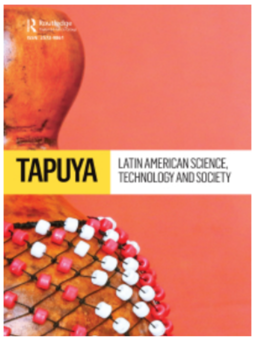

Routledge
Taylor & Francis Group

Tapuya: Latin American Science, Technology and Society

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ttap20

Evolution of the public understanding of science based on a bibliometric analysis of two major journals

Luciano Levin & Daniela De Filippo

To cite this article: Luciano Levin & Daniela De Filippo (2021) Evolution of the public understanding of science based on a bibliometric analysis of two major journals, Tapuya: Latin American Science, Technology and Society, 4:1, 1954381, DOI: 10.1080/25729861.2021.1954381

To link to this article: https://doi.org/10.1080/25729861.2021.1954381

Published online: 04 Oct 2021.

TAPUYA: LATIN AMERICAN SCIENCE, TECHNOLOGY AND SOCIETY
2021, VOL. 4, 1954381
https://doi.org/10.1080/25729861.2021.1954381

Routledge
Taylor & Francis Group

Evolution of the public understanding of science based on a bibliometric analysis of two major journals

Luciano Levin [a] and Daniela De Filippo [b]

[a]Universidad Nacional de Río Negro, CITECDE, CONICET, San Carlos de Bariloche, Argentina; [b]Universidad Carlos III de Madrid, Madrid, Spain

ABSTRACT

This paper is part of the reflection initiated in 2016 following the 20th anniversary of the Public Understanding of Science Journal, analyzing both the thematic evolution of the journal itself and broader aspects of the evolution of the field. Here, we aim to analyze developments in PUS based on all the papers published in the field's two major journals: Science Communication and Public Understanding of Science. We propose to study the field based on the epistemic relations established between texts resulting from the references they include. Thus, although the aforementioned journals constitute our source of information, by incorporating in the analysis the references of all the papers in these journals – which include books and other journals – we significantly expand the scope and build the epistemic links that are established by the texts analyzed in a very specific way.

KEYWORDS
Science literacy; public understanding of science; science communication

PALAVRAS-CHAVE
Alfabetização científica; public understanding of science; science communication

PALABRAS CLAVE
Alfabetización científica; public undestanding of science; science communication

Evolução do campo "Compreensão Pública da Ciência" a partir da análise bibliométrica de seus dois periódicos mais importantes

RESUMO

Este artigo faz parte da reflexão iniciada em 2016 após o 20° aniversário do jornal Public Understanding of Science Journal, analisando tanto a evolução temática da própria revista assim como aspectos mais amplos da evolução do campo. Aqui, pretendemos analisar os desenvolvimentos em PUS com base em todos os artigos publicados nos dois principais jornais da área: Science Communication e Public Understanding of Science. Propomos estudar o campo a partir das relações epistêmicas estabelecidas entre os textos decorrentes das referências por eles inseridas. Assim, embora os jornais referidos constituam nossa fonte de informação, ao incorporar na análise as referências de todos os artigos desses jornais – que incluem livros e outros jornais – ampliamos significativamente o escopo e construímos os vínculos epistêmicos que se estabelecem nos textos.

CONTACT Luciano Levin llevin@unrn.edu.ar, lucianolevin@gmail.com

Supplemental material for this article can be accessed here: https://doi.org/10.1080/25729861.2021.1954381.

Evolución del campo "Public Understanding of science" basado en el análisis bibliométrico de sus dos revistas más importantes

RESUMEN
Este artículo es parte de la reflexión iniciada en 2016 tras el 20° aniversario de la Revista Public Understanding of Science cuando se analizó tanto la evolución temática de la propia revista como aspectos más amplios de la evolución del campo. Aquí, nuestro objetivo es analizar los desarrollos en el campo de la Comprensión Pública de la ciencia basados en todos los artículos publicados en las dos revistas principales del campo: Science Communication y Public Understanding of Science. Proponemos estudiar el campo a partir de las relaciones epistémicas que se establecen entre las referencias que incluyen los textos. Así, si bien las revistas mencionadas constituyen nuestra fuente de información, al incorporar en el análisis las referencias de todos los artículos de estas revistas, que incluyen libros y otras revistas, ampliamos significativamente el alcance y construimos los vínculos epistémicos que establecen los textos.

1. Introduction

This paper is part of the reflection initiated in 2016 following the 20th anniversary of the journal *Public Understanding of Science* journal (*PUSJ*), when a series of articles was published analyzing both the thematic evolution of the journal itself and broader aspects of the evolution of the field of the public understanding of science (PUS) (Bauer and Howard 2012; Suerdem et al. 2013; Smallman 2014).

