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Knowledge and Perceptions of Open Science among Researchers—A Case Study for Colombia

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Abstract: Open science can provide researchers diverse opportunities to collaborate, disseminate their research results, generate important impacts in the scientific community, and engage in effective and efficient science for the benefit of society. This study seeks to analyse and evaluate researchers' knowledge of open science in Colombia using a survey to determine adequate instruments with which to improve research in the framework of open science. The aim of the study is to determine researchers' current awareness of open science by considering demographic characteristics to analyse their attitudes, values, and information habits as well as the levels of institutionalism and social appropriation of open science. A representative sample of Colombian researchers was selected from the National Research System. An anonymous online survey consisting of 34 questions was sent to all professors and researchers at Colombian universities and research institutes. Sampling was random and stratified, which allowed for a representative sample of different categories of researchers, and principal component analysis (PCA) was used for the sample design. A total of 1042 responses were received, with a 95% confidence level and a margin of error of 3%. The majority of respondents knew about open science, especially in relation to open science tools (software, repositories, and networks) and open data. Researchers consider open science to be positively impacted by factors such as the rise of digital technologies, the search for new forms of collaboration, the greater availability of open data and information, and public demand for better and more effective science. In contrast, a lack of resources to develop research activities within the open science approach and the limited integration between traditional and open science are identified as the most important barriers to its use in research. These results are important for building adequate open science policy in Colombia.

Keywords: open science; survey; perceptions; researchers; Colombia

1. Introduction

In recent years, open science has generated changes in the scientific research process, including in the development, evaluation, and use of new knowledge for researchers and society. The improvement and application of information technology has created alternative ways to assess, publish and disseminate research results that are characterised by their quality and veracity and researchers' scientific reputation, whereby different stakeholders are affected by this new scientific perspective [1].

Open science is a new approach to scientific practice based on cooperative research and new methods of knowledge distribution using digital technologies and new collaborative tools that promote joint effort along with the sharing of results and new knowledge as early and as widely as possible. The goal of open science is to participate with broader communities to address global challenges more effectively and guarantee that science and research are fundamental to the innovation, growth and development of countries [2].

Different approaches to open science have emerged, emphasizing different aspects. These include [3] (i) democratic, which aims for all knowledge to become free and available to everybody, including open access, open data and codes, and intellectual property rights; (ii) pragmatic, where the objective is the open process of knowledge creation, including networking and open data and codes; (iii) infrastructure, which is derived from open and available platforms, tools, and services for scientists; (iv) public, which implies that science should be accessible to society, including citizen science, scientific projects with social participation, and science blogs; and (v) measurement, which refers to the development of a new system to evaluate scientific impacts through alternative metrics. These approaches indicate the importance of analysing open science and taking into account the entire research process to determine the main perceptions, ideas, opinions, and knowledge of researchers in the application and use of different elements and tools of open science with the aim to improve research process.

In the Latin American context, studies on the perceptions of open science are limited. However, various countries have developed political initiatives to promote open science and open data. In particular, Argentina, Brazil, and Ecuador seek to guarantee equal access to knowledge, reduce gaps in cooperation and transparency, increase the impact of research in the region, and articulate an open science policy that strengthens the scientific process as a driver of growth, development, and innovation [4].

In this context, the objective of this study is to assess researchers' knowledge, perceptions, and experiences with open science in Colombia, to examine its impact and to understand how Colombian researchers use the scientific process and research cycle to promote open science in their country.

The scope of this study is based on the need to update science, technology, and innovation policies in the framework of open science in Colombia based on three relevant sources: the Colombian Digital Library Project, the National System of Open Access, and the Open Data Platform. An analysis examines the perceptions, opinions, and recommendations of Colombian researchers in order to strengthen the open science process in the country. The general hypothesis of this study is that Colombian researchers who consider open science in the research process are limited.

The remainder of the paper is organised as follows. Section 2 provides a literature review related to previous studies of the perception of open science. Section 3 explains the methods used in this study. Section 4 describes the main results and provides a discussion. Finally, Section 5 presents the main conclusions.

2. Literature Review

Open science represents a new perspective of scientific development and the scientific process based on cooperative work and research as well as information circulation through networks using advanced technologies and collaborative tools. Open science seeks to facilitate knowledge generation and acquisition through collaborative networks and to encourage the generation of solutions based on openness and sharing [5].

Open science includes the following components [6,7], (i) open access implies free access to scientific knowledge for everyone without restrictions, and its use according to creative commons licenses is assumed; (ii) open data are data that can be freely used, shared, and built upon by anyone, anywhere, for any purpose, although the integrity and authorship of the data must be guaranteed [8]; (iii) open reproducible research provides access to the results (open access), to the process (open data), and to the methodology and other aspects of the research process that make it possible to understand how the results were achieved and to allow the research work to be replicated and reproduced; (iv) evaluation of open science implies the use of cybermetrics, webmetrics, altmetrics, and different types of impacts (impact factor and the H index), including social impacts, for the dissemination of solutions to society's problems; (v) open science policy refers to all governmental or institutional actors or programmes that seek to encourage and regulate open science in a specific society or academic community through different strategies and resources; and (vi) open science tools are technological

tools that help in the development of open science, such as platforms for integration (software and hardware) and networks.

This project emerged from the requirements of Colombian public policy and the guidelines of the National Development Plan, which prioritizes the establishment of solid ecosystems of open data where science, technology and innovation play an important role. The country needs to define a formal policy to promote open science that benefits society, especially for the scientific community with respect to legal requirements (copyrights) and institutional rules and requirements of researchers. Moreover, in this country, the main studies on open science focus on Colombian researchers' access to information, transparent science, and open access [9–11]. Various universities have research groups and initiatives to promote open science with the help of libraries and research offices.

To analyse how acquainted Colombian researchers are with open science and its tools, a survey was used because it is the most frequently applied mechanism to explore researchers' perceptions, opinions, and knowledge of open science. Prior studies have examined specific knowledge areas based researchers' age, territorial scope or academic education. The main studies of the perception of open science and its components, such as open access, are the following.

- To analyse data policy research in institutions, Leaders Activating Research Networks (LEARN) [12] developed the study 'Ready to manage research data?' in Europe and Latin America. It included thirteen questions to evaluate data management in different institutions.
- To examine users' experience with open science networks, Open Science Grid [13] developed the Open Science Grid PKI General User Survey study with different network users. It included nine questions on users' experience with open science and their interactions in the network.
- To evaluate the particularities and context of research and its relationship with global changes, Belmont Forum [14] established the study Skills for e-infrastructures and data management in global change research worldwide. It used twenty-one questions on research contexts related to data infrastructure requirements to promote open science.
- To evaluate the knowledge and perceptions of open access in social science and the humanities, Edith Cowan University (ECU) [15] developed a study with thirteen questions related to knowledge of open access and its application as well as users' experience publishing in open access contexts.
- To compare the perceptions, motivations, and behaviours of researchers in relation to open science in three areas—physics, economics, and medicine—the study called 'Open science: one term, five schools of thought' [16] was developed. It included eighteen questions to analyse the degree of acceptance of open science by researchers in three different areas of knowledge.
- A study on perceptions of open access based on the experience and age of researchers was conducted on academic research faculty members possessing a PhD at U.S. universities and colleges. It included four questions on open access perceptions [17].
- In Spain, a study was performed to determine the perceptions of open access among PhD students, professors and researchers at a university. It included thirty-seven questions related to different elements of open access [18].

