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ARTICLES

After all, what is science popularization? Explanation and a proposition of a plural concept

Afinal, o que é divulgação científica? Explanação e proposição de uma definição plural

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Abstract

The term science popularization is an established nomenclature in policies and research studies that focus on the relationships between science and the public in Brazil. However, the multiplicity of means and players through which it operates, and of communication processes and intentionalities that guide it, require historical, political, theoretical, and linguistic boundaries. Communication, diffusion, dispersion, and dissemination are some terms that are sometimes considered different and, at other times, synonyms for popularization. This text proposes a reflection on this conceptual plurality, emphasizing the importance of improving the understanding of science popularization as a pedagogical and cultural effort, a set of social communication practices, an academic field of study, and a basis for public policies. Inspired by theoretical formulations by communicators and educators, we propose a definition considering five aspects: sources, players, vehicles/means, languages, and intentions of science popularization.

Keywords: public communication of science, science and society, non-formal education

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Resumo

A expressão divulgação científica parece consagrada nas políticas e nas pesquisas que tratam das relações entre ciência e público no Brasil. No entanto, a diversidade de veículos e atores pelas quais opera, e de processos de comunicação e intencionalidades que a regem, exigem demarcações históricas, teóricas, políticas e idiomáticas. Comunicação, difusão, dispersão, vulgarização e popularização são alguns termos que, ora divergem, ora são apresentados como sinônimos de divulgação. Este ensaio propõe uma reflexão sobre essa pluralidade conceitual, reforçando a importância de aprofundar os entendimentos da divulgação científica como um esforço cultural pedagógico, conjunto de práticas sociais de comunicação, campo de estudo acadêmico e base de políticas públicas. Inspirado pelas formulações teóricas de comunicadores e educadores, propõe-se uma definição que considera cinco elementos: fontes, atores, veículos, linguagens e intenções da divulgação científica.

Palavras-chave: *Comunicação e Educação, Cultura Científica, Educação Não Formal*

Scientific communication, education, and citizenship

According to Mansur et al. (2021), the coronavirus pandemic (COVID-19 or Sars-Cov-2) tore down the walls that separated society from scientists and exposed an urgent need for science to quickly approximate the hermetic language of scientific articles to the language used in journalism, social networks, audios, and videos that circulate among non-initiated people. The authors consider that this type of initiative

> (...) has been gaining importance worldwide. It occurs partly as an intuitive response from scientists to antiscience movements but also mainly due to the understanding of the political and economic interests related to scientific evidence questioning (Mansur et al., 2021, p.1).

However, since Ziman's (1991) and Miller's (1992) fundamental works, understanding the relationships between science and the public has been a considerably challenging task for educators, researchers, communicators, the academy, and lay communities. Over the past decades, science started to be seen and produced from new epistemic perspectives. Science communication practices, both internally and externally, also underwent transformations mainly due to the new Digital Information and Communications Technology (DICT).

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Information society did not confirm itself as a democracy of knowledge. On the contrary, considering the algorithmization of content in digital networks, there are fewer social and technical devices able to generate and regulate a "safe truth". The current context encompasses epistemic and communicative disputes: place of speech, narratives, knowledge, and information sources. Well-known frauds and crimes are also reinvented: charlatanism, gossip, disinformation, false debates, data manipulation, offences, libel, and defamation (Brockington & Mesquita, 2016; Castelfranchi, 2018; Oreskes & Conway, 2010; Posetti & Bontcheva, 2020).

The public knowledge about how science and technology are devised as human, theoretical, and material constructs has become even more crucial to understanding society and fully exercising citizenship nowadays. The works published by Laugksch (2000) and Valladares (2021) and the contributions of Gil and Vilches' (2001) and Lorenzetti's (2017) allow us to understand that Scientific and Technological Literacy (STL) is essential to mastering basic concepts of the sciences, their history and nature, their relationships with other cultural aspects, and the capacity to operate the comprehension of said concepts in public, private, and collective life in an ethical and altruistic way, thus envisioning the possibility of a citizenship that is politically active, individually autonomous, collectively committed, and not submissive to experts.