The term "public understanding of science" encompasses a heterogeneous suite of disciplines very loosely knit around descriptions and analyses of how science is communicated. It includes communication through professional and institutional channels (museums, specialized publications) and, more often, cultural channels (e.g. journalistic or cinematographic discourse). Defining the methods, objects of study and areas of interest of PUS has become an area of research that has spawned some controversial papers (Bauer and Schoon 1993; Bauer, Allum, and Miller 2007; Bauer 2009) that address both academic issues and professional practice (what and how to communicate). In endeavoring to understand how the field of PUS has developed, we began by looking at previous scholarly observations. We found some general studies, but we chose to start our discussion by contrasting our findings with Bauer's paper (2009).

Martin Bauer clearly delimited the field and defined its historical periods. We are interested in discussing these periods in order to try to introduce some specificity by using a more powerful methodology. Bauer contended that the earliest paradigm, science literacy, which appeared in the 1960s, was based on the belief that the public at large had a deficit of scientific knowledge. The research strategy prevailing at the time was to measure scientific literacy to quantify the deficit in order to design and implement scientific education policies. Bauer defined a second period beginning in the mid-1980s, when the paradigm was based on the public's understanding of science. The emphasis then was to determine attitudes toward scientific knowledge, challenging the assumption that greater knowledge would automatically lead to a more positive attitude toward science. This was visible especially in the way scientific controversies were treated. Research problems increased in complexity during this stage, because the lack or excess of knowledge proved insufficient to explain the attitudes adopted by the public at large. The pursuit of an explanation for public opinion prompted researchers to resort to a variety of rhetorical tools. The third period identified by Bauer, termed "science-in-and-for-society," has been the focus since the 1990s. The paradigm here differed substantially, assuming public opinion to be informed not by a knowledge deficit about science and technology, but by a loss of confidence. According to Bauer, most of the actors involved in the paradigm are committed activists who do not generally analyze each action separately. Given that science communication action often goes hand-in-hand with public events (hearings, jury deliberations, deliberative public surveys, panel discussions, round tables, science fairs and national debates), the organizers assume the role of mediators between a disenchanted public and scientific institutions, industry and policy-making. A summary of Bauer's periodization is presented in Figure 1.

Here, we aim to scrutinize this periodization in an attempt to flesh out Bauer's description and update his analyses which, in the best of cases, run only up to the late 1990s. To date, most studies of the field have sought a theoretical understanding of the relationships among the subject areas most frequently addressed in the literature, i.e. academic discourse on PUS and broadly defined social processes. Very few analyses have been based on sound empirical grounds. Some have used meaningful, though limited, examples of the processes (Bauer 2009; Jensen 2011; McNeil 2013; Roland 2007), while others have described realities observed only locally (Bowen and Borda 2009; Bucchi and Saracino 2016; Villarroel et al. 2013). We aim to analyze developments in PUS based on all the papers published in the field's two major journals, *Science Communication* (*SCICOM*) and *Public Understanding of Science* (*PUSJ*).

Unlike previous studies, in which the description of the field were based on lexicographical analyses of the words in the abstracts of all *PUSJ* articles (Suerdem et al. 2013) or

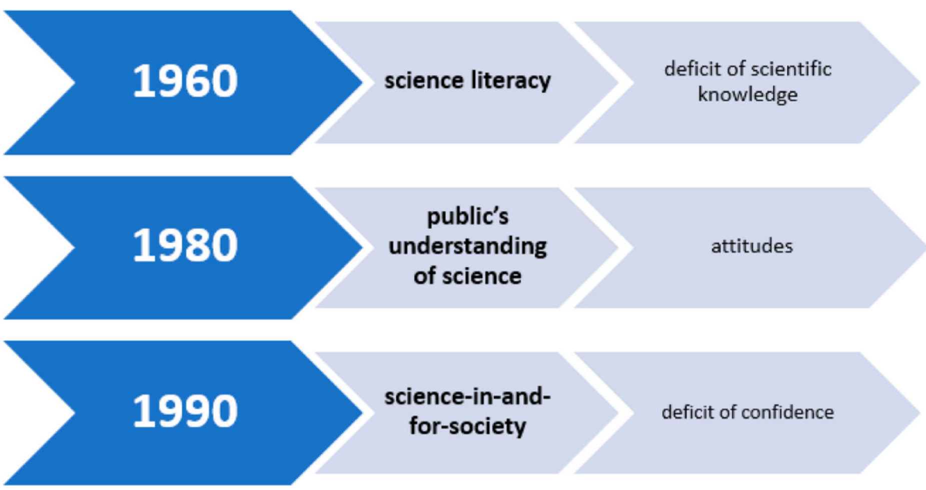

Figure 1. Bauer's periodization of the PUS field.

analyses of the full text of the 50 most frequently cited papers (Smallman 2014), we propose to study the field based on the epistemic relations among texts resulting from the references they include. Thus, although just two journals constitute our source of information, by incorporating into our analysis the references of all the papers in these journals (references that include books and other journals), we significantly expand the scope and can trace the epistemic links among the texts. This enables us to analyze the dialogue among texts, journals and concepts.