These studies included questions that evaluated researchers' knowledge and use of open science, although some studies only included open access as a component of open science. Moreover, the studies analysed the main barriers or constraints for open science, which include (i) the lack of evaluation by academic peers, (ii) publications of lower quality or prestige, (iii) studies in draft form, (iv) the danger of open science publishing harming one's career, (v) the lack of institutional support for open access, (vi) the unclear benefits of open science, (vii) the lack of financial support for open science, and (viii) the lack of national and institutional policies and guidelines for open access publishing.

These results show that open science is important to the research process. In general, studies of the perceptions of open science consider specific elements or components such as open access. Hence, this study seeks to design a survey that includes different open science approaches to add value

for determining researchers' perceptions of open science. As explained in the methodology section, various facets of these studies informed the design of the survey (see Table 1).

Table 1. Conforming categories in Colombian departments of study.

Category	Colombian Departments	Sample Size
1	Amazonas, Boyacá, Caldas, Caquetá, Casanare, Cauca, Cesar, Chocó, Córdoba, Cundinamarca, Huila, La Guajira, Magdalena, Meta, Nariño, Norte de Santander, Quindío, Risaralda, Sucre, and Tolima.	242
2	Atlántico, Bolívar, Santander, and Valle del Cauca.	205
3	Antioquia.	136
4	Bogotá D.C.	459
Total		**1042**

3. Methodology

3.1. Study Area and Population

For this study, a survey was administered to Colombian researchers registered on the national platform Scienti in the application CvLAC, which contains the curriculum vitae of national researchers and is administered by Colciencias, the agency chiefly responsible for the administration of science, technology, and innovation in Colombia. The study population comprises 72,797 researchers registered on the Scienti platform as of December 2016, which are distributed in different Colombian departments.

3.2. Sampling Technique, Sample Size, and Data Collection

To achieve a suitable sample size from this population, a probabilistic sample was used to ensure, with confidence, that the different units of sample researchers have equal probabilities of being chosen. A sample size of 1042 researchers was calculated to guarantee a margin of error of 3% and a confidence level of 95%. Confidence intervals (CI) for the population proportion (P) were identified as defined in Equation (1), with sample proportion (P_s), population size (N), sample size (n), and the table value from the standard normal distribution at the 95% confidence level (Z = 1.96) [19]. Sample proportion (P_s) is the proportion of researchers in a sample who share a common trait [19]. Population proportion (P) is the proportion of total researchers who share a common trait [19]. The probability of acquaintance inclusion was assigned to be greater than zero, and a priori probabilities were assigned as a condition of the selection mechanisms, which allowed for precise and reliable statistical inferences of the target population and a national representative sample of Colombian researchers from the National Research System.

$$CI\ for\ P = P_s \pm Z \sqrt{\frac{P_s(1-P_s)}{n}} \sqrt{\frac{N-n}{N-1}} \quad (1)$$

To determine the different categories from the geographical distribution and the presence of researchers in every Colombian department, the technique used was random and stratified sampling. This study used principal component analysis to identify high correlations between selected variables for grouping (according to size of the researcher population in every Colombian department, the number of affiliated institutions, and the number of research groups). These variables indicated strong correlations (see Figure 1). Next, this study applied a hierarchical method with Ward's method and the k-means method using the function cluster.carac and selected the algorithm for strata Fan–Muller–Rezucha. Table 1 shows the categories and sample size of the survey.

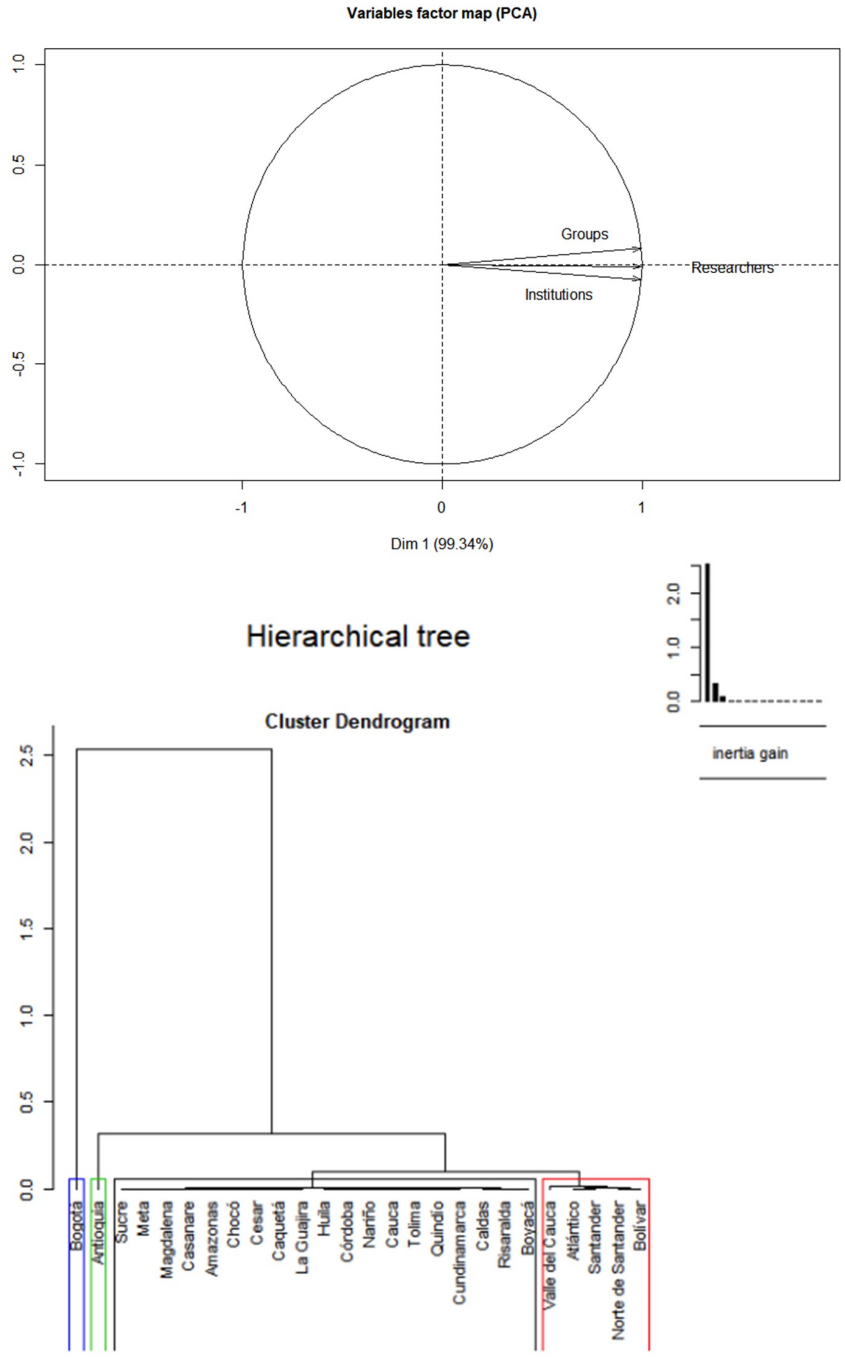

Figure 1. Factorial maps and hierarchal tree (using the Ward technique) of variables used to conform categories of Colombian departments.

