Original Article

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Taxonomy of Open Science : revised and expanded

Taxonomia da Ciência Aberta: revisada e ampliada

Taxonomía de la ciencia abierta: revisada y ampliada

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ABSTRACT

Objective: To review the terminologies and applications of Open Science taxonomy to build a more comprehensive version that represents the knowledge surrounding the subject in accordance with the current scenario of scientific communication and the recommendations of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Method: This is a qualitative investigation with an exploratory focus. The first step taken was the revision of existing taxonomies by 12 researchers[1], who met weekly for conceptual and epistemological discussions related to Open Science and methodological and procedural definitions for the realization of the study.

Results: As a result of these discussions, a proposed taxonomy was developed for revision by experts. Evaluation of this taxonomy was carried out using a questionnaire with open questions about each main axis of the taxonomy, which was sent to 68 specialists. A total of 21 responses that analyzed the modeling and exposition of terms in the proposed taxonomy were received. The final taxonomy has 10 main-level facets and a total of 96 labels.

Conclusions: the responses of the experts brought to light a panorama consistent with UNESCO recommendations and the current scenario of Open Science.

KEY WORDS: Open Science-Taxonomy, scientific communication, knowledge representation, UNESCO.

RESUMO

Objetivo: revisar as terminologias e aplicações da taxonomia de Ciência Aberta para a construção de uma versão mais abrangente, que represente o conhecimento em volta do tema, em conformidade com o cenário atual da comunicação científica e com as recomendações da Organização das Nações Unidas para a Educação, a Ciência e a Cultura (Unesco).

Método: trata-se de uma pesquisa do tipo exploratória com abordagem dedutiva. A primeira etapa foi a revisão das taxonomias, com 12 pesquisadores que se reuniram, semanalmente, para discussões conceituais e epistemológicas relacionadas à Ciência Aberta, e definições metodológicas e procedimentais para a realização do estudo.

Resultados: como resultado das análises, foi desenvolvida uma taxonomia para ser avaliada pelos especialistas. Para isso, foi enviado um questionário com perguntas abertas, sobre cada eixo principal da taxonomia, para 68 especialistas. Foram obtidas 21 respostas que cooperaram com a modelagem e exposição dos termos para a nova taxonomia. A taxonomia oriunda desse processo de revisão tem 10 facetas de nível principal e o total de 96 rótulos.

Conclusões: a percepção dos especialistas trouxe à tona um panorama congruente com as recomendações da Unesco e do atual cenário da Ciência Aberta.

PALAVRAS-CHAVE: Ciência Aberta - Taxonomia. Comunicação Científica. Representação do Conhecimento. Unesco.

RESUMEN

Objetivo: revisar las terminologías y aplicaciones de la taxonomía de la Ciencia Abierta, para construir una versión más completa, que represente el conocimiento en torno al tema, de acuerdo con el escenario actual de la comunicación científica y las recomendaciones de la Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura (Unesco).

Método: se trata de una investigación exploratoria con un enfoque deductivo. El primer paso fue la revisión de las taxonomías, con 12 personas dedicadas a la investigación, que se reunieron semanalmente, para las discusiones conceptuales y epistemológicas relacionadas con la Ciencia Abierta y las definiciones metodológicas y de procedimiento para la realización del estudio.

Resultados: como resultado de los análisis, se elaboró una taxonomía para ser evaluada por las personas expertas. Para ello, se envió a 68 personas expertas un cuestionario con preguntas abiertas sobre cada eje principal de la taxonomía. Se obtuvieron 21 respuestas que cooperaron con la modelización y exposición de los términos de la nueva propuesta de taxonomía. La nueva taxonomía tiene 10 facetas de nivel principal y un total de 96 etiquetas.

Conclusiones: la percepción de los expertos puso de manifiesto un panorama congruente con las recomendaciones de la Unesco y el escenario actual de la Ciencia Abierta.

PALABRAS CLAVE: Ciencia Abierta - Taxonomía. Comunicación Científica. Representación del Conocimiento. Unesco.

[1] This investigation has involved the members of two groups: The first group of investigators consisted of the authors of this article, who analyzed previous taxonomies and proposed a new one to be evaluated by independent experts (also investigators, but not authors of this article). In this document, the term “investigators” will be used to identify the group of authors, and the term “Expert” will pertain to the group of outside experts who evaluated the proposed taxonomy.

1 INTRODUÇÃO

On the occasion of the 40th edition of the UNESCO General Conference, held in 2021, in a joint decision of 193 Member States, the responsibility for preparing an international standardization document on Open Science was delegated, in the form of recommendations bearing the organization's seal. This action was intended to stimulate the creation of a guide for the advancement of science, innovation and technology at an international level. At this event, UNESCO published a report entitled "Recommendations for Open Science" (UNESCO, 2021), which presents a set of guidelines for the promotion of Open Science worldwide, including open access to scientific data and the opening of the research process itself, from planning to the dissemination of results.

A significant point mentioned in the UNESCO recommendations (2021) for Open Science is the need for a common taxonomy to facilitate communication and knowledge sharing among different actors, from different regions and speaking different languages, who participate in scientific research through the use of documentary language (for example, controlled vocabularies and ontologies). Values such as quality and integrity, collective benefit, equity and justice, and also diversity and inclusion are emphasized in the recommendations. In addition, these recommendations cite guiding principles that point to the possibility of conditions and practices for Open Science to become a reality: transparency, scrutiny, criticism and reproducibility, equal opportunities, responsibility, respect and accountability, collaboration, participation and inclusion, flexibility and sustainability (UNESCO, 2021).

