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Processes of communication and dissemination of science: the challenges of science policy guidelines in Colombia

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Introduction: The present study aims to identify the characteristics of public policy relating to the Social Appropriation of Knowledge (SAK) in Colombia, generated between 2020 and 2021, on the communication and dissemination of science. Furthermore, the study aims to determine what incentives are offered by these policies to promote the communication and dissemination of science, and what importance is given to the use of digital scenarios.

Method: This is done through a comparative analysis of Colombia's guidelines of public science policies using a bibliographical review.

Results and discussion: With this analysis, it is concluded that the policies resulting from 22 years of reflection in Colombia aim to strengthen the SAK in the communication of science, understood in specific relation to dissemination, which is understood as activities that make scientific knowledge accessible to a much wider audience.

Conclusion: The digital scenarios are proposed as communicative spaces to spread knowledge to communities and strengthen the science-society relationship.

KEYWORDS

science communication, popularization, digital scenarios, science policies, social appropriation of knowledge, Colombia

1. Introduction

The communication of science, as Sánchez and del Carmen (2013) comments, "is the transmission of scientific knowledge from its sources to the most diverse receivers." Science needs broad and systematic dissemination to ensure that the scientific community and society have access to the results from the research carried out by universities and specialized centers (Davis and D'Lima, 2020; Dearing and Singhal, 2020; Fraser et al., 2021; Schlechter et al., 2021; Brookman-Frazee et al., 2022). As Merino (2011) details, it appeared on the scene in the 17th century through the concretion of science academies, such as the Royal Society, in 1662, the Academy of Sciences of Paris, in 1667, and Berlin in 1670. It also became visible in the publications that belonged to these institutions: Journal des Savants, created in 1665, and the Philosophical Transactions, of the same year and, likewise, through the appearance of museums that spoke about science such as the Royal Garden of Medicinal Plants in Paris, founded in 1635, and the Greenwich Observatory, in 1675. This

communication of science was supported by the critical role that they began to have in the work of scientific researchers in the 18th century; that is, at that time, the very disclosure of their work began to be relevant.

This article first describes the theoretical framework to describe the steps in the dissemination of science, showing the role of the Internet in this process. Furthermore, the previous outcomes of the dissemination of science processes are discussed. In addition, this article explains the science communication process and the importance of citizens being able to read the outcomes of research, understand them, and use or apply them in their personal and organizational activities. One important issue described is that the process of dissemination needs the active role of teachers and students in order for the information to reach the population and even when citizens read the information, they need a complementary explanation of the outcomes. Finally, the article describes the experience of the dissemination of science in Colombia as well as the different policies implemented in that country; the current initiatives of other countries in the region are also shown in a concrete way.

2. Theoretical framework

Science communication was strengthened in the 1970s when a different vision of science began to emerge: not only from a positivist view but as a process that is part of society. In the 1990s, it was related to the importance of information and reflections on how science circulates. In the 2000s, as Gómez (2015) explains, science communication "characterizes areas of science communication about interactions in each specialty, internal relations science as a whole, knowledge community and society in general, and the mass media" (p. 17). The Internet has played a fundamental role in promoting the dissemination of science (Klar et al., 2020; Rosenberg et al., 2020; Betz et al., 2021; Bubendorff et al., 2021; Durazzi et al., 2021; Erskine and Hendricks, 2021; Fang et al., 2021; Tapper et al., 2021; Rivera-Trigueros et al., 2022; Singh et al., 2022; Zhao et al., 2022). The dissemination of science has also led to the commitment to fight against fake news that brings harm to the population (Alvarez-Risco et al., 2020; Ceron et al., 2021; de Oliveira et al., 2021; Ilias and Roussaki, 2021; Jussila et al., 2021; Llorca-Abad et al., 2021; Murayama et al., 2021; Alnazzawi et al., 2022; Frino et al., 2022; Velichety and Shrivastava, 2022; Zervopoulos et al., 2022).

Thus, in these contemporary times, science communication has become an important area, as there have been changes in the relationship between society and scientific knowledge (Rauchfleisch and Schäfer, 2018). For this reason, countries have opted to develop democratization processes (Domènech, 2017; Clyde, 2022), i.e., they have endeavored to ensure that science reaches non-specialized audiences and to get researchers to expand their audiences so that people have more decision-making power over scientific issues or, in other words, they have wanted to overcome a relationship based on the deficit model and build it on a democratic model (Escobar, 2017; Barba et al., 2019).