3.3. Survey and Instruments

This research used a survey questionnaire. Surveys are the best method to cover a large population and ensure an accurate sample. The questionnaire was divided into five sections, with a total of 34 questions (see Table 2). The questions were selected based on a literature review and an expert panel from Colciencias (Colombian government organization for science, technology, innovation, and Colombian universities), and Antigua Manual guidelines [20] for perception studies related to science and technology were followed to define the categories in the questionnaire. Moreover, the overall survey instrument underwent content validity analysis and pilot testing in an effort to purify and refine the survey instrument. It was determined that the survey completion took, on average, 35–40 min.

The pilot test was sent to a group of researchers to determine the response time, precision, and understanding of the questions with the aim to assure that the instrument was relevant and appropriate for the study. Most researchers replied that the survey was clear and easy to answer, and some made suggestions that were applied before the survey was sent to other researchers. Moreover, the Cronbach's test demonstrated that the survey instrument was suitable for this study. This test calculates the internal consistency and reliability of questionnaires with Likert-type scales and items [19].

Table 2. Categories and questions for the first national survey on open science in Colombia.

Categories	Questions	Source
Sociodemographic characteristics	Eleven questions: Name, age, institutional affiliation, position, years as a researcher, classification as researcher, level of education, etc.	[21], Authors
Knowledge and perceptions of open science	Seven questions: Knowledge of open science (Do you know about open science? What words do you think about when we talk about open science?), use of elements of open science (What elements of open science have you used?), information access (How informed are you about open science? Through what media platform do you mainly obtain information on open science?), use of media (Can you name a web portal/blog/journal/network that you consult/seek/use to investigate an approach of open science?)	[15,22,23], Authors
Attitudes towards open science	Four questions: Elements to promote open science (Availability of digital technologies and their higher capacity, Increase in the body of scientific research throughout the world, Public's demand for rapid solutions to social challenges, Researchers seek new forms of dissemination of their results, Critiques of the current evaluation system for research results, Public recognition of scientific integrity and accountability for science and technology, and other), barriers to open science (Lack of legitimacy regarding the quality and rigour of scientific production, lack of recognition of the process and tools of open science, lack of integration between infrastructures of traditional science and open science, limited knowledge of the potential benefits of open science for researchers, lack of adequate resources for financing open science, uncertainty regarding the benefits of open science, legal restrictions related to copyrights, constraints to using the tools of open science, uncertainty regarding ethics and privacy in the open science context, and other), deficiencies of current system that open science could overcome (Restricted access and delays in disseminating academic results that limit the transfer of knowledge to researchers and other members of society, many of the research results cannot be reproduced due to a lack of underlying data, instructions regarding the process and contextual information, lack of transparency of traditional science, results of the research are often valued more for their quantity, academic communication is limited by the current incentive structures that privilege the publication of research results in indexed journals, digital technologies and their possibilities in academic communication are not used and fully applied, limited access to scientific resources and products decreases the efficiency and productivity of the research system, and other) and implications of open science (more reliable and efficient science, faster and wider innovation, greater scientific integrity, data-intensive science will become a key driver of economic growth and development, greater connection between science and society, science is more committed to solving social problems, research is more receptive to society, increase in research funding sources, greater promotion of public disclosure and social appropriation of science, technology and innovation, greater global benefits of knowledge transfer, and other).	[14,23], Authors

Table 2. *Cont.*

Categories	Questions	Source
Capacities and abilities for open science	Three questions: Use of open science tools (consult public repositories to search for information and research results, include your research in the repository of your institution to disseminate your research results, publish your articles in open access publications after paying a monetary fee or without paying a monetary fee, use and update academic networks (academia, ResearchGate), exchange of information, data or research results with colleagues and/or researchers in your area of knowledge, training in open science, use and management of bibliographic managers (Zotero, RefBase, etc.), I have a researcher profile (Google academic, Orcid, Researcher ID, Scopus author ID, etc.), I consult bibliographic reference indexes (Google academic, CiteSeerx, and Scholarometer); achievements from open science (Conducted research with other researchers nationwide, Conducted research with other researchers at an international level, I have received feedback on my publications from other researchers, I have received invitations from other academic and scientific communities to share my research results, I have been invited to be evaluator of open access scientific articles, I have participated as an expert researcher in projects developed by international organizations I have exchanged information or data about my research, other); and applications of elements of open science in projects (some individual in society has collected information or data from your project, some individual in society has played an active role in your research project, You have jointly conducted research with the community, You have shared your research results with the community, Your research questions arise from community problems, other.	[12,13,16], Authors
Experiences and participation in open science	Nine Questions: Institutional topics on open science (Does your institution have open science guidelines for its researchers, in your institution, what open science tools are used?); publication in open access contexts (Approximately how many articles have you published as a researcher? Of those articles, how many have been in open access publications? Of the articles published in open access publications (open access), how many have involved you making a payment? Where do the resources for the payments to open access publications come from?); and requirements of an open science policy (Do you believe that the country should have an integrated public policy on open science? What elements should be included in a public policy of open science in the country? How do you prioritize public policy actions to promote open science?).	[16,23,24], Authors

3.4. Survey Administration

All surveys included a cover letter that explained the purpose of the survey, the benefits of participation, and background information on the study. It also included contact information, the time required to complete the survey (on average 35–40 min) and a submission deadline. The survey was sent using QuestionPro online survey software. The strategies to motivate participation in the survey included email broadcasting as well as communications with research directors of different universities to promote the study and to complete the survey. Every week, books were delivered to different universities, and researchers completed the survey through a draw. Every five days, the researchers were sent personalised reminders through the researcher database.

A total of 3000 surveys were e-mailed to Colombian researchers registered on Scienti, the database for categorised Colombian researchers. During a 30-day time frame in the first semester of 2017, 1280 surveys were returned, of which 238 were incomplete. Therefore, the total number of usable surveys was 1042, which provided a suitable sample size, as explained in Section 3.2. Of these

1042 surveys, 40.40% were in Category 1, 16.12% Category 2, 14.30% Category 3 and 29.17% Category 4, which are representative of Colombia, according to the sampling plan.

4. Results and Discussion

This section presents the main results of the national survey on open science calculated using statistical techniques to ensure high reliability. A total of 1042 responses were received, with a confidence level of 95% and a margin of error of 3%. The majority of respondents knew about open science, especially as it relates to open science tools (software, repositories, and networks) and open data. These results indicate that researchers have different perspectives of open science.

4.1. Sociodemographic Characteristics

A national representative sample of 1042 researchers participated in this study. Of these researchers, 38% were women and 62% were men; 40% were between 25 and 55 years of age; 33.5% had completed a Master's and 25.8% had completed doctoral studies. With regard to areas of study, 37.38% of the researchers were in the social sciences and humanities, 19.78% in engineering, and 13% in the natural sciences. A total of 37% had between 5 and 10 years of experience as researchers, and the majority worked for a higher education institution or research center (87% and 8%, respectively). These sociodemographic characteristics ensure the study's representativeness in relation to different sociodemographic features.