While the assumption that the two selected journals represent the entire field can be debated, the influence of these journals on international research agendas is well known within the community. Articles published by *SCICOM* and *PUSJ* are typical in the references cited in other journals and international congresses specializing in the area, as can be seen in any review of the agendas for events such as the Public Communication of Science and Technology Conference (PCST) or the International Congress of Public Communication of Science (COPUCI). A detailed measurement of influence could be another subject for research. The aim here, however, is to describe the evolution of PUS through the specific lens of these journals. Given their influence, we also aim to establish general lines which, in an exchange with other interpretational contexts, enhance the vision of developments in the field by validating the ideas contained in those contexts or by proposing others. At the same time, the methodology accommodates an analysis of the subject history in the selected journals.

Previous reflections have shown that there is a persistent interest in issues related to public attitudes and mass media and changes in the theoretical language used, indicating a conceptual consolidation of the field in its rhetorical aspects. At the same time, as reported in previous studies (Bauer 2009), perspectives associated with the definition of "public understanding" have evolved toward a discussion of "public engagement" (Suerdem et al. 2013). It has also been reported that case studies have come to dominate the field and that the discussion of different aspects of PUS has become more international over time (Smallman 2014).

Although some of our research questions are similar to those addressed by other authors, our methodology enables us to analyze new issues. Which topics are of most interest, and how do they relate to one another (Smallman 2014)? Is there evidence that the language shift identified by Suerdem et al. (2013) reflects a conceptual change, or is it simply a change in terminology (Smallman 2014)? Are there any new topics not reported in previous studies based on *PUSJ?* Lastly, is the process of internationalization homogeneous, or can any biases be proposed?

2. Sources and methodology

The methodological strategy was implemented in several stages: (1) Journal choice; (2) Paper extraction; (3) Parsing; (4) Clustering; (5) Cluster identification and labeling; (6) Period division. This methodology was tested by comparison to earlier partial analyses of the data (Bauer and Howard 2012, 2013; Suerdem et al. 2013; Smallman 2014) and by comparison with other scientific fields (Grauwin et al. 2012; Levin, Jensen, and Kreimer 2016) or social issues. Figure 2 summarizes the steps followed.

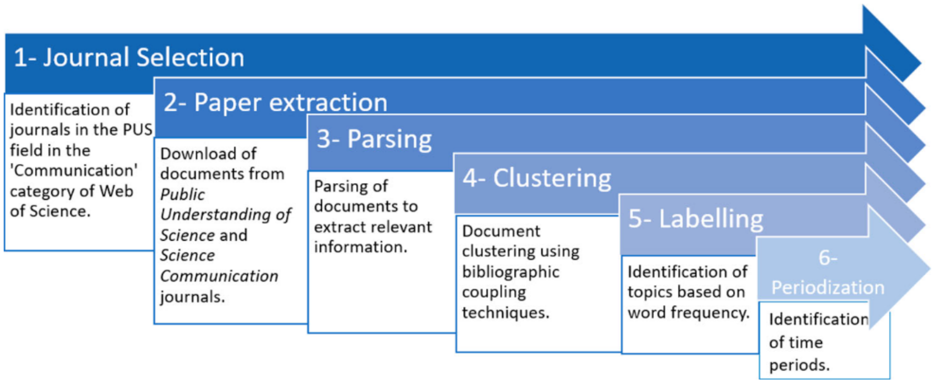

Figure 2. Methodological stages.

2.1. Journal choice

To select the best journals to represent the PUS field, we used the Web of Science (WoS) as our source of information. We chose this source despite its acknowledged limitations such as subject area, language and geographic biases (Gómez and Bordons 1996), because WoS contains information of great value for our proposed analysis, holding journals to the highest quality standards and enabling us to select journals from specific subfields. As we worked with a large volume of data, it was important to have a reliable source with a high level of standardization and encoding.

To identify the journals, we used the 2018 edition of Journal Citation Reports, which indexed 88 journals under the subject category "Communication" (Clarivate Analytics 2019). To select the most accurate sources, we consulted the websites of all journals and analyzed their scope. We intentionally left out communication journals on specific topics or specialities, such as environmental or medical communication.

The first general "communication" journal was Journal of Communication (*JOC*) (listed fifth of the 88 journals). We decided to include this journal as the starting point for our inquiries but ultimately discarded it because of its broad scope (see Supplemental Material). The first "science communication" journal indexed was *PUS* (13th), followed by *SCICOM* (21st). The list included no other specific journals of science communication.[1]

2.2. Paper extraction

All the papers published in the journals were then retrieved from the Web of Science Core Collection using the following search criteria (February 18, 2019): SO = Public Understanding of Science OR SO = Science Communication. We did not limit the period, thereby obtaining all the documents included in the Web of Science from 1994 for *SCICOM* (542 documents) and from 1997 for *PUSJ* (874 documents).

[1]Furthermore both journals formed part of the same interaction network, sharing several key references and main topics. Most importantly, all the metadata could be labelled similarly.