For Gómez (2015), science communication should be understood as a process of "transcoding" various forms of topics related to science and technology, inside and outside the spaces of academia, to "inform, disseminate or divulge about science and technology, making use of any media or social activity for cultural purposes and giving media response to the problem that arises in the scientific and technological endeavor" (p. 1).

On science communication, Trench and Bucchi (2010) determined that it is a field that has been consolidating over the last 20–30 years, "at the intersections of science education, social studies of science, mass communication, museology, and various other long-established academic and professional activities; it was shaped as much by political and institutional concerns as by intellectual interests" (p. 4). Thus we do not say that bringing research to a lay audience outside the academy is science communication since it involves other practices, such as exchanging information among peers, specialists, or experts. Science communication is also understood as:

> A two-way, inter-active dialogue involving experts, the public and stakeholders. Through formal contexts such as public meetings and other consultation exercises, the public and stakeholders are invited to be active participants in deciding what is discussed, contributing to the production of expert knowledge and the formulation of policy options and decisions (Nisbet and Markowitz, 2016, p. 3).

Although several authors have determined that there is no apparent difference between the concepts that underlie the communication of knowledge to a lay population or to define the relationship between society and science, as mentioned by Massarani et al. (2017), it is necessary to determine the concept of dissemination. In this way, dissemination must be understood as any activity that makes it possible to bring knowledge to a non-specialized population (Hernando, 2003; Fog, 2004; Sanz-Lorente and Guardiola-Wanden-Berghe, 2017). Also, it must be through language "more accessible, allowing greater understanding" (Fernández and Angulo, 2011; de Souza Pereira, Ademir., 2018) or as described by Zamboni (2001), through the popularization of science and the popularizer must work for the construction of a "different discourse" so that people have a greater understanding and greater access to science.

For his part, González-Arribas (2007) stated that the difference between science communication and popularization lies in the fact that the former is the "practice carried out by scientists or specialized communicators, while the latter corresponds to a global project with specific theoretical foundations, which always takes into account its audiences" (p. 70). In this regard, Cediel et al. (2019) reinforce the idea of the importance of discourse in the definition they propose: "popularization consists of recontextualizing in a common communicative situation (for a non-knowledgeable and mass audience) a knowledge previously built in specialized contexts, among scientists, with special communicative instruments" (p. 98). In this sense, it is necessary to emphasize that the commitment to popularization does not imply that the language is lowered or that academics lose recognition. When the concept of popularization is spoken of in some academic environments, it is not understood. When it is explained, it is not well-received since, for some, it represents "wasting time" as there is no bibliometric recognition for popularization practices. Teachers-researchers only think of publishing in indexed journals, in other languages, or in journals with high quartiles, which has a negative impact on the production of other types of practices that are outside this framework of recognition. This reinforces the idea of Martínez et al. (2012) that the need to be visible, recognized, and cited within scientific communities leads researchers

to try to publish in journals highly recognized by international rankings and to leave aside dissemination which is also necessary for society as it contributes to people understanding scientific advances.

Science communication and popularization become more meaningful when thinking about a greater purpose: the Social Appropriation of Knowledge (SAK), which as Marín and Alejandro (2012) explains, is "a process that implies, on the one hand, the availability of scientific and technological knowledge in a common scenario and language for society; and on the other hand, that human beings made such knowledge their own as useful and necessary elements for their benefit and profit." In this same sense, Urrego-Estrada et al. (2021) emphasize that civil society is empowered and becomes the owner of knowledge to achieve social change.

But how can scientists disseminate knowledge to achieve these objectives? The Internet has brought with it a different way of reaching audiences since a mediator (media) is no longer needed to reach the general public. The idea is then that knowledge arrives through the producers, that people get to directly know those who are in the world of science and identify with them. As Jucan and Jucan (2014) expressed, "researchers and students in the field of science should learn about social networks to understand how they work, how they affect science and life, to become aware of social networks and use them efficiently."

By performing an analysis of academic publications on science communication, Rauchfleisch and Schäfer (2018) found two lines that are of interest for the present work: one that has to do with "scholarly communication," which focuses on scientific publications and the turn they are taking toward publication in digital spaces. The other was on "scientists as communicators," from where all issues that involve the scientist and their relationship with society are understood. Erviti and Stengler (2016), using interviews with different providers of scientific content on YouTube, conclude that as we are living in an era in which digital scenarios are necessary, the use of "social networks to expand audiences" (p. 12) is relevant, since they are of "great importance for two-way interaction with the public in scientific communication" (p. 12).