Beyond these recommendations, the UNESCO document addresses Open Science as an inclusive construct that combines various movements and practices with the aim of making multilingual scientific knowledge openly available, accessible, and reusable by all, in such a way that scientific collaborations and the exchange of information for the benefit of science and society are increased, opening the processes of creation, evaluation and communication of scientific knowledge to social actors beyond the traditional scientific community. Likewise, for UNESCO (2021), the movement encompasses all scientific disciplines and all aspects of academic practices, including basic and applied sciences, natural sciences, social sciences and humanities, building on the following key pillars:

open scientific knowledge, open scientific infrastructure, scientific communication, open engagement of social actors, and open dialogue with other knowledge systems.

Various scientists and researchers have attempted to characterize the level of knowledge about the conceptual ramifications of Open Science and understand its variations: Pontika *et al*. (2015), Baumgartner (2019), and Silveira *et al*. (2021), among others, have sought to explain the variations in this modus operandi for doing science.

In the light of the previous discussion, a question arises: what other components and labels can contribute to a new and broader proposal for a taxonomy of Open Science that is in accordance with the current scenario of scientific communication and the recommendations of UNESCO (2021)? This is the guiding question for the current investigation, which considers dynamic knowledge, which in turn requires amplification and representation, and can contribute to new reflections on policies and strategies for developing more transparent and efficient research through Open Science. The proposed taxonomy must therefore reflect these changes and consider emerging practices and technologies that are helping to transform scientific communication.

This investigation is intended to propose a broader taxonomy of Open Science in accordance with the current scenario of scientific communication and the UNESCO recommendations (2021). It seeks to systematize the operational bases of Open Science to enable the expansion of indicators and demonstrate its impact on scientific communication, represented in a taxonomy that describes the main axes of its operation. Its specific objectives are as follows a) compare the three taxonomies of Pontika *et al*. (2015), Baumgartner (2019) and Silveira *et al*. (2021); b) identify components and labels that can be added to the taxonomy, based on UNESCO recommendations and the conceptual ramifications of Open Science presented in the research cited, and c) validate the revised and expanded proposal with experts.

By achieving these objectives, the Open Science Taxonomy update can provide researchers, teachers, librarians, publishers, policy makers, managers of funding agencies and others involved in science communication with an overview of their practices and contribute theoretical support for the development of public, institutional and editorial policies, among other benefits.

Following the UNESCO recommendations (2021), it is necessary to propose a broader taxonomy in line with the current scenario of scientific communication that is impacted by the elements of Open Science, to improve aspects such as access, transparency, accountability, collaboration and sharing of resources (data, services, infrastructure and persons).

By analyzing the different components and approaches that characterize Open Science, the proposed taxonomy will contribute to new thinking about policies and strategies that will make research more transparent and efficient. It can be understood as a representation of the domain of knowledge that surrounds it, and can be used as a guide in the dynamic construction of a common vision of its structure.

The sections of this article were organized to present the process of knowledge construction in this investigation: some of the steps that ensured the application of scientific methods and principles are discussed in the introductory section, which is followed by a review of the methodology used, a presentation of results, a discussion and presentation of final considerations, complemented by appendices that help to structure the results. The answers received for the validation questionnaire on the proposed taxonomy are included.

2 METHODOLOGICAL PROCEDURES

This is a qualitative investigation with an exploratory focus, which involved both an analysis of three Open Science taxonomies (Pontika et al., 2015; Baumgartner, 2019; Silveira et al., 2021) and recommendations by UNESCO (2021) on the same subject, and the creation of a questionnaire as a data collection instrument, all of whose results were to be used to validate a proposal for a revised and expanded taxonomy of Open Science.

Equipped with the results of analyzing these earlier taxonomies and recommendations, and aided by expert opinions gathered in the questionnaire, general and specific knowledge was gained which made it possible to create a new taxonomic proposal, detailed in two stages that are described below.

The objective of the first stage of the investigation was to compare the three taxonomies mentioned previously and the elements recommended by the UNESCO (2021) in conceptual, epistemological and methodological discussions, which led to the proposal of a new taxonomy. The results of these comparisons can be found in Section 3 and

Appendix A[2] of this document. The designs of the models of Pontika *et al*. (2015) and Silveira *et al*. (2021) were taken into account when creating the extended proposal for the taxonomy (presented in Appendix D[3]); however, although Baumgartner's (2019) model was initially consulted, the structure of subcomponents/subframeworks used by this author were not presented in sufficient detail to be useful for this purpose.

A first version of the Open Science taxonomy was elaborated, with the participation of 12 Investigators, the authors of this article, with specific knowledge of the subject, representing five countries: Brazil (6), Colombia (2), Costa Rica (2), Peru (1) and Spain (1). Thirty (30) meetings were held using the Google Meet[4] and BigBlueButton[5] platforms. An Excel spreadsheet was used to insert components and labels, including the taxonomy of Silveira *et al*. (2021) and UNESCO elements (2021). Using this method, the Investigators inserted their opinions in writing – that is, if the term and the order/organization were considered in to their area of specialization. Points of disagreement were discussed in virtual meetings.

[2] Disponível em: https://periodicos.ufsc.br/index.php/eb/article/view/91712/53445
[3] Disponível em: https://periodicos.ufsc.br/index.php/eb/article/view/91712/53449
[4] Learn more at https://meet.google.com/.
[5] Learn more at https://bigbluebutton.org/.