Nevertheless, over more than two centuries since the expansion of large education systems and the massification of school education, it has been believed that propaedeutic formation should occur within these institutions. However, the scenario has changed definitively. Since the late 20th century, the exhaustion of formal education as the quintessential education space has been highlighted, with non-school environments (such as other cultural activities and spaces) being recognized as responsible for and capable of contributing to the education of individuals and the community (Falk & Dierking, 2002; Gohn, 1999; Marandino, 2017; Rogers, 2004). Nowadays, means of communication, artistic manifestations, cultural spaces, and, more recently, online environments form the landscape of education and science and technology public communication. This is the place of meaning for what we conventionally call science popularization.

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Science popularization: a fragile concept?

In 1954, when José Reis, a doctor, microbiologist, and one of the founders of *Sociedade Brasileira para o Progresso da Ciência* (SPBC- Brazilian Society for Science Progress) and *Associação Brasileira de Jornalismo Científico* (ABJC- Brazilian Association of Scientific Journalism), published his article titled *Divulgação Científica* [Science Dissemination] in *Revista Ciência e Cultura*, it was impossible to know that future generations of researchers and communicators would enter the 21st century academically indecisive and/or excited when debating what science and technology popularization is, why and how it is done, and who is authorized to communicate it. On social media, intense disputes take place whenever someone does not cite sources, produces content for niche audiences, uses science to legitimize their personal opinions, or suggests that their intention is not educational[1].

Half a century ago, José Reis defined science popularization as the "communication, in simple terms, of science as a process, the principles established in it, and the methodologies it uses" (Reis, 1982, p. 116, our translation). However, other definitions arose as science, education, and communication transformed. In the mid-1980s, for instance, a journalist, Wilson Costa Bueno suggested that the activity was defined as a process of transmitting scientific and technological information to a broad audience through decoded and accessible language (Bueno, 1985). In the 21st century, Germano and Kulesza (2007, p. 20) emphasized the intention to "make science known, expanding it to a wider audience".

Wilson Bueno (1985), the author of the first doctoral thesis on scientific journalism in Brazil, later acknowledged the maturation of the practices and the field of study and academic investigation and because of it, a stir or, at least, a conceptual fragilization. Bueno (2010) states that "the Brazilian literature on communication and science popularization has not been contributing, over time, to refine some basic concepts of science communication and popularization: approximations that support theory and practice in these fields (p. 1).

Barata et al. (2018) have a similar opinion when affirming that it is "a developing field that needs to develop stronger theoretical contributions and to solve frontier problems with other fields of knowledge" (p. 2539). Thus, in line with Magalhães et al. (2017) understanding,

[1] In 2020, streaming platform Netflix announced a series called *Mundo Mistério* (Mystery Lab), hosted by YouTuber Felipe Castanhari. The show's content and form triggered a heated debate on what science popularization in the field of History is and who should or can do it.

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we agree that such lack of development prevents the limits and the scope of the concept from being clearly defined.

Furthermore, the research conducted by Rocha et al. (2017) reassessed the concepts used in other studies conducted in Latin America and found nine different expressions[2], suggesting that there is no consensus about the similarities and differences among the various terms. The study systematized the geographical variations in the usage of the term over time, as well as the semantic differences regarding the different scenarios and areas that would compose the field (means of communication or science and art museums, for example).

Ogawa (2012) went beyond and understood that the

> Difficulties in definition may arise not only from the complexity of the area itself but also from a diversity of visions and dreams within the science communication community. Individuals, groups, and organizations within this community have their respective ideals of "future" in terms of the relationship between sciences and society, but they neither explicitly express them nor are even consciously aware of them. It goes without saying that such images of an ideal "future" emerge from their own values. [...]. Differences in values or value orientations within the science communication community have not generally been taken into serious consideration thus far (p. 4).

It is not surprising that in an Editor's Note text called "*Por uma crítica à divulgação científica*" [For a critique of science dissemination], published in *Revista Psicologia* from *Universidade de São Paulo* (USP), Professors Massola, Crochík and Svartman (2015) questioned where the power of the term science popularization would come from because it is impossible to understand it as a single movement and there is nothing that characterize it specifically.

In this respect, it is relevant to mention the language issue pointed out by Caribé (2015): the Brazilian Portuguese words *divulgação* and *vulgarização* share an etymological origin, *vulg*, which means *people*. Derivations of the Latin word *vulgus* are only present, therefore, in languages of Latin origin, such as French, Spanish, and Portuguese. In English-speaking countries, the term *divulgação científica,* meaning to make science popular, is not used (Caribé, 2015; Mueller & Caribé, 2010). In English, expressions like *science popularization* or *scientific dissemination* are used as

[2] The nine acknowledged terms in the original language of the aforementioned article are: *Divulgación de la ciencia; Comunicación de la ciencia; Educación no formal en ciencia; Popularización de la ciencia; Alfabetización científica; Comunicación Pública de la Ciencia; Percepción social de la ciencia; Democratización de la ciencia; Apropiación social del conocimiento científico / apropiación de la ciencia.*

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synonyms for *divulgação científica*. More recently, *science communication* (SciCom) or *public communication of science and technology* (PCST) seem to be preferred in academic references.