Information technologies enhance scientific communication spaces to build a relationship that brings people closer to science and researchers and scientists closer to the community. This view is strengthened by the work of Nisbet and Markowitz (2016), which identified a growing interest in research papers that delve into the ability of scientists to become opinion leaders. Furthermore, the information can create leaders from other fields who can recommend information on science topics. Another way is the creation of websites by scientists and knowledge communities where they periodically upload reports and other material that serves the needs of their audiences (p. 4), which means that there must be a commitment on both sides, from both the audience and the scientists, to make a real leap in this relationship. However, understanding the importance of disseminating scientific knowledge to a broad audience without the need for mediators is not enough for this type of practice to become a reality. It also requires the commitment of the State to encourage scientists to take this step toward dissemination, which can impact, in turn, the SAK. Jucan and Jucan (2014) state that if researchers disseminate knowledge, it allows people to understand that science is not far from their lives and to make informed decisions regarding issues that may impact their daily lives. This includes their participation in dialogs, discussions on public policies, and resolving their problems from science and technology (Fernández Polcuch et al., 2016).

In Colombia, discussions about science began to have relevance around 20 years ago due to the imminent need for society to have a more direct relationship with science, as science and technology became an essential part of the daily development of life. Since then, policies have been promoted in the country that have resulted in strategies, proposals, and activities to enhance and create other types of encounters between science and society by strengthening places where science communication takes place (Daza and Arboleda, 2007; Daza-Caicedo et al., 2014). This relationship was understood, in principle, from a positivist vision and deficit models, i.e., those that postulate that people have a gap in scientific knowledge and, therefore, the producers of knowledge must fill it (Pérez-Bustos et al., 2012). In the process, there has been a move toward a democratic model (Daza and Arboleda, 2007; Daza-Caicedo et al., 2014) which implies that society in general actively participates in issues related to science, given that it has discernment and experience and because it is interested in that knowledge for its application in specific contexts.

These ideas are reflected in the laws that have been promoted in the country and in the different reflections that come from Colciencias (Administrative Department of Science, Technology and Innovation), currently elevated to the category of Ministry of Science, Technology and Innovation (Minciencias), through the sanction of Law 1951 of 2019 (Congreso de Colombia, 2019) as the entity in charge of giving guidelines about science and technology. It seeks a greater production in the dissemination of knowledge to reach more and different audiences so that there is greater participation in resolving scientific problems.

The work by Minciencias has been carried out under the guidelines of a strategy for the whole country from the ideas of the SAK of Science, Technology and Innovation (ASCTI) in order, as stated by Rátiva et al. (2011), to achieve a communication different from the unidirectional one between science, technology, and the public.

It has also been promoted by work teams that have carried out what is known in Colombia as Missions, whose main objective is to discuss, reflect, and recommend ideas and strategies for consolidating advances in the country's science and technology policies. The first one took place in 1988 and is known as "the Science and Technology Mission," from which several ideas on SAK were extracted and included in Law 29 of 1990, "whereby provisions are issued for the promotion of scientific research and technological development and extraordinary powers are granted" (Congreso de la República de Colombia, 1990). Among the most important content of this Law is Article 2, which states that "The State organize a National System of Scientific and Technological Information to consolidate the respective institutional system and provide incentives to creativity, taking advantage of its productions to improve the life and culture of the people." Furthermore, Article 10 is important, where it is determined that the Government should "assign permanent spaces in the mass media owned by the State for scientific and technological dissemination" (Congreso de la República de Colombia, 1990).

To reinforce the idea of contributing to the "culture of the people," in 1991, the National Council of Science and Technology was created as "a management and coordination body of the National System of Science and Technology and as the main advisor to the National Government in these matters" (Colciencias,

2005). It also emphasized the need for Colciencias to work on creating strategies to communicate and inform about science and technology.