Table 1 - Participants in the evaluation of the Open Science 2022 taxonomy and their responses

Name	Country	Institutional affiliation	Specialty	Formation and origin	Authors*	ID.**	In the text
1. Specialist	Colombia	----------	Open access, databases, altmetrics, bibliometrics, open infrastructures	Systems and Computing Engineer - Google Academic	Yes	No	Expert 1
2. Thaiane Moreira de Oliveira	Brazil	Universidade Federal Fluminense	Open Science, altmetrics, scientific communication, disputes over information and scientific communication	Ph.D. in Communication Plan de estudios Lattes	Yes	Yes	Oliveira
3. Specialist	El Salvador	----------	Open Science tools and repositories	Computer and Systems Engineer - Google Academic	Yes	No	Expert 2
4. Specialist	Uruguay	----------	Open access, Open Science tools, repositories and digital archives and Open Science.	Master's degree in Information and Communication - Linkedin	No	No	Expert 3
5. Specialist	USA	----------	Open data, reproducible Open Science	Ph.D. in Statistics - Google Academic	Yes	No	Expert 4
6. Saray Cordoba Gonzalez	Costa Rica	Honorary Member of Latindex	Open Science, Open Access	Bachelor's degree in Library and Information Sciences - Orcid	Yes	Yes	Gonzalez
7. Specialist	Guatemala	----------	Open Science and Open Science policies	Master's degree in Knowledge Management and Research on Public Policies - Orcid	Yes	No	Expert 5
8. Washington Segundo	Brazil	Brazilian Institute of Information on Science and Technology	Open data, open access, Open Science tools: interoperability between open information systems, open digital repositories, scientific data repositories, data science	Ph.D. and Master's degrees in Computer Science - Curriculum Lattes	Yes	Yes	Washington Segundo
9. Robinson Zapata-Pino	Panama	National Secretariat of Technology, Science and Innovation	Open access, Open Science policies, Open Science tools	Master's degree - Orcid	Yes	Yes	Zapata-Pino
10. Specialist	Brazil	----------	Scientific communication	Ph.D. in Physics - Google Academic	Yes	No	Expert 6
11. Specialist	Mexico	----------	Scientific communication, scientific dissemination, open access, Open Science	Ph.D. in Physics - Linkedin	Yes	No	Expert 7

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Name	Country	Institutional affiliation	Specialty	Formation and origin	Authors*	ID.**	In the text
12. Danny Murillo	Panama	Universidad Tecnológica de Panamá	Open data, bibliometrics, data analysis	Master's degree in IT Project Management - Orcid	Yes	Yes	Murillo
13. Fernanda Beigel	Argentina	Conicet, Universidad Nacional de Cuyo	Sociology of science, evaluation of Open Science, open access	Ph.D. in Political and Social Sciences - Orcid	Yes	Yes	Beigel
14. Andrea Marin Campos	Costa Rica	Universidad de Costa Rica	Open Science Evaluation, research management	Master's degree - Linkedin	Yes	Yes	Marin Campos
15. Diego Alejandro Gomez Hoyos	Colombia	Internet and Society Center ISUR - Universidad del Rosario	Open data, citizen science, participatory science	Bachelor's degree in Philosophy - Orcid	Yes	Yes	Gomez Hoyos
16. Specialist	Argentina	----------	Open access, Open Science policies, Open Science tools	Liibrary Science and Documentation - Linkedin	Yes	No	Expert 8
17. Specialist	Peru	National Council for Science, Technology and Technological Innovation	Open access, Open Science policies	Master's degree in Public Management -Linkedin	Yes	No	Expert 9
18. Maria Soledad Bravo-Marchant	Chile	National Research and Development Agency	Open access, Open Science policies, scientific information, bibliometric and scientometric indicators, repositories and editorial management	Diploma in Communication and Education - Orcid	Yes	Yes	Bravo Marchant
19. Paola Carolina Bongiovani	Argentina	Universidad Nacional de Rosario	Open access, scholarly communication, open data, institutional repositories	Ph.D. in Documentation: digital archives and library - Linkedin	Yes	Yes	Bongiovani
20.Bianca Amaro***	Brazil	Brazilian Institute of Scientific and Technological Information	Scientific communication, copyright, open access repositories of information and scientific data and Open Science	Ph.D. in Applied Linguistics - Curriculum Lattes	Yes	Yes	Amaro
21. Viviane S. de Oliveira Veiga***	Brazil	Oswaldo Cruz Foundation	Scientific communication, evaluation of science, Open Science, open access, research data, data management plan; FAIR principles; digital repositories	Ph.D. in Sciences – Major in Health Information and Communication - Curriculum Lattes	Yes	Yes	Veiga

Source: Authors' elaboration based on survey data (2022). Avalilabble in: https://zenodo.org/record/7837274.

* Do you want your name and surname to appear in the list of collaborators in the acknowledgments section of the published article?
** Do you want your contributions to be identified using only your last name?
*** Experts who requested a meeting to present their contributions.

In the second phase, 68 experts from different countries were selected, and a table was created with information about these possible participants, carefully chosen based on whether or not their professional activities and the content of their publications indicated that they publish or guide research on Open Science or any of its components. In this document, we have chosen to share only information about the 21 experts who agreed to participate in this investigation (Table 1) and authorized or refused the publication of their names. The network of relationships of the authors of this investigation was used to create the initial list, which was then refined by consultation of sources such as the Lattes curriculum, profiles in Google Scholar, LinkedIn, and Orcid, and direct consultation with experts. As a result, 19 experts initially responded to our questionnaire, and a further two experts requested a meeting to present their contributions verbally, bringing the total to of respondents to 21 persons. The experts received a questionnaire with 10 open questions to evaluate the proposed taxonomy, prepared using the Google Forms[6] platform. The suggested terms or expressions were then reviewed by the Investigators, and were grouped into a single file.

It should be noted that all of the experts who agreed to collaborate with this investigation were asked about their interest in being mentioned in the list of collaborators in the acknowledgments section of the published article, and if their contributions should be identified with their last name. The options were accepted by the survey participants and their collaboration was acknowledged, when requested, using their last name. For those who preferred anonymity, the mention of their statements was identified using the term “Expert”, and each Expert was assigned a code in ascending order.