Nevertheless, in Brazilian productions, the expression *divulgação científica* is still the most common term (Fetter, 2022; Germano & Kulesza, 2007; Rocha et al., 2017), but the rationale and the theorization behind what science popularization as a practice means remain polysemous and even controversial. This conclusion is also present in a study by Fetter (2022), who analyzed 114 Brazilian articles based on the Communicative Theory of Terminology. The large number of theoretical contributions, especially from the fields of communication and education, requires that discourse should always be delineated, situated, and contextualized. Journalists speak based on the Communication framework, whereas educators are, obviously, based on Education. Unfortunately, the intersections and permeabilities have not been satisfactorily discussed and reconciled.

Therefore, there are still questions over how science popularization actions have been (and will be) constituted as cultural and educational public policies. In Brazil, where the activity is recognizably vigorous (Entradas et al., 2020), *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq- National Council for Scientific and Technological Development) uses the term divulgação científica to identify actions related to the theme – such as naming one of their supporting committees and an award in the field (*Prêmio José Reis de Divulgação Científica e Tecnológica*) (CNPq, 2022). In the scope of *Ministério de Ciência, Tecnologia e Inovação* (MCTI- Ministry of Science, Technology, and Innovation), to which CNPq is connected, the sector dedicated to the field refers to science popularization - *Popularização da Ciência*, a popular term in Spanish-speaking countries. Another good example is the text of the decree establishing the *Programa Nacional de Popularização da Ciência (PopCiência-* National Program of Science Popularization), which uses the term "popularization" as a motto, but also uses the expression *divulgação científica (e tecnológica!)* [scientific and technologic dissemination] when citing research studies and other works in non-formal education spaces. Moreover, the expression *comunicação pública da ciência* [public communication of science] also had relevance in the document, both as a goal and as a way of acting (Brazil, 2023).

Hence, this text seeks to expose and situate the terms of this terminological variety and the debates about the definition of science popularization nowadays to achieve some conciliation based on the references already consolidated in the education and communication

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fields. After all, the development of the area as a field of research and professional activity is compromised if there is no single definition that accommodates all of the nuances of the expression, considering the institutional dimension, the theoretical contributions from related areas, the formulations available in academic productions, the historicity of public policies and, of course, the diversity of actions, practices and initiatives characterized as science popularization in Brazil (Barata et al., 2018; Fetter, 2022; Moreira & Massarani, 2002; Reynoso, 2012; Rocha et al., 2017; Silva, 2007).

The definitions guiding us so far

In Brazil, the first theoretical productions about science popularization were systematized and published due to José Reis' work. He wrote three articles, published between 1954 and 1967, under the laconic but eloquent title *Divulgação Científica* [Science Dissemination]. Since then, the author has established a difference between science communication among peers and science communication with a broader audience. José Reis wrote that the process dates back to the origins of modern science and its institutionalization in European societies and scientific academies. However, the author situates the germ of science popularization in early 19th-century France. His theoretical focus was centered around intentionality and materialized in passages such as

> The press and the media must understand that science is not worth only the headlines it could generate (and they are not usually created by science itself) but also the value of information, which needs to be clear among broader audiences. Thus, partial science and charlatanism will not be mistaken for science (Reis, 1957, p. 48, our translation).

Thus, the activity should be organized, systematized, and developed based on intentionality. According to Reis (1976), it should be "more than the presentation of a scientific fact, thus implying the investigation of problems related to philosophy, history, politics, sociology, and science organization" (p. 61).

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Nevertheless, the community and the literature more frequently referred to Wilson Bueno (1985) when defining science popularization[3]. According to the author, the practice consists of "using resources, techniques, processes and products (channels or vehicles/means) for the dissemination of scientific or technological information or information related to innovations to the lay public" (p. 1421). Unlike José Reis' proposal, this definition does not focus on the intentionality of the practice, but on its forms and contents. The concept of *dissemination* dialogues directly with the consolidated reach of mass media; and the conception of *information* dialogues with a directional communication model – from where information "abounds" to where it "is lacking".