2.3. Parsing

We used Bibliotools scripts to parse the documents (Grauwin and Jensen 2011). When we parsed all the documents to extract relevant information (authors, title words, abstracts, keywords, journal, references, referenced journals, subjects and countries), approximately 10% of the papers were excluded from the database due to their document type (editorials, reviews, notes, etc.). This is because documents without references cannot be processed by the scripts. We kept only documents with complete information, mainly articles.

2.4. Clustering

Once we had parsed all the documents, we applied bibliographic coupling (BC) techniques (Kessler 1963), a method that clusters texts on the grounds of the relationships among the papers cited, on the assumption that the larger the number of references shared by any two papers, the more similar is the subject matter addressed. This analysis is especially useful to detect relationships between texts and to build a documentary corpus to study the shape of disciplines, emerging fields and institutions. Bibliographic coupling reduced our corpus again. Any cluster containing less than 10 documents was excluded. Moreover, a few articles did not share any references with other documents and were therefore not included in any cluster. Thus, our final data corpus included 476 articles from *SCICOM* and 840 articles from *PUSJ* when we worked with the two separately, and 1286 articles from both journals when we applied joint analysis.

We created the bibliographic coupling network by computing the:

$$\text{BC} = \text{weight}\ (w_{ij} = n_{ij}/sqrt(n_i * n_j))$$

between each pair of articles, where n_{ij} is the number of shared references and n_i is the number of references of article *i*. Then we detected the bibliographic coupling communities by using the louvain algorithm, based on the maximization of a weighted modularity function that proposes a hierarchy of community partition (Blondel et al. 2008). An example of the graphics that result of this procedure can be seen in Figures 4, 5 and 6.

2.5. Cluster identification and labeling

Once we had the structure of our bibliographic coupling-based clustered network, we organized the metadata according to two criteria: the frequency in a cluster (f) and an indicator of the general occurrence in the sample (σ):

$$\sigma = \frac{\sqrt{N}(f - P)}{\sqrt{P(1 - P)}}$$

where N is the number of articles in a cluster and f and P are the proportion of articles in the cluster and in the total papers analyzed. Only the most significant values (the first 20) were displayed in an automated table.

The highest values of f and σ afforded semantic meaning to the sets of papers and an understanding of the main topics addressed. The information gathered was listed in tables (for example, see Table S3 in Supplemental Material) summarizing the characteristics of each cluster, including all the variables analyzed. This procedure provided one table per cluster.

The information was used to identify each cluster and assign it a label summarizing the subject matter. Labeling, the key to comprehending the information, is explained and exemplified in detail below.

This clustering procedure was performed:

(1) with all the papers in both journals, jointly
(2) with all the papers in each journal separately
(3) with all the papers in each journal separately, divided into five periods (1990–2000; 1995–2005; 2000–2010; 2005–2015; 2010–2019).

To label each cluster, we followed two consecutive strategies designed to gain an understanding of the cluster's main topics: first, a qualitative-quantitative methodology based on metadata analysis and, second, personal interviews with scholars in the field.

For the qualitative-quantitative method, with the clustering performed and the metadata associated with each paper extracted, we built tables summarizing the information (one table per cluster). Thus, each cluster was represented by several suites of information: keywords, title words, subjects, authors, journals, references, referenced journals and countries. These tables (for example, see Table S4 in Supplemental Material) identify each cluster. The frequency of appearance of each element in the cluster and its significance, i.e. the specificity of the element relative to the cluster, were obtained for each sub-set.

For a fuller understanding, the most significant references were studied, again under the assumption that citations denote the main thrust of the papers in which they are cited. We read the complete papers to find their main topics.

In order to contrast and confirm the labels, we conducted personal interviews with specialists in the PUS field. We showed them our data, explained in detail how the clusters were built and asked them to assign their own set of labels to each cluster. Then we asked them for their opinion of the labels we had assigned to describe the content of each cluster and compared the sets of labels. We conducted this procedure with three senior researchers in the field. The procedure generated some very reliable labels with which to compare clusters between the two journals and across different periods. Just as an example, the "Participation" label was changed to "Engagement."

2.6. Period divisions

Conceptual elements stemming from the history of the field and methodological elements with which to glean useful information were taken into consideration to establish sub-periods that served as grounds for the analysis of field dynamics.

Papers were sorted into ten-year periods with five-year overlaps. Thus, papers from two adjacent periods could be included in the same cluster to detect the presence of similar subject matters and identify continuities or interruptions between clusters in different periods. This strategy allowed us to build a continuity between clusters, in the attempt to analyze the dynamics of the field while avoiding unexpected effects of the periodization itself.

The periods established were 1990–2000, 1995–2005, 2000–2010, 2005–2015 and 2010–2019.

3. Results

Table 1 shows the main indicators for each journal. Both journals are included in the "Communication" category, which held just over 30 journals in 1997 and 92 journals in 2019. Until 2018 both journals were in the first quartile of the category, dropping to Q2 in 2019 mainly due to the entry of new journals and a greater increase of citations in other journals. However, *PUSJ* is also included in the "History and Philosophy of Science" category, where it maintains a top position.