Data were analyzed in meetings in which comments and suggestions were discussed, and decisions to accept or reject participant evaluations were made in a reasonable fashion. Subsequently, the results were incorporated into the taxonomy using the Illustrator program (Software licensed from Adobe). In keeping with the principles of Open Science, the data related to the development of this investigation are available for consultation in the Zenodo repository, Silveira et al. (2023)[7].

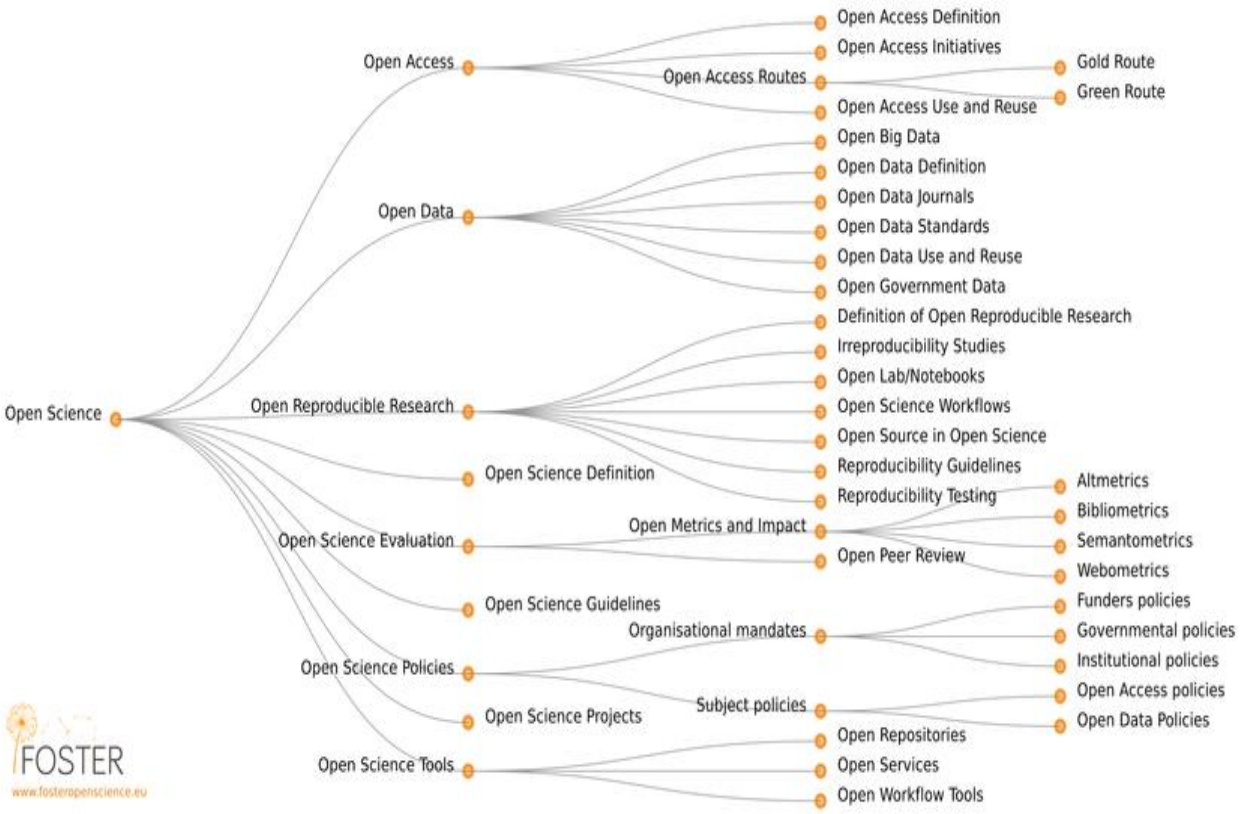
[6] More information at https://www.google.com/intl/pt-BR/forms/about/.
[7] More information at Avalilabble in: https://zenodo.org/record/7837274.

3 COMPARISON OF OPEN SCIENCE TAXONOMIES

A taxonomy is a systematic and hierarchical classification of concepts, objects or events based on their common characteristics or properties. According to Pontika *et al*. (2015), a taxonomy can be used to help better understand Open Science and its different components, as well as to guide the development of Open Science training and education policies and programs. Baumgartner (2019) emphasizes that a taxonomy is important to provide a clear conceptual framework for Open Science, facilitating its understanding and promoting its adoption.

Due to the complexity of delimiting and understanding its variations and boundaries, various efforts have been made to represent the domain of Open Science. An example of this is the first version of the taxonomy by Pontika *et al*. (2015), presented in Figure 1, developed by the consortium of the European project Facilitate Open Science Training for European Research (FOSTER), which was created with the objective of providing a framework for the organization and classification of Open Science practices and resources. This taxonomy has nine main components: Open Access, Open Data, Reproducible Open Research, Open Science Definition, Open Science Evaluation, Open Science Policies, Open Science Guidelines, Open Science Projects and Open Science Tools. Most of the components are divided into subcomponents, which help to better understand the diversity of practices and resources related to Open Science (Pontika *et al*. 2015).