Before the turn of the century, Manuel Calvo Hernando, another journalist, revisited Phillipe Roqueplo's classic book *Le partage du savoir. Science, culture, vulgarization* [Knowledge sharing. Science, culture, and vulgarization], from 1974, and made a negative definition of *science popularization* reverberate widely. Roqueplo (1974, our translation) cited Le Lionnais (1958) when he explained that science popularization (dissemination, in this case) was

> the action of explaining and diffusing knowledge, culture, and scientific thinking under two conditions, under two reservations: the first one is that the explanation and diffusion of scientific and technical knowledge should occur out of the scope of official education or equivalent education [and] that these extracurricular explanations should not intend to train experts, not even to improve their expertise, because, on the contrary, we intend to complete specialized culture outside their expertise area.

Finally, discussions on how to do science popularization started to mature in the 2000s, and the definitions started to reflect the need for an intentional and systematic transposition process from restricted language to a more colloquial and intelligible language for non-initiated audiences. Science communication started to appear in the literature produced in English as a synonym for science popularization. Authors Schiele and Landry (2012, p. 34) crafted the concept from this perspective, stating that science communication encompasses "all activities related to the mediation, interpretation, dissemination, and explanation of sciences – the extent of efforts to inform, raise awareness and mobilize the public." From another perspective, Germano and Kulesza (2007) harnessed references from Latin American popular education to

[3] Wilson da Costa Bueno's academic production has been referred more than 4700 times by the scientific community. His articles from the 1980s have been cited more than 150 times each, and the article *Comunicação científica e divulgação científica: aproximações e rupturas conceituais*, from 2010, has been cited more than 770 times.

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favor the use of the word popularization rather than *divulgação* [dissemination], thus valuing liberating cultural actions and the people as the focus of reflective and dialogical communication.

When such a variety of formulations is put together, we are taught that there is a set of elements taken into consideration so that science popularization is acknowledged (and acknowledges itself) as an activity: its origins or sources; the publics at which it is aimed; the construction of a new discourse through the transformation of language; and, finally, the values and intentions that motivate or guide practice.

The five essential elements to define science popularization

Starting from the references cited so far, our experiences when producing and consuming science popularization, and from heated debates within research groups, practice collectives and undergraduate and graduate classes, we understand and defend that science popularization should and could be acknowledged in any cultural manifestation that 1) is not a formal, propaedeutic, and systematized teaching activity, 2) originates from or has academic science as a source, 3) is aimed at the lay public, 4) is characterized by the adaptation or transposition of scientific language, and that 5) intends to democratize scientific culture and rationality.

Therefore, activities not situated within or related to institutionalized scientific knowledge, whether academic literature or scientific field professionals, should not be considered science popularization. Publications in journals, communication in events, public databases, interviews, and public manifestations provided by institutions and players from the 'circle' are what define the sources of science popularization. Even science popularization mediated by communication professionals, such as the public relations team of an institution or specialized journalists, will be closer to the good practices of science popularization as long as they are loyal and committed to understanding their sources. Thus, if the origin or source of the social dialogue has academic practices or characters as its declared reference, or if it is closely related to the context of production of institutionalized and formal scientific knowledge, then it is, potentially, science popularization.

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However, as Vogt and Morales (2018) suggested, popularization is the meeting point between science and society – something which, as a rule, does not occur in journals or academic conferences. Sources are based on institutional science but means/vehicles or ways of popularization are not. They are spread over culture: science popularization happens through the communication means and practices that circulate out of the academic diffusion and dissemination setting. Therefore, it is through the Arts, such as Literature or Theater, or through news media, for example, that popularization takes place in society. In the specific case of the media, in addition to traditional broadcasting, the past decade saw the migration of the relationship between science and the public to social networks (Brossard & Scheufele, 2013; Brossard & Scheufele, 2022).

On the other hand, science communication – meaning dissemination – occurs among peers, among those who have been initiated, through specific rites and language. That is to say, an article or a symposium should not be mistaken for science popularization.

The third fundamental element is the players who practice science popularization. The activity can be done directly by people who compose and act within the scientific field (researchers, students, technicians) or mediated by communication professionals who use the former as their sources. Even science enthusiasts, such as amateur entomologists or astronomers, bird watchers, fossil collectors, or even a child participating in a citizen science project, could be potential popularizers. After all, their activities dialogue closely with science as a process and are subject to criticism from the community.