In addition to the main indicators of impact factor and quartile, which give us a general view of each journal, we looked at the diversity of author countries in an approach to one of our research questions about the field's internationalization. The first analysis shows a clear increase in the number of countries, as we can see in Figure 3. For *PUSJ* there are seven countries represented by at least five articles in the 1990s. That number increased to more than 12 countries in the following decade, reaching almost 30 countries in the current decade. Something similar occurs in *SCICOM,* though with slightly lower numbers.[2]

3.1. Bibliographic clusters

After the parsing process, the clustering stage was performed. To summarize, the analysis of the documents from both journals together yields five significant clusters. The main keywords that characterize each cluster are shown in Table 2, with the selected label,

Table 1. Main journal indicators.

Indicator	SCICOM	PUSJ
Year	1979	1992
Country	USA	UK
Number/year (2014)	6	8
SSCI category	Communication	Communication/History & Philosophy of Science
Quartile	Q2	Q2/Q1
Impact factor (2019)	2.328	2.338
# art. 2019	30	73
Rank	26/92	25/92 (Comm); 5/48 (H&P of S.)
Total # art. published	898	1138
# art. analyzed	542 (476)	874 (840)

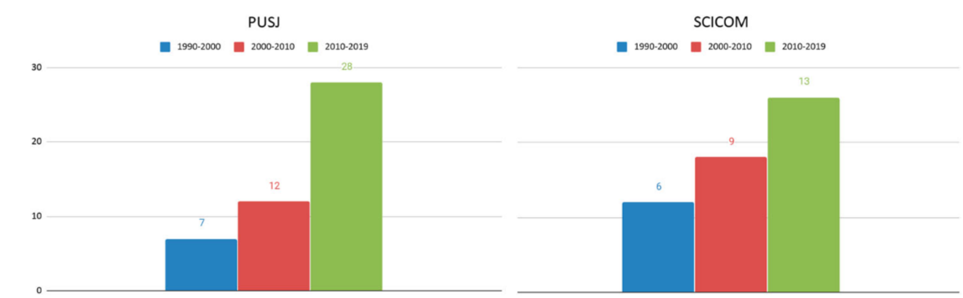

Figure 3. Number of countries that published at least five articles.

[2]Details on the countries are provided in Table S2 in the Supplemental Material.

Table 2. Main characteristics of *PUSJ* + *SCICOM* (joint analysis of bibliographic clusters).

Cl	# art.	KW1	KW2	KW3	Label	Referenced Journals	%*PUSJ*/ *SCICOM*	APY	Countries (>5%)
1	441	Participation	Governance	Democracy	Engagement	*PUSJ; STHV; SSS; SCICOM; Nature*	75/25	2009	UK; US; Can, Neth; Aus
2	338	News	Climate	Coverage	Climate News	*PUSJ; SCICOM; JCOMM; Science*	50/50	2010	US; UK; Ger
3	214	Emerging Technologies	Trust	Attitudes	New Tech Attitudes	*SCICOM; PUSJ; Risk Anal; Science*	45/55	2009	US; UK; Can; Neth
4	183	Literacy	Attitudes	Knowledge	Literacy	*PUSJ; Science; SCICOM; Nature; STHV*	80/20	2010	US; UK; Spain
5	110	Scientists	Science Communication	Mass Media	Scientists	*PUSJ; SCICOM; Science; Nature; PLOS*	50/50	2013	USA; UK; Aus; Ger

the average publication year (APY) and the main countries involved in authorship. Although the information was scant due to the length of the timespan, it afforded enough of an initial idea of how the data were organized to assign the preliminary general labels and pose the questions to be initially discussed with the expert consultants.

When the clusters were arranged in order of decreasing number of publications, the five topics into which the information was grouped were labeled as (1) “Engagement,” which refers to texts about processes of public participation in the governance of science; (2) “Climate News,” which concerns texts whose central focus is the analysis of news on science topics, especially climate issues; (3) “New Tech Attitudes,” where we find texts that analyze public attitudes, risk perception and trust in emerging technologies such as biotechnology, nanotechnologies, cloning and stem cells (This cluster is the oldest of the five, APY = 2009); (4) “Literacy,” which is mainly texts on the degree of public understanding of scientific concepts, along with discussion of the models of public communication of science, particularly the deficit model; and finally (5) “Scientists,” where we find texts analyzing different aspects of activities by scientists in the mass media for the public communication of science (This is the newest cluster, APY = 2013).

We find only seven countries that can lay claim to a larger than 5% share of papers. The reference network is large, including journals such as *Science, Technology and Human Values: Social Studies of Science, Nature, Risk Analysis, Global Environmental Change, Journal of Communication, Communication Research, Daedalus* and *PLOS One*.