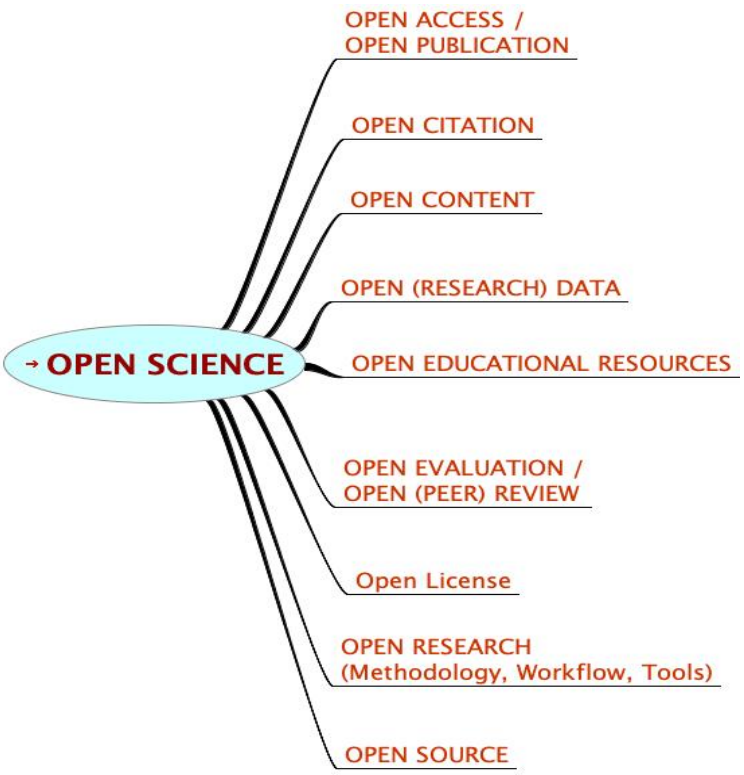
Figure 1 - Pontika *et al.*' Taxonomy of Open Science



Source: Pontika *et al*. (2015).

Another example of such a taxonomy is the framework proposed by the Australian Baumgartner (2019) in his Open Science Education blog, which is made up of nine components, with a didactic framework for teaching Open Science, ranging from motivation for Open Science to challenges and barriers to its implementation. The nine components are Open Access/Open Publication, Open Citation, Open Content, Open Data (research), Open Educational Resources, Open Evaluation/Open Review (peer), Open Licensing, Open Research (Methodology, Workflow, Tools) and Open Source, as shown in Figure 2.

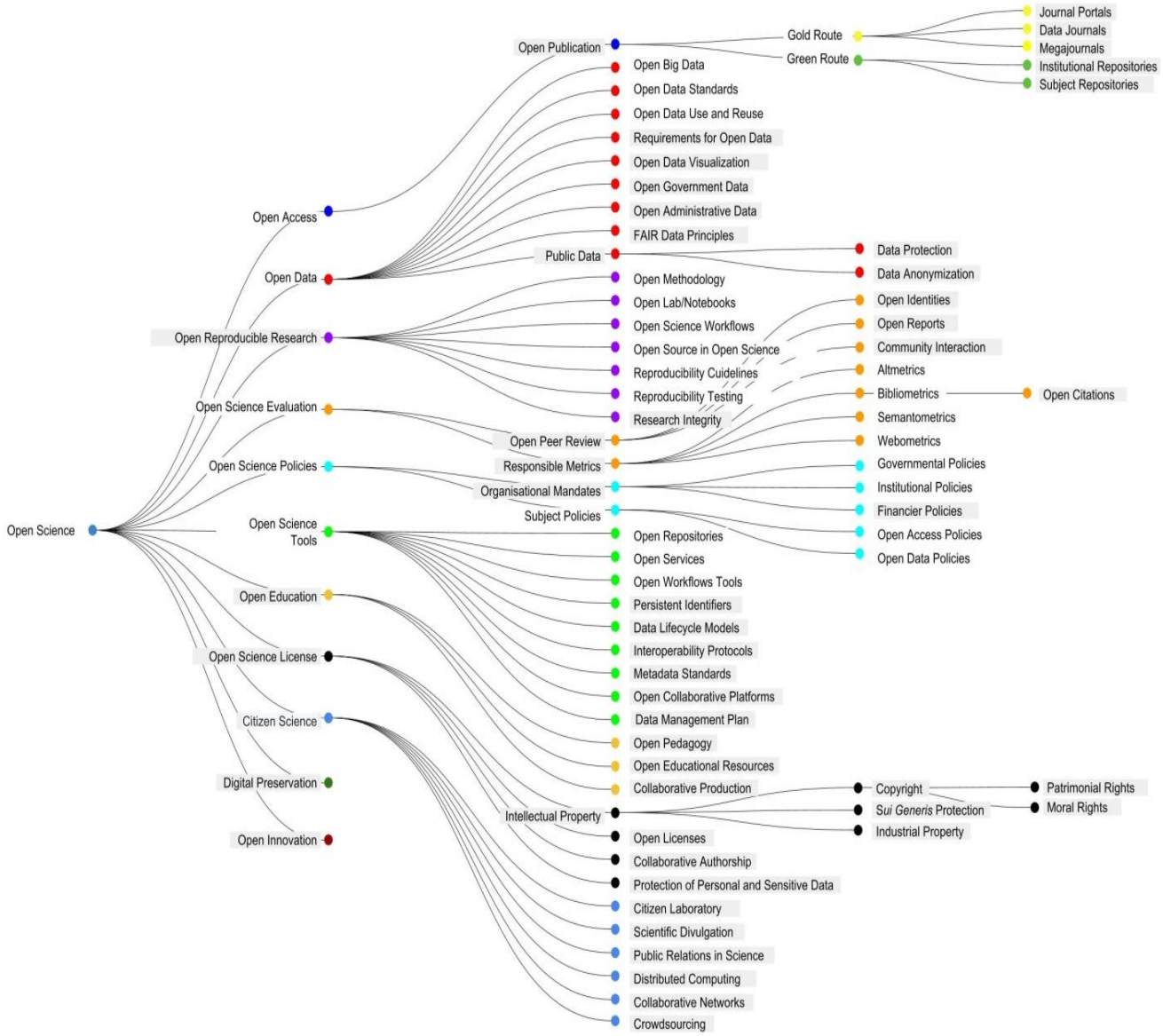
Figure 2 - Baumgartner Taxonomy of Open Science



Source: Baumgartner (2019).