The fourth element is related to the fact that the identity of the initiatives' target audience is as important or even more important than the popularizer's profile. It is not about communicating with audiences who are already interested and familiar with the topics disseminated but promoting a secondary communication (Epstein, 2012) with people who do not circulate where that specific scientific knowledge was produced; or, moreover, with people who are distant or detached from formal education environments – who are conventionally called lay public.

Although it seems to be a trivial concept, its comprehension is more challenging in practice when popularizers need to plan and assess their audiences. According to Warner (2002, p. 420), "the reflexive circulation of a given discourse" should be situated within the social space

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and historical context in which it occurs or is being created. That is, audiences "do not exist apart from the discourse that addresses them" (Warner, 2002, p. 416).

Still in this respect, a significant passage in the foreword for Science in the Public Sphere: A history of lay knowledge and expertise reads:

> Once the walls between those who know and those who do not have been shaken, we all at some point become active publics of science, as students, visitors, spectators, users or patients, but also as disseminators, amateurs and experts of a given corpus of knowledge. Even the leading world experts in subatomic particles or molecular biology, to cite just two emblematic examples from the latest frontiers of science, are also ignorant in other spheres of knowledge or other human skills. This dynamic view of the construction of knowledge is thus based on this flexible use of the idea of 'publics (Nieto-Galan, 2016, p. 08).

Thus, there is no absolute separation between the learned and the lay, but a continuous and flexible gradation of audiences, leading to the niching of some science popularization actions – a challenge closely linked to the processes of language transposition.

In this respect, Semir (2002) evoked the end of the 17th century by referring to Bernard de Boyer de Fontenelle on the need to search for *explanatory language* that pleases both "the wise world" and "the lay public". There the author situated the dawn of the definition of science popularization. Nieto-Galan (2016) explained that, in the two following centuries, the professionalization and specialization of science created a growing gap between experts and the lay public. The phenomenon of specialization and professionalization of scientific language is also discussed in an article by Sun et al. (2021), who analyzed the first scientific journal in history – *Philosophical Transactions of Royal Society*.

Based on Gaston Bachelard's epistemology, Nieto-Galan (2016) stated that scientific progress stemmed from the victory of specialized knowledge (*episteme*) over public opinion (*doxa*). The 20th century widened the gap between the discourse of science authority and public opinion. Silva (2007) warned about it by suggesting that maybe science popularization did not bring science closer to the public; on the contrary, it circumscribed interlocution spaces. Regardless, a certain type of popular science remained alive in books, public conferences, games, and presentations, with professional popularizers aiming at the proper language to share knowledge with all emerging social segments (Mueller & Caribe, 2010; Nieto-Galan, 2016). Therefore, everyone, including scientists and popularizers, must understand that a particular

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sort of science, albeit introductory and apodictic (Fleck, 2010), is present in society and will always affect academic science to a greater or lesser extent.

From this perspective, the research group led by Professor Martha Marandino, from the Education College of the *Universidade de São Paulo* (USP), for example, has contributed to understanding science popularization in museums and science and technology centers. Their works are based on Yves Chevallard's Theory of Didactic Transposition and its derivation, the Anthropological Theory of the Didactic, both originated in the fields of Science Teaching and Education, to investigate what is taught and how it is learned in these spaces (Marandino et al., 2003; Marandino et al., 2016).

We understand that academic science is not the popularized science. The wise knowledge, the object of reference, undergoes a reformulation to become likely to generate interest and be understood by audiences detached from the context where it is produced and gains meaning. This new knowledge results from recontextualization, syncretism with other forms of knowledge, simplification or extrapolation, and communication techniques and creativity.

From the communication field, Epstein (2012) offers concepts that allow us to differentiate the language of communication between peers from science popularization. While the former is "predominantly referential", the latter navigates through fantasy and imagination as instruments of persuasion, thus performing an emotive, poetic, and phatic function. They are different languages and styles, but both are committed to scientific truth. When discussing scientific journalism, Zamboni (2001) stated that this linguistic phenomenon resulted in a new text genre different from the one that originated it. Sánchez-Mora's (2022) definition of science popularization is based on the same aspect: the author understands that popularization is a multidisciplinary activity aimed at communicating scientific knowledge to different audiences by recreating knowledge with fidelity and contextualization in order to make it accessible.