In the report presented by this Mission (Aldana et al., 1994), the gaps in state decisions to achieve the objectives of continuous and intense work concerning the importance of bringing science and technology closer to society in a clearer way are evident. During the 1994 Mission, support for doctoral development, changes in education, support for young people interested in research from the first semesters, and investment in projects from the national GDP, among others, were proposed. Also, through the National Strategy for SAK of Science, Technology and Innovation (Colciencias, 2005), it to the support of traditional actors in the field of science, i.e., scientists, teachers-researchers, and state and non-state organizations was proposed, and to promote actual actions that allow society in general to be part of this structure of knowledge. In relation to these proposals, a characterization made by Lozano et al. (2016) shows that in Colombia, there was a significant advance in the promotion of public policies that advocated for the appropriation of society in science and technology issues between 2005 and 2015, given that the responsibility no longer fell only on Colciencias. However, the space was opened for other actors to participate in consolidating strategies to achieve this.

This article aims to recognize the characteristics of the most recent public policy, generated between 2020 and 2021, on science communication, outreach, and SAK in Colombia to determine what incentives the policy offers to promote them and the importance given from there to the use of digital scenarios.

3. Materials and methods

Based on a literature review, a comparative analysis was developed to measure the importance of science communication within the most recent national science policy documents in Colombia issued by Minciencias: guidelines for a National Policy of SAK of Science. The following documents were analyzed: Technology and Innovation by Citizens for Citizens (Minciencias, 2020), National Call for the Recognition and Measurement of Research, Technological Development or Innovation Groups, and the Recognition of Researchers of the National Science, Technology and Innovation system – 2021 (Minciencias, 2021, 2022). The analyzed content of these documents included:

a. The relevance of science communication to strengthen the science-society relationship and the conceptualization of dissemination and SAK defined by public policy.
b. The existence of indicators to measure the achievements of outreach and SAK.
c. Policy-driven practices for achieving science outreach and SAK from digital scenarios.

For the analysis of the policies, a content analysis was used to describe the information. The source of the information is from official organizations in Colombia. The first characteristic is proposed considering the conceptual framework presented, where ideas on communication are presented. The second characteristic relates to the importance of the dissemination of knowledge to reach the wider public and the last one relates to the relevance that digital scenarios have come to occupy as places to disseminate science. These three characteristics are developed within the documents reviewed, reflecting the need to work on them to consolidate the relationship between science and society, as shown in Table 1.

4. Results and discussion

4.1. On the conceptualization of communication, dissemination, and social appropriation of knowledge in the public policy

The documents from science and technology policies and guidelines in Colombia presented the importance of consolidating science communication practices to access a wider audience. While mentioning the importance of research generating a fundamental transformation through SAK, emphasis is placed on the need to disseminate. From what is expressed in the texts, it is possible to extract the definitions that set the guidelines for developing public policy in this area, as shown in Table 2.

In the above definitions, it is possible to observe that public policy is coherent on the need for scientific knowledge to transcend academic spheres and the organizations which produce the knowledge so that the different communities of people that make up society can use this knowledge in their context. Likewise, the notion of public communication of science is proposed, which is nothing other than dissemination, as an intentional action of telling science from perspectives and languages closer to the population not specialized in these topics, promoting reflection and critical thinking, and bringing the practical use of research results closer. This is expected to result in a better perception of scientific research in Colombia. The conceptual clarity observed in the three documents analyzed should be evident in the strategies that make

TABLE 1 Categories of analysis.

Category	Objective	Indicators
Conceptualization of science communication, outreach, and SAK from public policy	To recognize what is expected of science communication, outreach, and SAK based on what is expressed in the Colombian public policy	Definition of outreach and SAK in the documents
Incentives to strengthen the science-society relationship through communication	To determine which are practices and products valued for communication, dissemination and SAK in public policy, and the importance of digital scenarios for this purpose	Valued practices on communication, dissemination and SAK. Products valued about digital science communication.

TABLE 2 Conceptualization of communication, outreach, and SAK in public policy.