4.2. Knowledge and Perceptions of Open Science among Colombian Researchers

These questions focused on analysing the researchers' beliefs, knowledge, and information habits regarding open science. The questionnaire began with a filtering question: respondents who knew about open science were asked to continue the survey, but if the answer was negative, the survey was considered complete because the researcher had no knowledge on the topic. The results indicated that 54.13% of respondents knew about open science. Figure 2 depicts hierarchical connections for words related to open science (from a sequence by repetition frequency) that it generates among words and concepts with an increased number of responses by survey respondents and how these words and concepts are associated and related by more and fewer mentions by researchers (e.g., free access is one of the words most often mentioned and is interconnected with accessibility and databases, and accessibility is related to open information and then with community).

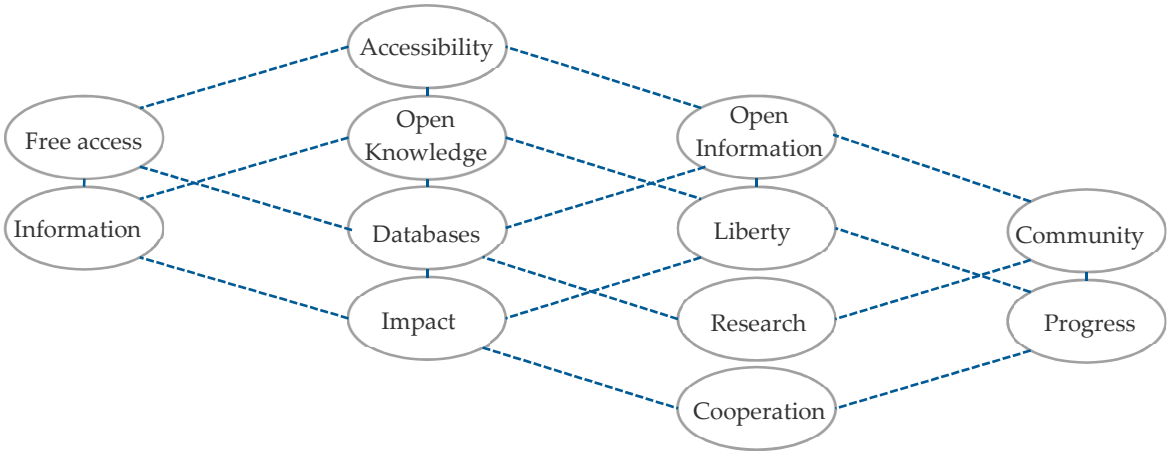

Figure 2. Words related to open science, according to Colombian researchers.

Among the respondents, the most well-known elements of open science are open access (26.71%), tools for open access such as software, repositories, and networks (20.31%), and open data (19.96%).

The least known elements are institutional policies on open science (2.88%) and evaluation (3.69%), and researchers with PhDs had more knowledge about the elements of open science.

Another important aspect is researchers' application of different elements of open science (see Figure 3). Open access, the tools of open science and open data are the most used terms, which are similar to the most well-known elements. The results are similar across all sociodemographic attributes, indicating a direct relationship between knowledge and use in open science.

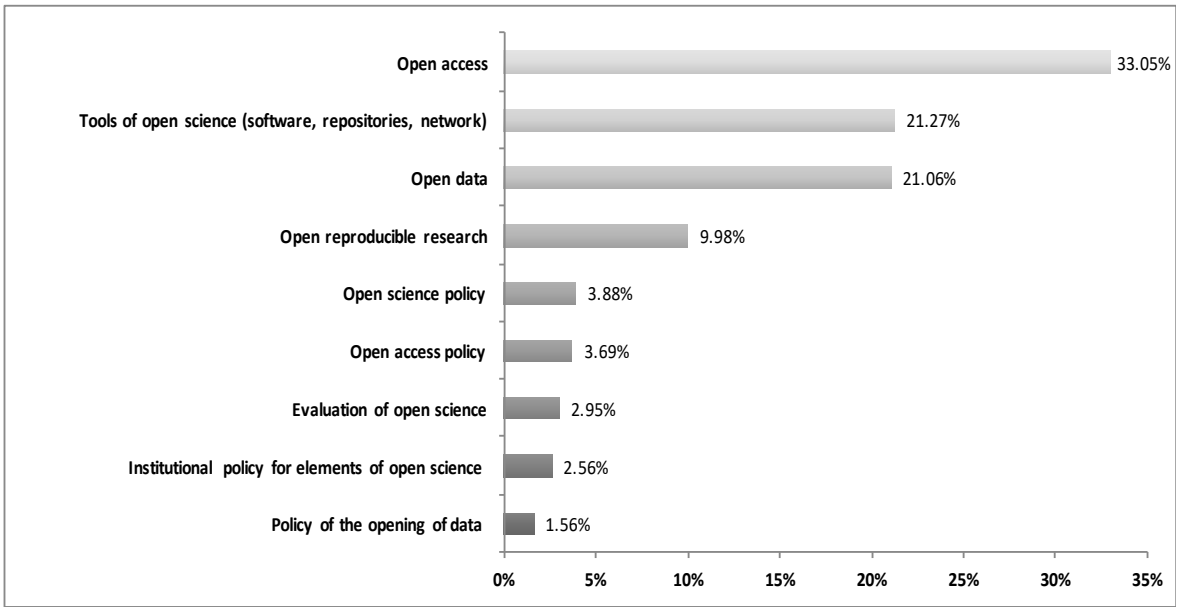

Figure 3. Elements of open science most used by Colombian researchers.

We found that 53.30% of Colombian researchers are not sufficiently well informed about open science, while 40.38% are informed. The Internet is the main media platform used to inform researchers about open science, followed by academic events (see Figure 4).

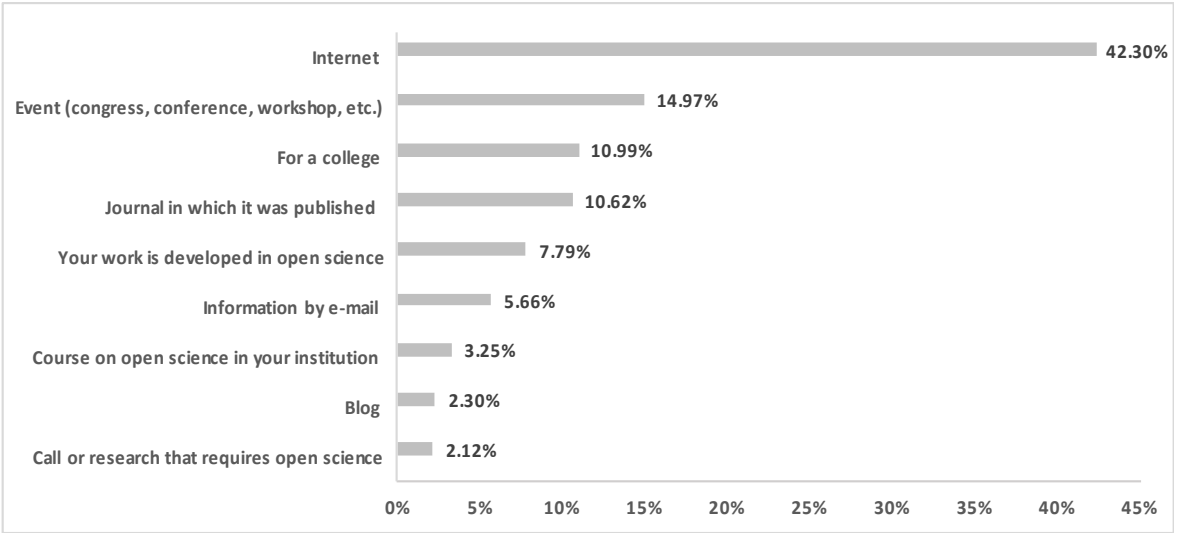

Figure 4. The main media platforms used by Colombian researchers to find information about open science.