From the field of Education, it is possible to add a perspective related to Social Studies of science and technology and to the concept of Discourse. Based on Ramos et al. (2006) and Magalhães et al. (2017) proposal, we understand that science popularization should undo the conception of linguistic transparency to better understand and plan the effects produced on the public, based on what is said – and not said – about science and technology. After all, the production of meaning does not occur only based on the sender's message, and the

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transposition of scientific language to science popularization language is undoubtedly a process imbued with power.

In these aspects lies the understanding of reciprocal relationships between science and the public and of the transformation processes of scientific knowledge into a new discourse, which is the focus of Valle and Andrade (2022) original study. Employing Pierre Bordieu's concept, they assessed science popularization as a research field.

Here we emphasize the role played by the values and intentions that guide the initiatives or practices for the definition of science popularization; they are not always clear, conscious, or declared, as previously described by Ogawa (2012). And this is the fifth element from our reflections: intentionality.

In their Handbook of Public Communication of Science and Technology, Bucchi and Trench (2014) stated that science popularization historically started as a popularization effort through spectacularization between the 18th and 19th centuries and then became an ode to science in the first half of the 20th century. Only after World War II did the coverage and public display of science become more critical, even suggesting the need for some public participation and control in the 1980s. This perspective only transformed in the late 1990s by overcoming the paternalistic model, characterized by a vertical, top-down relationship. Finally, the 21st century reverberated proposals of involvement and engagement from political participation and citizen science perspectives.

Furthermore, the aforementioned authors suggested that the first decade of the 21st century saw the crisis of traditional mediation (magazines, museums and mainly mass media – TV and newspapers) with the unfolding of expertise democratization through social networks – and a possibility of transparency and visibility for science institutions and professionals.

In the dispute among the referred models, Caribé (2015) points out that there seemed to be a certain subordination of science popularization (and other practices) to the scientific community, with the centralization of its intentionality and pertinence on the sender. The highest representation of this relationship was in the informational or deficit model. Thus, other fields of interlocution, such as the public understanding of science (PUS) and scientific and technological literacy (STL), would be responsible for directing the community's eyes to the receiving public.

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From Bodmer (1985) to Bucchi and Trench (2021), clear and necessary relationships were established: between the perception and public understanding of science, and between scientific communication/education and scientific culture. Here, the aforementioned exhaustion of formal education at schools is reaffirmed, so José Reis must be cited once again to give pertinence to the pedagogical meaning of science popularization and its manifestation forms.

Reynoso (2012) states that revisiting the concept of popularization reaffirms the social and pedagogical intentionality of popularization, which materializes in the goal of achieving scientific and technological literacy and the social appropriation of science and technology. Such *educational dimension* also appears in theorizations like the one by Burns et al. (2003), who define science popularization as a search for "producing one or more of the following personal answers to science [by drawing an analogy with the vowels AEIOU]: awareness, entertainment, interest, opinion-forming and understanding or comprehension" (p. 183).

Finally, Bueno (2010) expands his previous proposals and states that even the pedagogical dimension (in the sense of educating) should go beyond the enunciative tradition, from one who knows to those who do not, by using dialogicity and interaction. This proposal stems from a type of communication fully supported by education, thus pointing out that permeabilities and connections between fields are possible.

Defining without limiting: science popularization as a plural concept

As we have seen so far, several literature collections and reviews highlight that there is no peremptory definition, a strict meaning, that can be applied to all contexts, means, practices, and actions that claim to be or are identified as science popularization.

We agree with Bueno (2010), who wrote that maybe we cannot (or should not) try to overcome the conceptual imbroglio over the term through historical or filiation disputes. On the contrary, considering some disruptions and approximations is necessary and appropriate, as it is a flexible, graded, and plural concept. Just like biologists, who formulated and make use of at least five different definitions for the concept of species (typological or phenetic, biological,