We graphed the networks for a visual representation of the relationships within clusters.[3]

All the clusters in Figure 4 are related, although there is one cluster that is more central than the rest, “Literacy.” The “New Tech Attitudes” cluster has two very weak relationships, one with “Scientists” and the other with “Engagement.” The first is easier to explain in terms of the data, due to the novelty of the smallest cluster (“Scientists”; APY = 2013), but we could also argue that the “Scientists” cluster leads with scientists’ media appearances, and scientists are less likely to discuss truly controversial topics (such as new technologies) on big media platforms, preferring instead to be involved in the public communication of more stabilized knowledge. The weak relationship with “Engagement” is a little stranger. Further analysis is obviously required, and we shall endeavor to provide it later, but here is a preliminary idea in line with what we have said thus far: When the subject is new or emerging technologies, a somewhat distant focus is generally taken. When more stabilized technologies or scientific phenomena are discussed, however, public strategies related to engagement, participation and so on are more easily found. This weakness could indicate how limited we are in the ways we tend to think about the governance of recently launched or developing ground-breaking technologies. This is also in line with the fact that the strongest relationships we found are “Engagement”/“Literacy” and “Scientists”/“Literacy,” where the goal is to improve the general scientific culture of society.

In order to gain further understanding of the meaning of these clusters and their relationships, we deployed an analysis of the two journals separately. The results are shown in Table 3.

[3]All papers within a given cluster are colored the same (left graphs). Closer clusters mean more closely related topics. All the papers within a cluster are joined to simplify the view and display the strength of the links between clusters (right graphs).

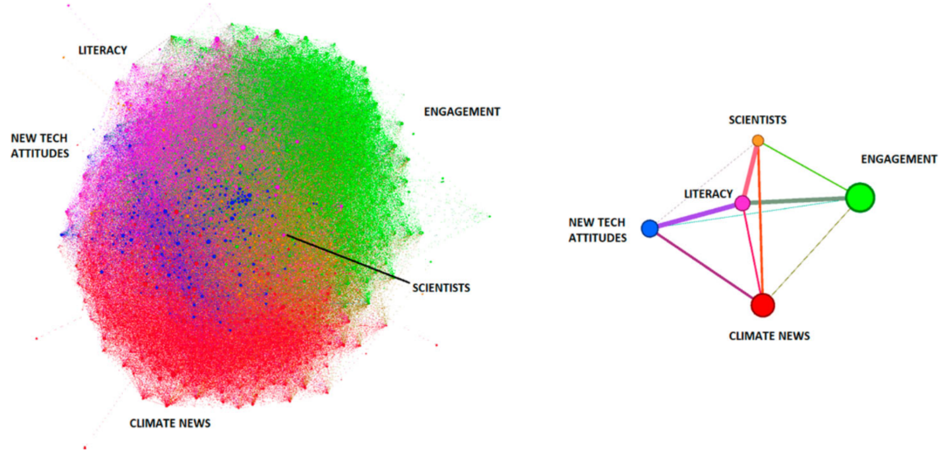

Figure 4. Spatial distribution of clusters in joint analysis of *PUSJ* and *SCICOM*.

In *SCICOM* the largest cluster ("News," 89 documents) contains papers relating to science coverage in the news. Most of the texts are from the US. It is one of the oldest clusters (APY = 2005) in both *SCICOM* and in the entire analysis; only "Organizations" is older (APY = 2001).

The second cluster ("Climate Polarization," 84 documents) mainly includes articles about the analysis of public opinion on climate change communication and the dynamics of public engagement with climate news, also published mainly by the US and slightly more by the UK than in the first cluster. In contrast to the largest cluster, this is the newest cluster in the analysis (APY = 2014). The topic's importance is evinced by the fact that it has almost the same number of papers as "News," but published in a shorter period. The main difference with the second cluster in the joint analysis lies in the role of engagement and participation; greater engagement and participation are signs of a more updated approach to the subject.

The third *SCICOM* cluster ("Engagement," 80 documents) mainly contains texts about scientists' and lay people's engagement in science communication activities. This is somewhat similar to the smallest cluster in the joint analysis, but it also bears a resemblance to the largest cluster, which explains why it has the same label. The resemblance is confirmed when we look at the authors of the papers (Besley in first place) and the main references (i.e. Poliakoff and Webb 2007 and Davies 2008 for "Scientists" and Irwin and Wynne 1996 for "Engagement"). The UK and the US are also the most important countries, with some showing by the Netherlands and Australia.

The fourth cluster is "New Tech Attitudes," with 76 papers published, mainly by the US. In addition to the similarity with the third cluster found in the joint analysis, here we find a slight increase in papers from the US and a decrease in the participation of Canada and the UK. Another difference is the use of the "framing" background (Entman 1993) to characterize public opinions.

The fifth cluster ("Organizations," 70 documents; APY = 2001) is exclusive to *SCICOM*. It is a cluster about knowledge transfer and how S&T organizations use knowledge, focusing on social uses and health. The absence of "transfer" as a keyword is due to the wide range of words used to name similar processes, such as "dissemination," "diffusion," "impact"

Table 3. Main characteristics of *SCICOM* and *PUSJ* (bibliographic clusters).