	Guidelines for a National Policy on Social Appropriation of Knowledge of Science, 2020	National Call for the Measurement and Recognition of Research Groups 2021	National Open Science Policy 2022
Social Appropriation of Knowledge (SAK)	SAK is a process that summons citizens to dialogue and exchanges their knowledge, wisdom, and experiences, promoting environments of trust, equity, and inclusion to transform their realities and generate social wellbeing	The SAK approach from Research + Creation is a process of dialogue and exchange of knowledge that produces results, knowledge, and experiences, which can be obtained from direct experimentation with the object of knowledge, and therefore promote a feeling of identification and appropriation. Within this process, concerning the results, it is evident that they require appropriation from the sensitive and propitiate scenarios of creative appropriation, fostering the possibility of generating social transformations	To achieve the opening of science as an instrument of democratization of access to scientific knowledge, but also thought of as a public good and assuming the challenges involved in the implementation of an Open Science policy adapted to the realities of the territories, taking as a premise the need to transcend knowledge that only flows in academic scenarios, to value its impact and social use
Disclosure	Public communication of science refers to exercises to construct meaning through shared imaginaries, collective actions, cultural constructions, political interactions, social movements, and the common interest. Public communication deals with the contents and messages so that they are visible and participate on equal terms in the circles of construction and circulation of the public agenda. In this sense, the nature of popularization is rescued as an intentional action of telling science in different ways to rescue traditional knowledge, making visible the results of research processes, their impacts and risks, proposing new aspirational models for children, adolescents, and young people, encouraging critical and reflective thinking and promoting the appropriation of topics and concepts associated with science, technology, and innovation by the target audiences	Communicative products for the public dissemination of STI are the result of research processes and contribute to understanding the transformative power and relevance of science, technology, and innovation in life, communities, and territories. These are communicative products that are designed to strengthen the generation of critical and reflective capacities in audiences regarding the relationship between science, technology, and society; they also seek to renew perceptions about STI to improve society's appreciation of the practice of scientific research in Colombia	The notion of public communication of science (PCST) is also proposed along with scientific communication. This process allows the opening of even more channels and means to generate processes of dialogic interaction for the social appropriation of science. For this reason, public communication of science refers to an essential process to ensure that the results of scientific research are known and appropriated by all.

it possible to make the final goal of achieving SAK a reality. This is analyzed in the following section (Table 3).

4.2. On incentives to strengthen the science-society relationship through communication

From the comparison of the three documents, it is possible to observe the main strategic objectives to encourage the science-society relationship, including communication, dissemination, and SAK.

As seen in the documents, it has become a priority to encourage researchers, especially those who are part of universities, to use production practices that are not restricted to publishing articles in indexed journals. However, these continue to have greater recognition in the weightings within the production measurements. In the National Call for the Recognition and Measurement of Research Groups, changes are proposed to the public communication of science, which is directly related to the generation of outreach products (Minciencias, 2021).

This not only invited the academics to produce for themselves but also for research to fulfill its purpose and impact society. The proposal to value communication and dissemination products is presented to promote the SAK generated by the research groups. These products, resulting from Activities of SAK and Public Dissemination of Science, are classified into four types. For the 2021 measurement, the weight in the each indicator for the scientific production was adjusted. The weights are on a scale of 0 to 10 and are related to the category in which the research groups are located. The highest category is A1 and the lowest is C2. The idea through this modification was to encourage the production of SAK in research groups, which today are focused on publishing articles in indexed journals. Table 4 shows the products recognized and measured within the SAK and Public Dissemination of Science type and the weights given in the measurement (Minciencias, 2021).

The Guidelines for a National Policy for the Social Appropriation of Science, Technology and Innovation Knowledge by Citizens for Citizens (Minciencias, 2020) indicates the importance of generating spaces for "the co-production of

TABLE 3 Strategic objectives to encourage the science-society relationship from the public policy stand point.

Guidelines for a National Policy on SAK of Science, 2020	National Call for the Measurement and Recognition of Research Groups 2021	National Open Science Policy 2022
Include more social, institutional, public, and private actors in the dynamics of science, technology, and innovation based on ownership	Incentivize production through dissemination strategies to achieve SAK	Expand the adoption and implementation of policies, regulations guidelines, directives, guidelines, protocols, and procedures in the strategic institutions of the country's Open Science model, which strengthens the governance of Colombia's Open Science model
Strengthen capacities in the territories and the communities so that in the medium and long term, they are strengthened in CTeI	Change in the weighted weight of the production of research groups about this typology of products, giving greater importance to SAK and Public Dissemination of Science products	To create a culture of openness, dialogue, inclusion, and social responsibility for the country's knowledge-generating actors to generate solutions to the problems and needs of the population
Develop experiences with new forms of dialogue, mediation, and articulation between actors and sectors in the field of STI	To integrate in an appropriate and pertinent manner the approach of SAK and Public Dissemination to research activities, their results, social impacts, the teams that participated, and the contexts in which they were developed	Institute a system of metrics and incentives to promote, value, and recognize Open Science practices, processes, and results in the Colombian scientific community and integrate it into the existing models and systems of metrics and incentives of the country's existing STI activities
The implementation of innovative convening modalities aimed at involving more diverse actors to increase citizen participation in the dynamics of CTeI	Products developed from the collective construction between research groups and citizens	Strengthen the knowledge, competencies, and expertise of the country's strategic Open Science actors
Create spaces to work with the community and collaboratively build digital communication content	Generate products that are promoted on digital platforms so that society, in general, has access to them	The openness of knowledge, not only to academic communities but also to society in general, through digital platforms.