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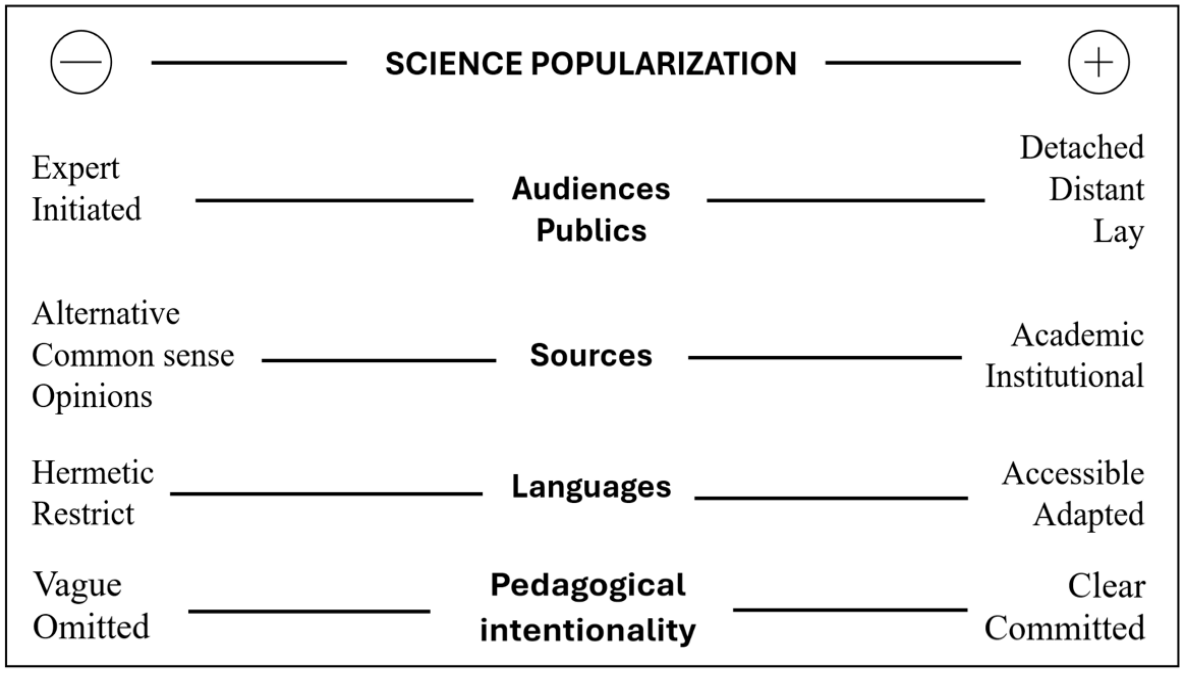
evolutionary, phylogenetic and ecological), maybe science popularization researchers and popularizers should navigate across the plurality and permeability of different domains.

If we agree that a definitive formulation is not necessary, we could analyze science popularization like a guiding scale, more accommodating of the profusion of variables surrounding the expression. Because of this, using the elements presented in the previous section, we propose a conceptual spectrum through which we can reflect upon and even characterize science popularization. In the figure below, we share the understanding that actions and initiatives are characterized as science popularization as they get closer to the extreme right of the spectrum.

Figure 01

Spectrum of science popularization practices from the perspective of a plural definition.



Amidst a range of possible actions (cultural manifestations and means of communication), it is important to understand that several elements can and should be considered for a proposed definition. After all, as we differentiate science popularization from formal educational practices, we also need to distance it from uncommitted initiatives and use credible sources of scientific knowledge. Thus, audiences can be niched, but it is not peer-to-peer communication; sources do not have to be in the latest publications, but they should be

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close to culture and institutional scientific practices; language does not need to rule out scientific terminology, but it should move away from hermeticism and closer to colloquial language; and even pictorial or entertainment actions, due to their potential, should be considered science popularization as long as they assume or allow us to recognize some pedagogical intention.

From this point, the most diverse forms through which science popularization can manifest itself in the public setting are legitimized: a poster at a bus stop, a demonstration at a public hearing, a tray liner with nutritional information at a restaurant, or a literary short story with a scientific theme would all be popularization. In fact, there seems to be no limit to the means or forms through which science can meet the public within a perspective of communicational interaction and pedagogical intentionality.

Based on the aforementioned interpretation and the other references brought to this discussion, we insist that popularization is not (and should not be) only related to scientific concepts but to practices, processes, players, stories, values, and attitudes. Scientists, students, initiated enthusiasts, and communicators willing to mediate the process are legitimate popularizers.

Further reflections and other debates

The crucial point of the discussion about the concept of science popularization seems to be the motivation or intention in its different manifestations. On the one hand, initiatives like producing a new museum facility or making a video for a social network usually start with the assumption that widely disseminating knowledge has a social value translated into education and democracy. On the other hand, this assumption is not what motivates the existence of actions like scientific journalism, which tends to be more clearly guided by professional and corporative dimensions. In light of this, we should acknowledge that the definition of science popularization is not detached from those who practice it – consciously or not.