Two years later, Silveira *et al*. (2021), working with a group of experts, proposed an expanded version, with 11 category components. The purpose of this taxonomy is to provide a broader framework that considers not only the practices and resources related to Open Science, but also the structural and political aspects that allow its implementation and dissemination (Figure 3).

Figure 3 - Taxonomy from the perspective of Brazilian researchers



Source: Silveira *et al*. (2021).

Table 2 points out the similarities and differences between the three taxonomies, and reveals that there are four similar elements: Open Access, Open Data, Open and Reproducible Research, and Open Science Evaluation. Of the three proposals, those of Pontika *et al*. (2015) and Silveira *et al*. (2021) are more similar to each other than either of these proposals is with the version by Baumgartner (2019). Elements that were not mentioned in the taxonomies are highlighted in gray in Table 2.

Table 2 - Similarities and differences between the three taxonomies

Pontika *et al.* (2015)	**Baumgartner (2019)**	**Silveira *et al.* (2021)**
1 Open access	1 Open access/Open publication	1 Open access
2 Open data	4 Open data	2 Open data
3 Open and reproducible research	8 Open search, 9 Open codes	3 Open and reproducible research
4 Open Science Definition	Facet not mentioned	Facet not mentioned
5 Open Science Evaluation	6 Open evaluation/open peer review	4 Open Science Evaluation
6 Open Science Guidelines	Facet not mentioned	Facet not mentioned
7 Open Science Policies	Facet not mentioned	5 Open Science Policies
8 Open Science projects	Facet not mentioned	Facet not mentioned
9 Open Science Tools	Facet not mentioned	6 Open Science Tools
Facet not mentioned	3 Open contents 5 Open education	7 Open education
Facet not mentioned	7 Open licenses	8 Open licenses
Facet not mentioned	Facet not mentioned	9 Citizen Science
Facet not mentioned	Facet not mentioned	10 Digital preservation
Facet not mentioned	Facet not mentioned	11 Open innovation
Facet not mentioned	2 Open budget	Facet not mentioned

Source: Prepared by the authors based on survey data (2022), see Appendix A for details.

It should be noted that the UNESCO Recommendations (2021) for Open Science document was prepared after a process of participatory discussion by experts which took two years (UNESCO, 2020). Among other guidelines, it was established that the elements of Open Science are essential for promoting collaboration, transparency, accountability and accessibility in science. The following elements described in that document served as the basis for developing the taxonomy proposal, present in Section 4. The original descriptions of the UNESCO were preserved to avoid misunderstandings or misinterpretations.

> Scientific publications (open access): that include, among others, peer-reviewed journal articles and books, research reports and conference papers. Scientific publications may be disseminated by publishers on open access online publishing platforms and/or deposited and made immediately accessible in open online repositories upon publication. Open research data: that include, among others, digital and analogue data, both raw and processed, and the accompanying metadata, as well as numerical scores, textual records, images and sounds, protocols, analysis code and workflows that can be openly used, reused, retained and redistributed by anyone, subject to acknowledgement. Open educational resources (OER): include teaching, learning and research materials in any medium

> – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restriction. Open source software and source code: these generally include software whose source code is made publicly available, in a timely and user-friendly manner, in human- and machine-readable and modifiable format, under an open license that grants others the right to use, access, modify, expand, study, create derivative works and share the software and its source code, design or blueprint. Open hardware: this generally includes the design specifications of a physical object which are licensed in such a way that said object can be studied, modified, created and distributed by anyone, providing as many people as possible with the ability to construct, remix and share their knowledge of hardware design and function. Open science infrastructures: refers to shared research infrastructures (virtual or physical, including major scientific equipment or sets of instruments, knowledge-based resources that are needed to support open science and serve the needs of different communities. Open engagement of societal actors: **r**efers to extended collaboration between scientists and societal actors beyond the scientific community, by opening up practices and tools that are part of the research cycle and by making the scientific process more inclusive and accessible to the broader inquiring society based on new forms of collaboration and work such as crowdfunding, crowdsourcing and scientific volunteering. Open dialogue with other knowledge systems: refers to the dialogue between different knowledge holders, that recognizes the richness of diverse knowledge systems and epistemologies. It aims to promote the inclusion of knowledge from traditionally marginalized scholars and enhance inter-relationships and complementarities between diverse epistemologies (UNESCO, 2021, p. 9-12).

According to the UNESCO Recommendations (2021), Open Science consists of four blocks: Open scientific knowledge (which includes open access to publications, data, open access to educational resources, open codes and open hardware); 2) Open scientific infrastructures; 3) Open engagement of social actors and 4) Open dialogue with other knowledge systems.

At the end of the investigation, after validation provided by experts (see results in the next section), a second comparison was made between the three taxonomies: Pontika *et al*. (2015), Silveira *et al*. (2021) and the new taxonomy proposal, the object of this study, available in Appendix A[8], and illustrated by means of an image in Appendix D[9] (a comparison with the Brazilian version). Baumgartner's proposal (2019) was not included in this step, since the author does not use the same component structure; see Figure 2.