TABLE 4 SAK products and public outreach of science.

Product	Definition
Processes of social appropriation of knowledge (SAK)	Processes of SAK for the strengthening or solution of issues of social interest, the generation of inputs for public policy and regulations, the strengthening of productive chains, or the result of joint work between a science center and a research group
Circulation of specialized knowledge	Scientific events with appropriation components, participation in specialized knowledge networks, creative workshops, cultural and artistic events, working papers, new genetic sequence, editions of scientific journals or books resulting from research, reports (final research and technical), and consultancies (scientific-technological and research-creation)
CteI public outreach	Non-specialized editorial publications, digital content productions, transmedia content and strategy production, and web development.
Bibliographic production	Dissemination books or dissemination compilations, training books (Q2 and Q3), technical manuals and guides, dissemination articles, articles and scientific notes published in book series, trade journals, and proceedings, dissemination bulletins, and creation books (pilot).

knowledge between scientific communities and other groups; the co-creation of artistic and communicative content, digital products, exhibitions and cultural events" (p. 17). On the other hand, within the guidelines of the Open Science document, it is specified that dissemination is enhanced through the opening of data, information, and research results to a broader public, which in turn would encourage the SAK (Minciencias, 2022). This is also strengthened by rethinking the conditions of access to information to enrich the people who use it and diversify the people who produce knowledge.

The Guidelines on Open Science (Minciencias, 2022) allow even more clarity on the contribution of digital scenarios to open knowledge, not only to academic communities but to society in general which indicates that the ideal of this policy is that research scientists are encouraged to publish their work on digital platforms so that different people can have access to knowledge. The Measurement document (Minciencias, 2021) proposes that research groups should present products that arise as a result of activities that enable the ASC to involve science communication, understood as part of dissemination:

> These communicative products are designed to strengthen the generation of critical and reflective capacities in audiences regarding the relationship between science, technology and society; they also seek to renew perceptions about STI to improve society's appreciation of the practice of scientific research in Colombia (Minciencias, 2021, p. 89).

The products indicated are those that use digital platforms, such as newsletters of this nature, creation of web pages, production of digital audiovisual content, sound, graphic resources, strategies, and transmedia content; hence it is understood that the use of digital technologies and environments for dissemination are desirable for Minciencias.

There is evidence in different countries in the Latin American region of efforts to disseminate science. There was a report on the digital observation of cultural identity in Argentina (Carbonari et al., 2019). In addition, the Government of Argentina's web page has a resource bank for research, which provides various links to facilitate research and dissemination of results (Government of Argentina, 2022). The positive results of the online program dedicated to educating people about lupus were also reported in Latin American countries (Drenkard et al., 2022).

In terms of political efforts of dissemination, some countries have developed specific laws about it. In Argentina, there are the National System of Digital Repositories (Government of Argentina, 2021), Law 26.899 on Open Access (Government of Argentina, 2013), Argentine Science and Technology Information Portal (Ministry of Science Technology and Innovation of Argentina, 2023), CONICET Digital Institutional Repository (CONICET, 2023), and the National Systems of Large Instruments, Facilities and Databases (Ministry of Science Technology and Innovation of Argentina, 2022). In Brazil, there are the Brazilian Portal of Open Access to Scientific Information (IBICT, 2023), Portuguese Open Access Scientific Repositories (dissemination agreement with Brazil) (FCCN, 2023), and the Directorate of Editorial Policies of Brazilian Scientific Journals (Diadorim) (IBICT, 2022). There are similar efforts in other countries: Chile with Open Scientific Data (CONICYT Chile, 2022), Costa Rica with Institutional Repositories of Scientific Publications and Cultural Heritage (CONARE, 2023), Mexico with National Repository (Government of Mexico, 2023), Peru with National Digital Repository of Science, Technology and Innovation of Open Access (CONCYTEC, 2023) and other countries.