These results indicate that the knowledge and perceptions of open science among Colombian researchers are limited. This finding confirms the hypothesis of this study that it is important to strategically develop their knowledge, especially at early education levels (university and Master's levels) and in departments with lower research capacities. These results concur with those of the

authors of a past paper [3], who consider open science to be a relatively underdeveloped topic of discussion that has emerged as a catchphrase in today's scientific society. They view technological innovation as providing new opportunities to share knowledge, and that the Internet can be used as an enabling tool to improve collective knowledge.

Sharing and collaborative research have become imperative in modern science, but they require opportunities for free access to, and use of, data, cooperation between scientists and researchers in different fields of knowledge, and progressive and increased dialogue between science and society [25], as noted by the respondents to this survey.

The open science movement is closely related to both the open data and open access movements, which support the sharing of data and publications, respectively [26]. The results regarding Colombian researchers' knowledge and perceptions reflect similar concerns, indicating that open data and open access are elements with higher recognition within open science.

Another important finding from the survey is that information technologies are fundamental to the research process, and the Internet is the preferred media for the search for information. Moreover, researchers seek information about open science from the web pages of university repositories, among other sources, which indicates that they employ diverse information sources to stay up to date on open science. This finding accords with that of the authors of a previous a previous paper [6], who found that the Internet is changing how science is conducted in the world. Moreover, open science communication has different stakeholders and activities at different steps in the research cycle, and it reflects aspects of collaboration, accessibility, and transparency. With open access and open research, data findings become more open, and there is more information about which people can communicate, which strengthens the value of research [27].

4.3. Attitudes towards Open Science

In this section of the questionnaire, we analyse the main drivers of open science, the barriers to the promotion and positioning of open science, the deficiencies of the current system that could be overcome by open science, and the implications of open science. These questions allow us to determine researchers' attitudes towards open science.

According to the Colombian researchers, the main drivers of open science are the following (see Appendix A Figure A1), open data and information (72% fully agree), the availability of digital technologies and higher capacity (62% fully agree), and new forms of dissemination and disclosure of results (59% fully agree). Thus, the researchers perceive that open science requires new technologies and strategies for information access and effective dissemination.

The main barriers to open science identified by the Colombian researchers are the following (see Appendix A Figure A2), lack of financial resources (52% fully agree), limited knowledge of the potential benefits of open science (41% fully agree), and lack of motivation and incentives (41% fully agree). Thus, the researchers perceive that it is important for both governments and institutions to promote better practices to include open science in the research cycle.

Colombian researchers consider the following to be the deficiencies of the current system that open science could overcome (see Figure 5). Restricted access and delays in disseminating academic results that limit knowledge transfer (67% fully agree), academic communication restricted by the current incentive structure (58% fully agree), and limited access to resources and scientific products (52% fully agree).

The main implications of open science and its impact on society, the economy, and research for Colombian researchers are as follows (see Appendix A Figure A3), greater connections between science and society (62% fully agree), improved dissemination and appropriation of science, technology and innovation (58% fully agree), and enhanced benefits of knowledge transfer (58% fully agree).

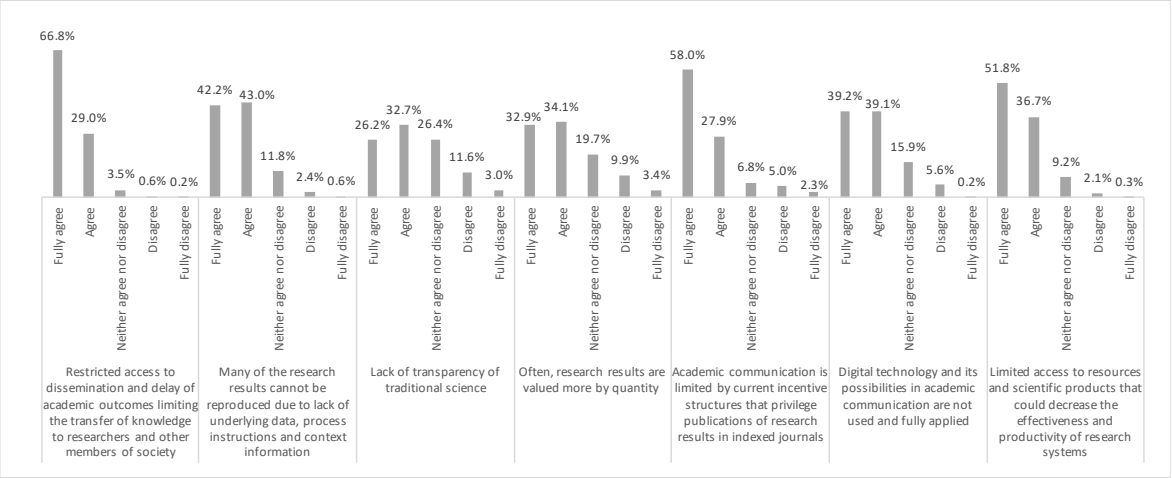

Figure 5. The deficiencies of the current system that open science could overcome, according to Colombian researchers.

These findings indicate that Colombian researchers perceive that open science is promoted by different elements. The authors of a past paper [28] described seven drivers: emerging digital technologies (to deliver more rapid, reliable, and sustainable results), the need for collaboration (new strategies and models to collaborate on and disseminate research), the evolution of traditional peer review models (more transparency and accountability of research results), increased public scrutiny (higher expectations for research results within society), changes to research assessment metrics (altmetrics as an alternative measure to improve research evaluations), accessibility of research (research with public funds must allow better accessibility and traceable impacts), and reproducibility of results (to improve the quality and transparency of research). Open science has gradually been incorporated into scientific endeavours because it has the potential to improve the efficiency and quality of research by decreasing the costs of data collection, helping researchers exploit dormant or inaccessible data at a low cost, and increasing the opportunities for collaboration in research and innovation [29].

Moreover, the survey results indicate that Colombian researchers perceive that open science can contribute to improving structures and research processes to ensure greater access to and dissemination of science. These results are important in the context of open science's advantages, which include the following [30], greater availability and accessibility of publicly funded scientific research output; opportunities for rigorous peer review processes; greater reproducibility and transparency of scientific works; and greater impacts of scientific research, which can be disseminated throughout the scientific community to strengthen and enhance the open science process as a new form of research and as a way to achieve greater transparency and impact for the new knowledge generated.

However, several studies have demonstrated that the main barriers to open science are research funding methods, the absence of alternative reputation systems for researchers' performance, research integrity to ensure that research findings are reliable, reproducible, and trustworthy, and the money spent on the research [31,32].

Moreover, the authors of a past paper [33] classified the barriers to open science into two categories: operational barriers (such as the difficulty of providing evaluations of the quality and rigour of research findings and the lack of skills and knowledge about the advantages of open science for research) and institutional barriers (such as inadequate funding schemes and institutional processes that inhibit processes related to open science).