Cluster	# docs	KW1	KW2	KW3	Label	APY	Countries
SCICOM							
1	89	News	Coverage	Press	News	2005	US; UK
2	84	Climate Change	Engagement	Polarization	Climate Polarization	2014	US; UK; Ger
3	80	Engagement	Governance	Participation	Engagement	2012	UK; US; Neth; Aus; Can; Ger
4	76	Emerging Technologies	Risk	Public Opinion	Emerging Technologies	2010	US; UK
5	70	Organizations	Dissemination	Innovation	Organizations	2001	US; UK; Swe
6	59	Planned Behavior	Risk	Perception	Planned Behavior	2009	US; Ger; Aus; Neth; Chi
7	18	Stereotypes	Women	Children	Stereotypes	2009	US; Sp; Fr; India; Neth; UK
Total docs.	476						
PUSJ							
1	240	Participation	Governance	Democracy	Engagement	2010	UK, US; Can; Aus; Den; Neth
2	205	News	Coverage	Representations	Science News	2011	US; UK; Ger; Can
3	201	News	Genetics	Medicine	Bio News	2010	US; UK; Can; Ger; Aus
4	194	Attitudes	Trust	Literacy	Literacy	2012	US; UK; Neth; Sp
Total docs.	840						

and "implementation." These papers are published mainly by the US, followed by Canada. The UK is very poorly represented in this cluster.

The sixth cluster ("Planned Behaviour," 59 documents) is about the analysis of lay people's and scientists' reactions to sensitive scientific information, with an emphasis on risk-related topics. Although the US is the country with the largest number of author affiliations, Germany has a small share, but the highest significance values belong to Greece, Botswana and China. In this case, the journal itself is the source most frequently cited (63%), followed by *Risk Analysis* (43.68%) and *PUSJ* (42.53%).

The smallest and seventh *SCICOM* cluster ("Stereotypes," 18 documents) is also exclusively found in this journal. It groups texts analyzing several cultural representations of scientists and science (gender, children, movies). Articles are published mainly by the US and Spain.

When we looked at the referenced journals, we found no novelty except in the case of "Organizations," where new journals are referenced, including *Knowledge, Diffusion Innovation and Research Policy*.

Relationships between clusters (Figure 5) show that "Organizations" is a very isolated cluster poorly related with other issues. This is because the cluster is quite old (APY = 2001) and the topic had almost been abandoned by the PUS field by the time other journals arose to publish articles related with technology transfer. "Stereotypes," on the other hand, is more or less evenly related with all other clusters, showing that the analysis of scientists' public image is transversal to fields and problems. Finally, there is a strong association among "Engagement," "News," "Climate News" and "New Tech Attitudes." Note that, as in the previous analysis, the association between "New Tech Attitudes" and "Engagement" is the weakest of the four. The data show that this slight change could be understood through association with the "framing" theory, which tries to gain a more contextualized understanding of relationships.

The largest cluster in the *PUSJ* ("Engagement," 240 documents) reveals different dimensions of citizen involvement in today's context of broad-based S&T governance and participation in debates over controversial issues (e.g. health, biotechnology, cloning). It involves the keyword "democracy," which does not appear in *SCICOM*. We will examine this point in depth in the analysis by periods. England, the US and Canada

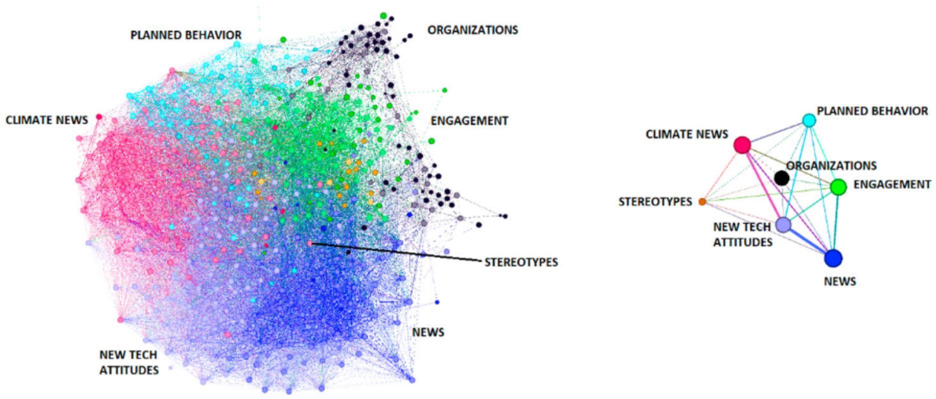

Figure 5. Spatial distribution of *SCICOM* clusters.

have the highest output in "Engagement," although the US's significance is lower in this cluster than in the journal average, whereas New Zealand has a σ value of >2.

The second *PUSJ* cluster ("News," 205 documents) concerns the analysis of scientific news, its producers and framing, mainly concentrating on climate issues and other risk-related news, such as biotechnology. Articles are published mainly by the US and the UK, followed by Germany.