These results related to the dissemination of science are linked to Michael Polanyi's linear model of science communication (Polanyi et al., 2000). The mission of universities is to promote the development, publication, and dissemination of research in the highest-impact journals, such as those indexed in Scopus or Web of Science. In this way, knowledge is transmitted to society. Thus, these inputs can be used to generate new research, generate patents, and develop policies that improve scientific production and develop proposals that generate disruptive innovation.

The dissemination of science is also related to Everett Rogers' Innovation Diffusion Model (Rogers, 1962) since universities are increasingly adopting virtual spaces to disseminate scientific findings. That is, not only through publication in journals but also through white papers, blogs hosted on university websites, and podcasts. This promotes greater collaboration among researchers. More scientific information needs to reach more people; however, the process is still slow, and it is necessary to generate a faster change toward open access models (Suber, 2004), as some scientific publishers do today to ensure that the results reach all readers without having to pay anything. Furthermore, facilitating communication through different media such as radio, television, and social networks such as Twitter, Instagram, and TikTok is necessary. In this sense, there are two paths to open access from universities. One way is for more resources to be allocated to publish in the open access format, which requires a mandatory payment for publication. This occurs in journals from different publishers such as Springer, Elsevier, and Emerald. The other way is through the generation of organic dissemination from a university through short scientific events aimed directly at disseminating findings; this information should be posted in the repository of the university for later review and even opinion.

A crucial aspect in the case of dissemination is the language barrier for potential readers. In the case of Spanish-speaking countries, it is necessary to consider the information gap. It is clear that there must be an urgency in providing information in the original language of the readers and even though efforts must be made to ensure that it can be read in English, the most important content must be provided in Spanish. According to Khun, expressed in The Structure of Scientific Revolutions (Kuhn, 1962), universities need to promote collaboration among their various academic staff so that dissemination can be multidisciplinary. Knowledge disruption requires the contribution of diverse knowledge and points of view so that the knowledge acquired can generate new knowledge and, above all, can transform society through new technologies.

5. Conclusion

The documents reviewed for this article, which have been guidelines from 22 years of reflection in Colombia and aim to strengthen SAK in science communication, can be understood in specific relation to outreach, which is understood as activities that make scientific knowledge accessible to a much wider audience. As indicated by Rauchfleisch and Schäfer (2018) in their proposal for scholarly communication and communication of scientists, these policies aim to strengthen the relationship between researchers, science, and society through communication. The communication of science is encouraged through outreach to make knowledge available to diverse communities (academic and social) through digital platforms, understanding that open science "allows access and participation of different actors in the processes of generation and use of scientific knowledge through Information and Communication Technologies" (Minciencias, 2020).

Universities can improve public understanding of science through clear and accessible communication of research findings and their relevance to society (Irwin and Wynne, 1996). Science literacy is a barrier for research institutions because the public usually has little understanding of the most general aspects of science, even if they have been taught in schools. In this circumstance, universities have the role of standardizing the minimum knowledge to be able to transmit recent advances so that they can receive the corresponding importance from the population and can be active agents for the changes that science proposes.

Digital scenarios are essential, which become places that scientists should use to approach people and bring knowledge so that people understand the importance of approaching science to reach a wider audience (Jucan and Jucan, 2014; Erviti and Stengler, 2016; Nisbet and Markowitz, 2016). As proposed by national science policies, these scenarios can be created by science researchers' initiatives or by co-creation with the community they research. The guidelines of these policies point then to the existence of a democratic model, in the sense that most of the actors of society are participants in knowledge dissemination through different strategies, among which digital scenarios are involved (Monsalve and Ochoa, 2014; Segado-Boj et al., 2014; Lopez-Perez and Olvera-Lobo, 2016; Sanz-Lorente and Guardiola-Wanden-Berghe, 2017; Besley et al., 2018; Calvo et al., 2018). The guidelines

also mention the importance for scientists to develop competencies to communicate science, insofar as knowledge of cultural environments is needed to be able to put in clear and understandable language the knowledge that impacts the daily lives of people, such as the intercultural approach proposed by García (2015), in which the population and cultural diversity of the countries are considered. Minciencias has promoted this type of space, with examples such as ONDAS, Jóvenes Investigadores, Ideas para el Cambio, and A Ciencia Cierta, to create science through collaboration and dialogue.

