations of science popularization practices are being carried out?

a) In the publications analyzing interviews with scientists, professionals, and science communicators

Investigations regarding the participation and perspectives of scientists in science popularization practices are undertaken in several publications (Kahlor et al., 2015; Massarani & Peters, 2016; Loroño-Leturiondo & Davies, 2018; Sanz & Tarhuni, 2019; Rocamora et al., 2019). These studies also take place in different contexts and regions and, overall, indicate that:

1) Experts acknowledge their social responsibility in public science communication (Massarani & Peters, 2016; Loroño-Leturiondo & Davies, 2018; Sanz & Tarhuni, 2019).
2) Policies to encourage the involvement of experts and students in public science communication practices and promote their training are still needed (Kahlor et al., 2015; Massarani & Peters, 2016; Sanz & Tarhuni, 2019; Rocamora et al., 2019).

In the publication by Loroño-Leturiondo and Davies (2018), the results of a focus group study with natural scientists in the Basque Country are presented. In this context, the participants emphasized their responsibility to ensure successful scientific communication, highlighting their commitment to society and public welfare, and that communication should produce 'good emotional experiences'. However, although this awareness may exist, there are still several obstacles that need to be overcome so that more researchers become directly involved in science popularization activities. In the publication by Sanz and Tarhuni (2019), the perceptions and attitudes of Mexican researchers from the National Council of Science and Technology (Conacyt) about SciTech public communication are explored. The results also indicate that there is an appreciation of the importance of public communication, despite the diagnosis of lack of time and academic recognition as determining factors in the difficulties of building science communication practices. In the context of Brazil, the publication by Massarani and Peters (2016), based on the results of a questionnaire applied to 1000 Brazilian scientists, showed that 63% had not communicate information related to their research in the last twelve months. Thus, this shows the need to promote a culture of popularization as part of doing science.

To promote this culture, public incentive policies are essential, as pointed out earlier (Massarani & Moreira, 2016; Massarani, 2022; Ishihara-Shineha, 2021), in addition to quality training in public science communication. Studies such as those by Rocamora et al. (2019) and Kahlor et al. (2015), for example, show that many experts have conceptions close to the deficit model and its literacy perspective.

b) In publications analyzing science journalism and digital media

Science journalism and digital media can be considered a subtopic within the theme of popularization of science. Overall, these studies indicate that:

1) Science journalism and digital media currently represent important means of interaction between the public and science and therefore have a great responsibility (Massarani et al., 2020; Massarani & Neves, 2021; Neves & Massarani, 2022).
2) Science journalism and media are not neutral; they are permeated by diverse interests and there are different positions and forms of communication possible (Palma, 2013; Sousa et al., 2014; Massarani et al., 2020; Massarani & Neves, 2021; Silva & Ovigli, 2021).

For example, Massarani and Neves (2021) explore the popularization of the COVID-19 vaccine by analyzing articles published by three newspapers. Their results indicate that each newspaper emphasized the importance of the vaccine developed by its country or through national partnerships, with a more politicized approach in Brazil and a more technical-scientific approach in the United States and the United Kingdom. They also highlight the media's responsibility not only to provide accurate information, but also to avoid creating stigmas related to the origin of the vaccine.

Palma (2013) provides a critical analysis of science journalism in the major print media in Argentina, arguing that, in his view, the logic of mainstream media does not coincide with the logic of science. Considering that the public science communication is an important and inevitable task for the modern world, it should not be exclusively or predominantly in the hands of the mass media.

c) In publications analyzing interactions in scientific-cultural institutions

Institutions of scientific and cultural nature can also be understood as a subtopic within the theme of science popularization. Articles that analyze the interactions and conversations of visitors in different institutions such as museums (Massarani et al., 2021; Lima & Rocha, 2021), aquariums (Massarani et al., 2022; Coelho et al., 2022), and zoos (Scalfi et al., 2022) were found. Each of these studies employed a qualitative approach, recording visitors' conversations and interactions through audiovisual recordings and analyzing them based on a specific research protocol. In general, these studies suggest that experiences in scientific and cultural institutions can be an opportunity for families to share experiences, discuss and develop ideas and knowledge about science and technology, thereby increasing public participation. In this case, the works converge towards this common characteristic, with no more than one subgroup within this classification.