Other examples as actions such as Pint of Science public conferences or the countless college initiatives to take science to the streets differ from a literary work or a film that approaches a scientific theme. Even among counterpart manifestations, such as in the case of cinema, there are clear differences between films like Jurassic Park and Interstellar. That is why it is not simple to establish general limits. What we call science fiction is a point of intersection

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between thinking and feeling, reason and emotion, skepticism and belief; it melts such dualities. It is unclear if we should consider science a character or a co-author when defining science popularization. Could science be the raw material for fiction and still be popularized? When Kip Thorne, an American physicist, was a consultant and producer of Interstellar, did he transform the film into something that went beyond cinematic entertainment? These are still unresolved questions for our research and practice community.

Particularly, we understand that science and technology can be texts or pretexts amidst culture and that there are several nuances of intentionality among what cultural manifestations seek. For instance, the works of Dutch graphic artist Escher are full of the most refined mathematical concepts. However, they are artworks before they could possibly become works of mathematics popularization. Cultural products are not transparent just because we want them to be. Even if we curated and organized Escher's works according to the concepts in them, what we could more clearly define as science popularization would be only one among several possibilities to understand and exhibit the artist's production.

Hence, it is difficult and probably inappropriate to establish an a priori measure of whether poetry or music is more (or less) capable of captivating or approaching, informing or clarifying, calling for a vocation or seducing, teaching or educating compared to a news article or to a podcast episode. Consequently, a definition of science popularization only seems to be possible by individually situating the initiatives, emphasizing their characteristics, revealing or interpreting their original intentions or measures and, perhaps, assessing their results.

Like Calvo Hernando (1992), we believe that a negative definition of science popularization could be beneficial in cases where some form of limitation is acceptable. Thus, we defend that it should be acknowledged as a pedagogical practice but not organized under the didactic terms of formal education (systematic, sequential, summative, propaedeutic, evaluative and certifying). In this sense, science popularization is part of what is conventionally called, in Brazilian Portuguese, non-formal practices or environments (Calvo Hernando, 2012; Gohn, 1999; Gohn, 2006; Jacobucci, 2008; Marandino et al., 2003).

When analyzing school within the scope of science popularization, Argüello (2001) said that while schools and science teachers educate poorly. It is also true that few popularizers know science and education, and that few scientists know how to popularize and educate. Such precariousness has obviously been minimized in the past few decades. However, we should still

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consider the distances and barriers between those who produce science, those who communicate it to the public, and those who teach it at school. What we know for sure is the close relationship between science popularization and science teaching at school. They share the goal of expanding the scientific and technological literacy of the whole society and consequently consolidate scientific citizenship and culture. Science popularization can complement, enrich, expand, illustrate, contextualize, and update formal education – although it depends on the quality of popularization and school didactics. The problem lies in the fact that the science propagated through science popularization is usually more up-to-date and controversial than school science and that the presence of science popularization at school still occurs fundamentally as a formative resource and supplemental material (Baldinato & Porto, 2008; Batistele et al., 2018).

In another sphere, it is important to pay attention to the institutional contexts when addressing the differences among science popularization, diffusion, and dissemination. Due to motivations from scientific practice itself, in addition to the specific peer-to-peer communication, scientific institutions are guided by institutional interests and not by public interest. In this respect, Fonseca (2019) wrote a text exposing how institutional communication (in this case, Brazilian universities) dismisses public interest and favors the circulation of internal information and interests, or based on public relations.

Nevertheless, from our viewpoint, it is important to situate science popularization as a possible academic practice linked to the core activities of institutions (especially public ones). We understand that science popularization should be accommodated and integrated as a valuable academic practice within the concept of university outreach given the role played by universities as science and technology producers and the community principles of social impact and dialogicity in extension actions (Valério, 2006). In Brazil, this link is already present in some institutions, such as the Science Popularization Department of *Universidade Federal de Minas Gerais*, located at the Office of University Outreach.

In conclusion, we have deepened some questions and proposed new ones for science popularization to ponder and strengthen the social and academic debates about the relationships between science and the public through science popularization. For this reason, we have proposed a possible definition of science popularization without intending to sound peremptory or limiting, aiming to avoid any divisions among actions or to diminish the practice's merit and

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power as a cultural phenomenon. On the contrary, we understand that a plural definition – wider and more accommodating – could make science popularization even more relevant within the context of philosophical and epistemic liquidity inherent to science today.

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