Another important aspect is the relationship between open science and society, as open science should empower populations through science and allow citizens to become involved in scientific efforts. In addition, open science can have positive implications for the development of a culture of scientific awareness [34].

4.4. Capacities and Abilities for Open Science

This section examines the perceptions of Colombian researchers related to the activities, processes and tools used in open science and how these elements have improved projects and research activities.

Colombian researchers have begun to use different tools related to open science to strengthen their research processes, such as consulting repositories of information (13%), using and updating academic networks (9.8%), having a researcher profile on Google Scholar, ORCID, Research ID, etc. (8.7%), consulting citation indexes (8.6%), investigating open access results (8.5%), exchanging information (7.8%), and open access publishing (7.6%) (see Appendix A Figure A4). These results indicate that the use of open science tools is limited in the Colombian scientific community.

The main opportunities provided by open science according to the Colombian researchers are the following (see Figure 6), information exchange (20.31%), feedback from other researchers (18.63%), invitations to serve as an evaluator or reviewer of scientific or academic papers (16.34%), invitations to share investigation results with academic communities (15.59%), and participation in joint investigations (13.47%).

Figure 6. The main opportunities provided by open science for Colombian researchers.

In their projects, Colombian researchers have used open science in the following ways, formulating a research question based on community problems (27.53%), sharing research results with a community (26.91%), and collecting information and data for research from people in the community (16.41%).

The capacities and abilities for open science imply the use of different tools that increase both the efficiency of the research process and its diffusion, thereby increasing the effectiveness and productivity of scientific and research systems to engage in powerful data manipulation, provide analyses at low cost, and reduce duplication costs for collecting, creating, transferring, and reusing data and science [35,36]. According to the results of this study, the scientific community must be better informed about these benefits of the open science tools.

Moreover, the survey results demonstrate that open science is becoming a research strategy that allows for improved research results and communication that can be enriched and strengthened through higher quality, transparency, and conformity with research networks through collaboration and information sharing. This finding concurs with previous works [5] that indicated that open science demands new forms of quality assurance to ensure the integrity of the research process when collaborative activities and data sharing are involved. They suggest adopting guidelines that allow journals to select which aspects are most relevant for their knowledge area and that increase transparency without becoming too difficult for journal editors and authors.

Another finding related to capabilities and abilities indicates the importance of connecting society with science and technology as a means of empowerment and to strengthen a country's scientific culture. Moreover, these results are closely connected with citizen science, which involves the active participation of citizens in data collection, scientific experiments, and problem solving and can also occur at the behest of individuals who are forced to find scientific solutions to problems without being scientists themselves [5].

4.5. Experiences and Participation in Open Science

This section of the questionnaire included questions related to open science guidelines in universities and research centers, publications in open access contexts and financial sources, national policy requirements for the open science environment, and policies requiring improved open science access in Colombia.

We found that 30.64% of the respondents affirmed that their institutions have open science guidelines, especially in areas with higher research competence, such as Bogotá (46.22%), Antioquia (16.38%), Valle (7.08%), and Atlántico (5.18%).

The institutional initiatives recognised by respondents include the following. Open access to databases, repositories, and publications; economic support for open access publications; promotion of open access institutional journals; and the development of policies or guidelines related to open access.

Open science tools with higher use by universities and research centers include the following (see Appendix A Figure A5), open access to institutional repositories (14.98%), open access to databases (13.64%), open access to journals (11.76%), and normalization of profiles in academic networks (10.94%). These results predominate in regions with greater research capacity, such as Bogotá and Antioquia, indicating that universities and research centers with better results include open science within their research processes.

We found that 50% of respondents had published at least six academic papers as researchers, with an average of three papers in open access publications using resources from the universities or research institutes where they work (52.5%), using resources from their research project (29.32%), and using their own resources (10.33%).

With respect to open science policies, 93.75% of respondents believe that Colombia should have an integrated open science public policy (see Figure 7) that includes open access (95% fully agree) and the promotion of open science projects (93% fully agree) and open science tools (92% fully agree). These results are important as inputs to design and establish an adequate open science policy from the academic community's perspective.

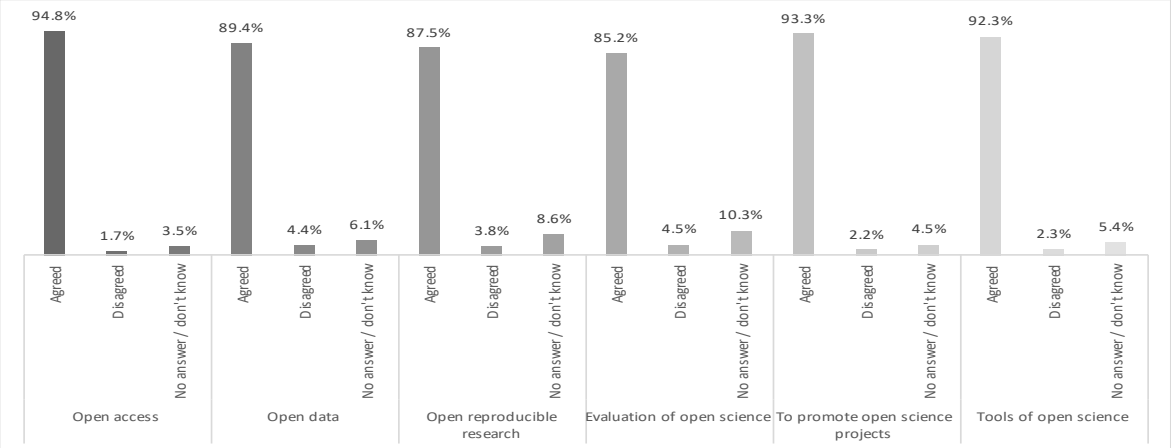

Figure 7. Elements that should be included in an open science policy in Colombia, according to Colombian researchers.

Moreover, the main priorities of an open science policy according to the respondents are as follows (see Appendix A Figure A6), developing strategies and instruments that guarantee free access to scientific information in a timely manner (91% fully agree), improving researchers' abilities and competence in the use of information systems (83% fully agree), and designing effective incentives to participate in open science among the scientific community. This indicates that such a policy should begin with open data, the generation of competences and the provision of incentives in recognition that the engagement and effort of all stakeholders are important for achieving an effective open science policy in accordance with the needs of the country.

These results demonstrate that open science faces different challenges, and considering that only 1.7% of the respondents reported attending training programmes in open science, it is important for Colombian researchers to be able to improve their capacities and knowledge of the tools used in open science.

The experiences and participation in open science by Colombian researchers indicate that regions with better research competences have employed some elements of open science, including using institutional repositories. This finding accords with the results of the survey by authors of a past paper [37], in which researchers download papers from institutional repositories or their personal or university webpages that are generally useful to their research.

Open access publication is still limited and focused on universities and research centers with greater recognition of their research activities, which indicates the importance of implementing initiatives and strategies to promote open science in all regions of Colombia to decrease regional disparities.