In addition, there are other aspects regarding the role of museums in the construction of SciTech that are often not considered in studies from the STS perspective (Spada, 2022). Spada (2022) reviewed the PCST/STS and Museum Studies to argue that PCST is insufficient for studying SciTech museums because it does not address issues related to the internal aspects and the museum's holdings. In other words, it is necessary to consider these spaces as sites of technoscientific knowledge production, involving more than their presentation to the public. A possible path suggested by the author is an STS approach based on socio-material ecologies to study museum practices.

From this perspective, museums are seen as a unitary organization in which practices are intertwined and inseparable from the social and material infrastructure, involving material and immaterial modules made up of technologies, patterns, knowledge, visible and invisible work to maintain the ecology and its balance. This recent transformation in Museum Studies is deeply connected to the appeal of the STS field to understand the production and experience of SciTech as integrated in a culture, a society, and a political context.

d) Other studies on the popularization of science

A number of articles were also found discussing topics other than those listed above:

1) Studies conducted in Higher Education aiming at science communicators training (Rodrigues et al., 2016; Sotério & Queiroz, 2023).
2) Analysis of talk shows featuring scientists' biographies (Armon & Baram-Tsabari, 2017).
3) Analysis of university radio stations (Vázquez Guerrero, 2019).
4) The role of scientific associations in external science communication (Delicado et al., 2014).
5) Analysis of popular culture through films (Krebs, 2022).
6) Analysis of public participation in activities of local communities and cultures (Possik et al., 2013; Nielsen et al., 2015; García-Guerrero & Lewenstein, 2020).

These studies emphasize the importance of considering cultural, political, and social issues that influence how science is understood and developed in collaboration with society. Additionally, some of these studies (as in items 1 to 4) can be considered closely related to the issue of training and involving experts in science popularization actions.

Final Considerations

By analyzing articles on the popularization of science within the framework of STS published in the last ten years (2013–2023), in the Brazilian and in the international context, this study aimed to report on some of the main themes, debates, and practical investigations that are currently under development.

The investigation of the studies considered theoretical indicates that there is a need to develop public policies to encourage and train universities and research institutions for science popularization practices to increase the quality and participation, not only in Latin America but also in other international contexts. Additionally, there is a trend towards moving beyond the deficit model and incorporating issues related to the epistemic role and asymmetries in the SciTech public communication. There appears to be a field of tension in the discussion, with resistance to a complete shift from the deficit model, but also an urgent political need for transformations in the proposed and perceived interactions in SciTech. As noted by Escobar (2017), deliberative participation models can be a path towards a democratic and non-deficit understanding of public science communication. Moreover, the discussion needs to be more explicitly tied to social justice (Dawson et al., 2022; Noga et al., 2021).

The analysis of publications classified as practices, in its turn, indicates the diversity of actions and possible analyses regarding science popularization, with a focus on studies of science journalism and scientific-cultural institutions. These practices are extremely significant for the development of SciTech in modern society, encompassing biases and interests not only from the scientific field, which need to be considered. In line with the results of theoretical studies, although fewer in number, investigations of science popularization practices involving experts and/or universities were identified (Delicado et al., 2014; Rodrigues et al., 2016; Armon & Baram-Tsabari, 2017; Vázquez Guerrero, 2019; Sotério & Queiroz, 2023). Therefore, such studies need to be continuously developed and expanded, especially considering different communicative models and their epistemic role.

The methodology and criteria used in this study have the potential to contribute to the understanding regarding the challenges involved in the popularization of science from the STS perspective. However, it is important to note that this approach follows the development of the STS field itself, which, due to its interdisciplinary nature, lacks homogeneity, in terms of theoretical and methodological perspectives for analyzing the problems it aims to address. Thus, there is a complexity of views on the subject which multiplies to the difficulties of producing review studies as the one proposed here. Nevertheless, as preliminary results show, the dynamics of the science, technology, and society triad mobilized by the presented perspective contribute to the development of more critical and democratic views on the practice of communicating science.

Acknowledgments

This work was supported by the Coordination for the Improvement of Higher Education Personal (*Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior* — CAPES).

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Journal financed by Associação Brasileira de Pesquisa em Educação em Ciências — ABRAPEC

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