It is evident that the communication of science is a dynamic domain, which entails a demand for innovation at all times, seeking to improve the practices of science guided by more transparent investigations, and more inclusive and more responsible evaluations. It is for this reason that we reflected on and developed a new version of a taxonomy to

[8] Disponível em: https://periodicos.ufsc.br/index.php/eb/article/view/91712/53445
[9] Disponível em: https://periodicos.ufsc.br/index.php/eb/article/view/91712/53449

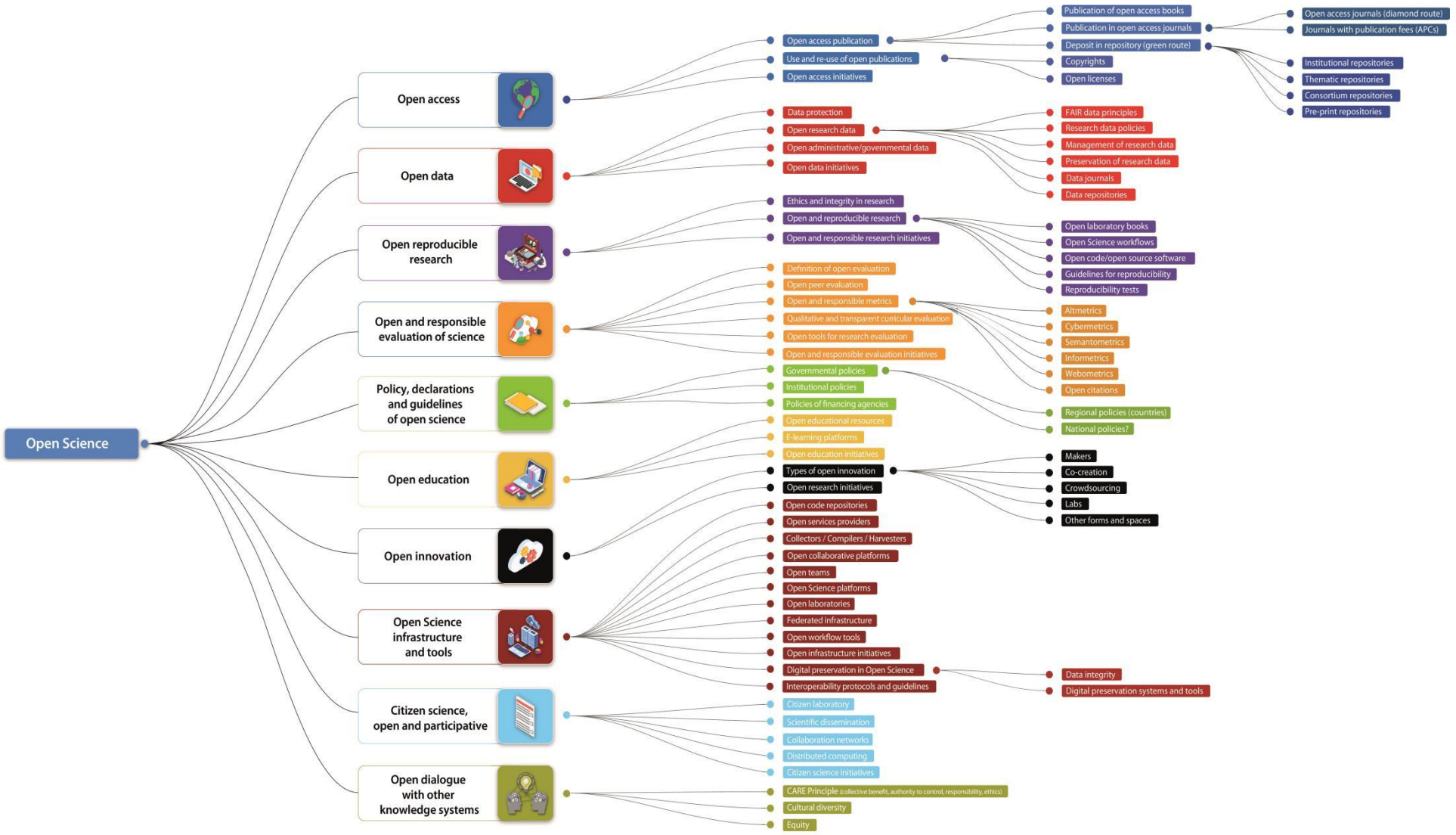
represent Open Science, which is described in detail in the next section and compared in Appendices B [10]and C[11].

4 VALIDATION OF THE TAXONOMY PROPOSAL BY EXPERTS

In the second stage of this investigation, the validation of the proposal, 21 experts participated in the research from the following countries: Argentina (3), Brazil (5), Colombia (2), Costa Rica (2), Chile (1), El Salvador (1), Guatemala (1), Mexico (1), Panama (2), Peru (1), United States (1) and Uruguay (1). They were asked to comment on the new Open Science taxonomy. After considering their comments, a taxonomy with 10 first-level components was proposed, subdivided into a total of 96 labels, 14 more than the version proposed by the Brazilians, Silveira *et al*. (2021), and 51 more than the initial version by Pontika *et al*. (2015), as shown in Figure 4.

[10] Disponível em: https://periodicos.ufsc.br/index.php/eb/article/view/91712/53447
[11] Disponível em: https://periodicos.ufsc.br/index.php/eb/article/view/91712/53449

Figure 4 - Inclusion of terms in the Open Science taxonomy



Source: Illustration by: Andrés Mauricio Enciso Betancourt; based on research data (2022). To enlarge the image click here.

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In general, the experts considered that the proposed taxonomy was representative and consistent with Open Science, and that it was a useful reference on the perspectives encompassed by Open Science which provides a structure that allows orderly thinking about this domain of knowledge (Expert 2).

Furthermore, the taxonomy is seen as complete (Washington Segundo, Murillo, Bravo-Marchant), while stimulating even more questions (Bravo-Marchant), and the separation by colors helps to identify the main components of Open Science (Murillo).

Although some experts agreed with the proposal, mention was also made of the need to include other terms and modify others that were considered to be transversal. For Experts 6 and 7, the taxonomy seemed correct, although there seemed to be some sections that were developed in more detail than others, namely open access, physical infrastructure, computing, and preservation of publications. Zapata-Pino also recommended the integration of dimensions such as gender equality and political statements. Similarly, Marín Campos observed that there are major concepts that could be considered as parts of others or to be transversal to them. In addition, although the form of visualization used involves organization by large subgroups, it could not contemplate this possibility. For example, Open Science infrastructure and tools could be transversal throughout the process, and highly relevant to subsets such as education and research, but it must be kept in mind that the topic of infrastructure is fundamental. He also questioned the non-linear or hierarchical approach used in the presentation of the taxonomy, even providing graphics that allowed a more comprehensive interpretation of movement and chaining, which are characteristics of the terms presented. Along the same lines, Gómez Hoyos commented that it is a very well summarized taxonomic table, but that some of the interactions between elements of Open Science are missing. For this Expert, the image should be dynamic and interactive rather than static as it is now presented, since each element can be further developed and better specified.