This study's findings are in accord with the authors of a previous paper [38], who found that open science goes beyond open access to include publications or data incorporating diverse issues in the entire research cycle. This implies interoperability of the scientific infrastructure, open and shared research methodologies (such as open applications and informatics codes), and machine-friendly tools (text and data mining). Moreover, an effective open science policy must include topics related to developing the necessary infrastructure (to share data and findings), legal frameworks to ensure transparency and copyright protection when sharing and reusing the research output produced by others, new strategies to evaluate and assess research results, and incentive mechanisms (financial incentives).

5. Conclusions

This study analysed the perceptions, experiences, and knowledge of open science among Colombian researchers through an online survey that used a probabilistic sampling strategy, which allowed us to ensure the representativeness of the study.

A total of 1042 responses were received, with a confidence level of 95% and a margin of error of 3%. The majority of the respondents had heard of open science, especially as it relates to open science tools (software, repositories, and networks) and open data. The researchers consider the rise of digital technologies, the search for new forms of collaboration, the greater availability of open data and information, and the public's demand for better and more effective science to be factors that have affected open science. In contrast, a lack of resources and the limited integration between traditional and open science are the most important barriers to the use of open science in research. These results are important inputs for building an adequate open science policy in Colombia, and they indicate the need to develop clear methodological and deontological rules regarding open science in which scientific collaboration and digital technologies are fundamental and involve both researchers and practitioners as well as rules concerning the use of data by nonscientific people. Moreover, these results highlight the importance of conducting behavioural studies on virtual research to understand the factors that influence the effective operation and performance of different open science tools [38,39].

A total of 43.54% of the respondents consider themselves to be very well informed or informed, while 53.30% do not consider themselves to be sufficiently well informed about open science. The main media platforms for information on open science are the Internet, conferences and universities.

The results indicate that level of education, experience, and area of study affect the affinity for open science and its application in research processes; thus, it is important to increase knowledge of open science among Colombian researchers.

Policy-makers can use these results as an input for formulating strategies and programmes that allow for increased knowledge of open science in order to increase its development through responsible decision-making and provide heightened equality with regard to knowledge access.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix The Main Detailed Results of the Survey

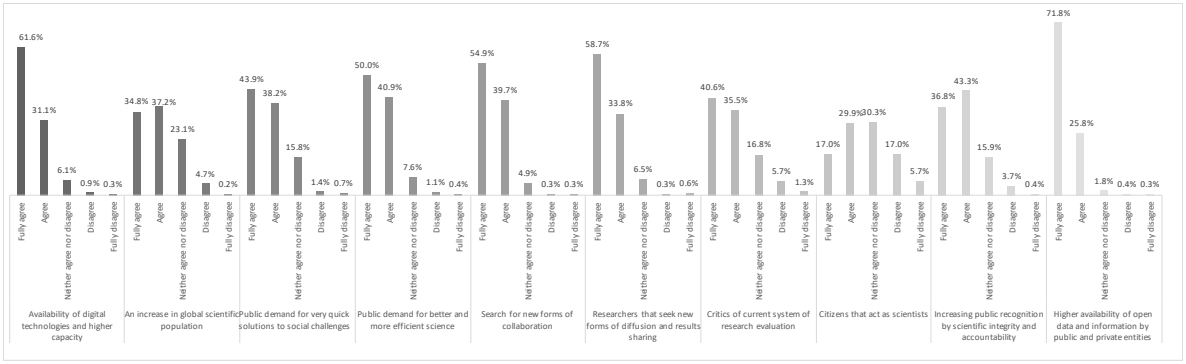

Figure A1. The main drivers of open science, according to Colombian researchers.

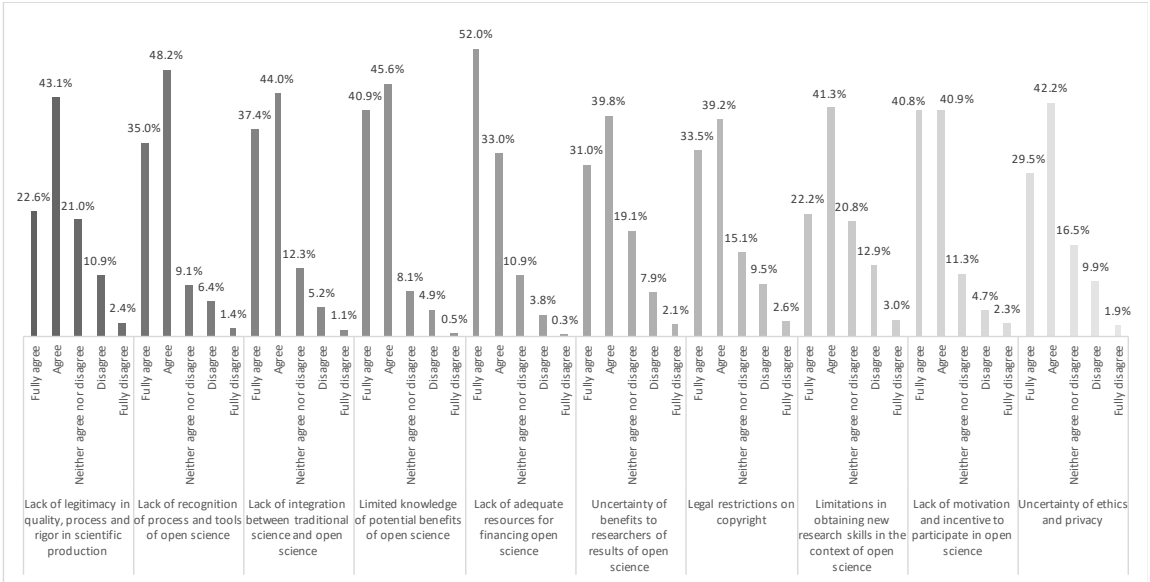

Figure A2. The main barriers to open science, according to Colombian researchers.

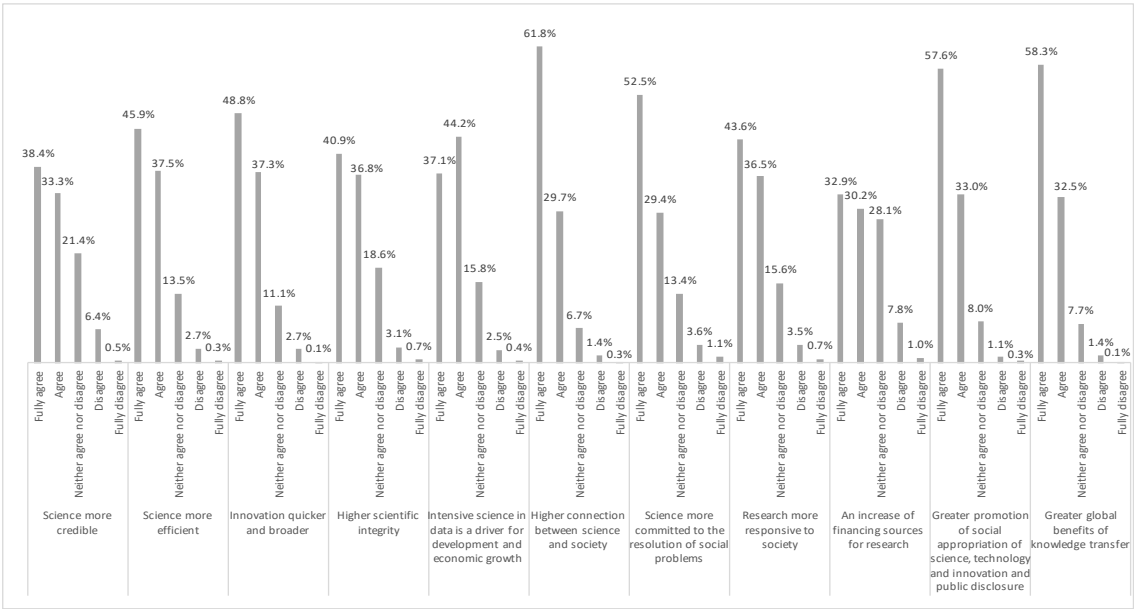

Figure A3. The main implications of open science, according to Colombian researchers.