One of the biggest challenges to achieving science communication is that researchers are trained in competencies for science communication (Jucan and Jucan, 2014). In addition to training research scientists from the policy guidelines, it is a challenge for researchers and Minciencias to encourage society, in general, to want to access knowledge and have the training to become familiar with the different scenarios proposed by the different policy guidelines. It is important to note at this point that, while it is true that outreach is necessary to communicate knowledge to a broader audience, not all researchers, who in the case of Colombia mainly belong to research groups, should work on it. Thus, it is also necessary that there is a willingness of scientists to make this happen.

Another significant challenge is the value of the measurement with precise indicators of the activities of communication and dissemination of science. Making the dissemination of knowledge in digital scenarios equal to the production of new knowledge creation generates incentives in the measurement model of groups and researchers and in the classification of journals for producing open scientific and technological research with quality and excellence criteria (Minciencias, 2020). In addition, Minciencias requires that universities develop policies for this type of product so that scientists linked to universities recognize this type of production as intellectual capital and do not only opt for publications in indexed journals.

The passage discusses policies that have been developed in Colombia over the course of 22 years to enhance the SAK (Knowledge Management System) by means of science communication. The SAK is a system aimed at managing and promoting scientific knowledge in Colombia, with the goal of contributing to the country's development. One of the strategies employed by these policies to enhance the SAK is to disseminate scientific knowledge, which involves making information or knowledge available to a broader audience, including policymakers, journalists, and the public who may not have expertise in the field. The policies acknowledge the importance of outreach in strengthening the SAK as it enables scientific knowledge to have a greater impact on society. The goal of the policies is to promote a culture of science in Colombia and encourage the use of scientific knowledge in decision-making processes. To achieve this objective, the policies propose the use of digital scenarios as communication spaces to disseminate knowledge to a wider community and include online platforms such as websites and social media.

It is necessary that the dissemination of scientific information be done according to the field of study, since each of them has a series of characteristics that must be considered so that the information is transmitted in an adequate and understandable way to the citizens. In the case of natural sciences, the information is often based on empirical data and objective observations that can be verified and replicated. Therefore, the dissemination of scientific information in this field is often based on the presentation of concrete data and facts and can be more technical and specialized. This may require a greater capacity for analysis and understanding on the part of citizens so information should be presented in a clear and concise manner, using technical but accessible language.

In the case of social sciences, the information is often based on research and studies that address more complex issues related to human interaction and society in general. Therefore, the dissemination of scientific information in this field can be more subjective and based on the interpretation of data. Therefore, it is important to present the information in a way that provides an understanding of the researcher's perspective and interpretation, and shows how the research results relate to the real world. In the case of health sciences, the information often relates to health and wellness issues, which can be of great interest to citizens. Therefore, the dissemination of scientific information in this field often focuses on providing useful and practical information that citizens can use to make informed decisions about their health. It is important to present information in a clear and accessible manner, using simple language and avoiding the use of complex technical terms.

For authors, the contribution of this study is that the policies show the potential of digital venues to reach a much wider audience than traditional methods of communication, such as scientific journals or academic conferences. Digital scenarios can also facilitate interaction between scientists and the public, allowing for a more dynamic exchange of ideas and information. Moreover, the policies aim to strengthen the film-society relationship, which pertains to the relationship between the film industry and society, and the potential of films to promote scientific knowledge and stimulate interest in science. The policies acknowledge the potential of film to engage and inspire audiences and promote a greater understanding of scientific concepts. By strengthening the film-society relationship, the policies aim to harness the power of film to promote scientific knowledge and foster a culture of science in Colombia.

Future research should be conducted in order to describe the progress of dissemination of research results. In that sense, it is vital that research be done on the variation in citizens' knowledge of science using altmetric measures since altmetrics focuses on the dissemination of research, i.e., how research is used and shared online. This is important for citizens because they can then access the scientific information being generated more quickly and efficiently. In addition, altmetrics also helps citizens to assess the quality of research and its relevance to society. Another advantage of altmetrics is that it can be used to measure the impact of research on society. For example, if a scientific article generates many mentions on social networks, this can indicate that the research is generating significant interest in society and can have a direct impact on political and social decision-making. Altmetrics is also important for citizens because it can help identify research trends and areas of interest in each country. This can help citizens understand how research is developing in their country and identify areas where additional investment may be needed. It is important to have research that is also associated with decision-making to investigate the effect of science dissemination policies.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

YN-S: conceptualization, methodology, software, validation, and formal analysis. YN-S and JS-U: investigation, resources, and data curation. YN-S, AA-R, JS-U, SD-A-A, and JY: writing—original draft preparation, review, editing, and visualization. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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