Beigel considers that the components reflect the definition of Open Science included in the UNESCO recommendation, as well as some specifically Latin American characteristics such as collaborative infrastructures and participatory science. However, this Expert also indicates that a fundamental element is missing, which are incentives for Open Science in research evaluation and funding policies.

Washington Segundo proposes adding more terms directly below the root term “Open Science,” such as “Open Scientific Social Networks,” following the example of the

Lattes Platform, available in Brazil, and similar networks those other Latin American countries. Expert 3 agrees with the components of the first level, but believes that citizen participation lacks concepts related to the formulation of policies and agendas in science and technology. For Expert 4, the components seem adequate, but he recommends that the last component, dialogue with other knowledge systems, be a transversal label, given that each of the topics on the list/sub-topics in that category, together with gender equality, should be reflected in all the components.

Experts 2 and 5 asked that the definition of the evaluation of science be explained to them, because they could not understand it clearly. Expert 15 stated that the scientific literature related to this topic has not reached a consensus about whether open evaluation has surpassed blind evaluation. This topic clearly raised doubts, and it should be noted that the main axis in question, open and responsible evaluation of science, concerns evaluation as a whole and not just its application in particular cases, in this case, evaluation of publication.

In the case of Citizen and Participatory Science, Expert 3 believes that scientific dissemination is related to scientific education. However, the Experts Oliveira and Gómez Hoyos disagreed, arguing as follows:

> *I don't know if scientific dissemination should be considered as a citizen and participatory practice. Mainly, dissemination is not a citizen or participatory practice. In this case, it should be considered much more as a science education practice than as science dissemination, which presupposes an editorial/institutional/individual decision on what to disseminate and how to disseminate it (a gatekeeper). Oliveira.*
>
> *This element is much more complex than what has been presented. There are many elements and approaches from Latin America that should be addressed. Presenting this element apart from open dialogue gives the impression that citizen science is considered here as a contribution of "citizens" to conventional science and not to other forms of knowledge, or approaches to knowledge production. In my opinion, an integrated presentation is more convenient, and the message is different. Gomez Hoyos.*

The authors of this document decided to keep dissemination linked to Citizen Science. Along the same lines, Expert 5 proposed a new facet, "Science Dissemination."

González, another responding Expert, also believes that a Latin American taxonomy must include some specificities about approaches and practices in the region, but that its concepts must be universal. In González's opinion, there are terms or transversal axes that apply to the 10 major components, such as gender, cultural diversity, equity, and initiatives that must be defined more precisely. He believes that they should not

be included as subcomponents, but rather in a section in which principles and concepts are presented.

The Brazilian Open Science taxonomy had 11 components (Silveira *et al*., 2021), including the UNESCO (2021) recommendations; and the two components of Digital Preservation and Open Licensing were redirected. Digital Preservation was added as a label in the Infrastructure and Tools components, as was Open Data. Open Licensing was added as a label in the Open Access facet, and the Open Dialogue with other knowledge systems facet was also added. These modifications are in line with the UNESCO recommendations.

5 Conclusions

Taxonomies are classification structures for the organization of knowledge domains, which allow the aggregation of information and data, as well as enabling access through navigation. The elaboration of taxonomies for interdisciplinary domains such as Open Science, the domain discussed in this article, are conceptually complex. Our efforts required the creation of a grouped and systematized theoretical foundation based on a revision of the scientific literature and the contributions of outside experts and the authors of this article. The efforts made resulted in a robust taxonomy with 10 components and 96 labels.

The proposed new taxonomy introduces innovative aspects, making it more complete; it also has a more adequate organization of Open Science concepts, and is more representative of a diversity of perspectives. The new taxonomy can help to understand Open Science in a more complete, structured and orderly manner, which allows researchers, publishers and institutions to better understand the political, theoretical and practical dimensions of the Open Science movement and its implications for scientific work. This will facilitate the development of more effective Open Science policies, strategies and practices, and promote collaboration, information, and resource sharing between researchers and institutions from different countries and regions.

The expanded and revised Open Science taxonomy seeks to overcome limitations observed in the literature and confirmed by experts, and also combines and adds perspectives from Latin America, which is especially important in a context where related

debates and practices about Open Science are still influenced by predominantly European and North American visions.

Despite the use of technologies enabling remote dialogues in weekly meetings when carrying out this research, the number of participants and the complexity of the subject represented a barrier which had to be overcome. Participation was voluntary, divergent opinions frequently arose and consensus was not always reached as quickly as expected. Language barriers constituted another problem, since not everyone was fluent in Portuguese and Spanish. This difficulty was overcome by following up on the minutes of each meeting and subsequent additional meetings between both the Brazilian and Spanish-speaking teams, which were useful for solving doubts, and guided research participants in the same direction towards our common goal.

Some expert contributions (Appendix C[12]) were not used in this article because they were not consistent with the taxonomies discussed previously, implying a need for new research to build a disruptive taxonomy of Open Science and carrying out deeper analyses. In future research, we intend to publish an extension of the present results, including debates and proposals, together with theoretical arguments for including, changing or removing components of the new taxonomy presented here. Furthermore, since many of the components included in this taxonomy have transversal characteristics, it has been proposed to analyze the possibility of developing an ontology intended to represent knowledge through a set of concepts within the domain of Open Science, including its entities, classes, attributes and the relationships between them.

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