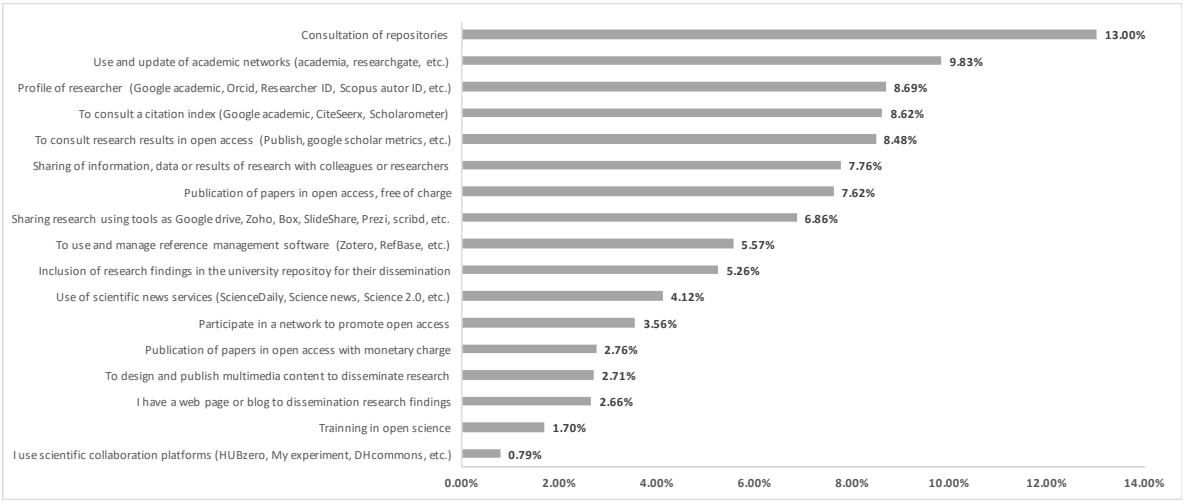

Figure A4. Open science tools used by Colombian researchers, according to the survey results.

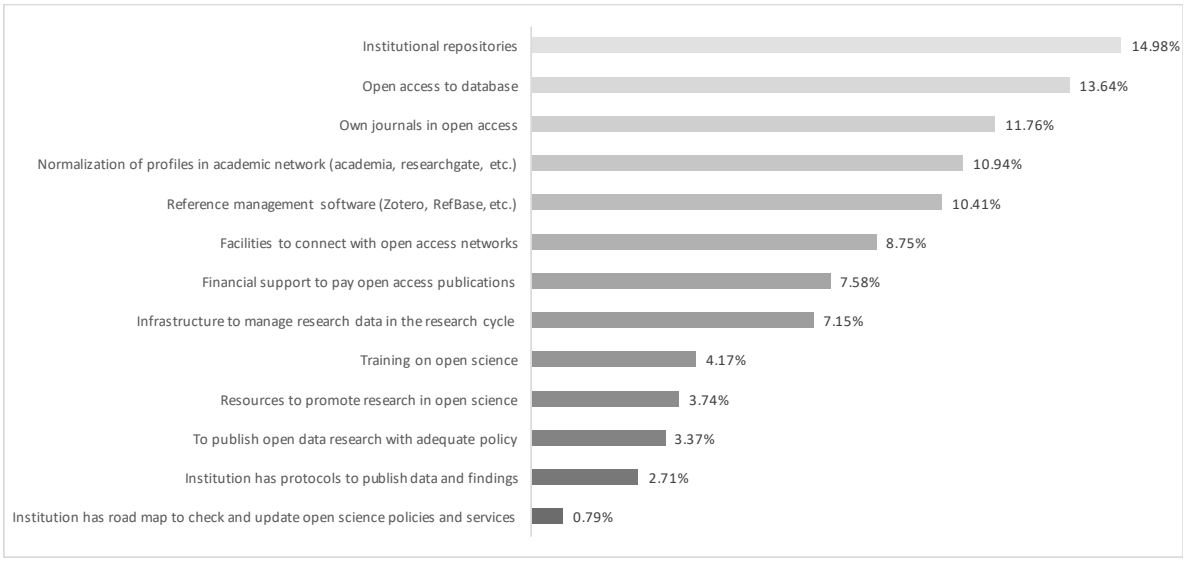

Figure A5. Open science tools used by universities and research centres in Colombia.

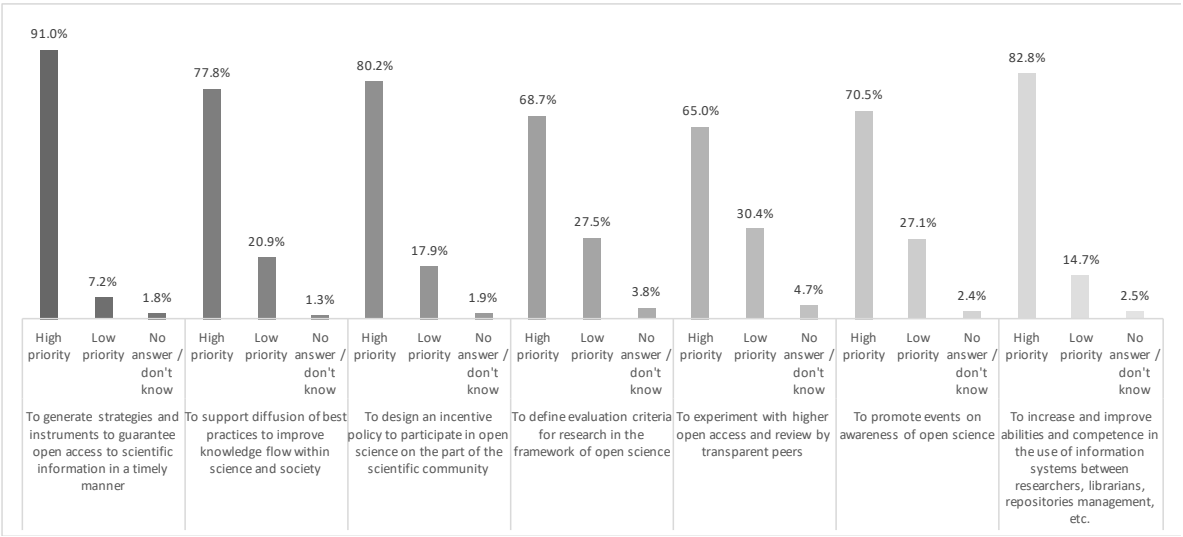

Figure A6. Main priorities for an open science policy, according to Colombian researchers.

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