The third cluster ("Bio News," 201 documents) is also related to science news but focuses more on the coverage of biomedical news and the analysis of scientific discourse designed to "sell" science, in line with Dorothy Nelkin's Book (Nelkin 1995).

The fourth cluster ("Literacy," 194 documents) is more related to science literacy, measurements of attitudes toward science, perceptions and risks of several public scientific and technological issues such as climate change, emerging technologies and so on. It greatly resembles the fourth cluster in the joint analysis; in fact, the resemblance continues to the proportion of articles in each journal (80/20). In the last two clusters, the US and the UK are the main publishers again.

The referenced sources are the same as in *SCICOM* plus *Minerva, Science & Public Policy, American Journal of Sociology* and *International Journal of Public Opinion*.

What can we learn about the distribution of *PUSJ* clusters (Figure 6)? Aside from the fact that all the clusters are clearly related, the weakest link lies between "News" and "Bio News," and the strongest, between "Engagement" and "Literacy." We have already mentioned the difference between "News" and "Literacy" where we found texts about the role of science communication and mass media in dealing with risk-related science issues. "Bio News" consists of texts focusing on trends in biomedical science coverage.

While in *SCICOM* the first cluster comprises primarily US and Canadian papers dealing with the specific role played by the communication of climate-related subjects in the formation of public opinion and risk perception, where APY = 2005, the first *PUSJ* cluster addresses subjects related to the role of science and its communication and use in the construction of a democratic society, with no emphasis on any particular case study

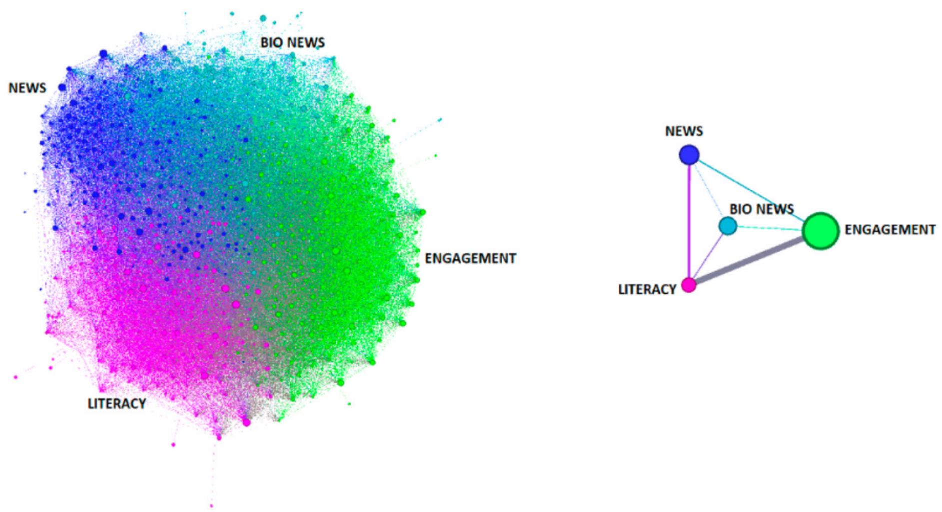

Figure 6. Spatial distribution of *PUSJ* clusters.

and a prevalence of papers by authors from British institutions, where APY = 2010. The inference drawn from the data on the journals is that the largest *PUSJ* cluster tends to be more current and sociological, whereas the *SCICOM* cluster focuses more on case studies.

Certain clusters, such as "Engagement," are present in both journals, but with minor differences, while other clusters only appear in one journal. For example, "Organizations" is present only in *SCICOM*. In a third group of clusters, both journals address the same subject matter, but from different approaches. One example is "News." In *PUSJ* this cluster is about more general news, including climate and biotechnology news, while in *SCICOM* it does not include climate news at all.

Looking at each journal in terms of the timespan it covers, we found two clusters exclusive to *SCICOM,* which we labeled "Organizations" (the oldest cluster in the whole analysis, APY = 2001) and "Stereotypes" (the smallest, with 18 documents). Although there was another cluster that we found exclusively in *SCICOM*, "Planned Behaviour," in the joint analysis "Planned Behaviour" was found to closely resemble "Scientists," as mentioned above.

When we analyzed *PUSJ,* we did not find the keywords "new tech attitudes," "scientists" or "stereotypes." However, upon looking at the clusters more closely in search of these missing items, we found the keyword "attitudes" in the *PUSJ* cluster labeled "Literacy" together with the keyword "emerging technologies," suggesting some kind of association between clusters. We shall see later how this topic behaves over time. "Scientists" was found in the *PUSJ* cluster "Bio News" (201 documents) and not in the previous cluster, "Science News" (205 docs). This may suggest that scientists are more usually involved in communicating science in a disciplinary way rather than in a "problem-oriented" manner. Finally, we were unable to find a cluster corresponding to "Stereotypes" in *PUSJ.* We shall go into greater detail regarding these peculiarities in the period analysis.

3.2. Analysis by periods

Here we used the same procedure to analyze journal dynamics. The papers were divided by periods and clustered, after which the metadata for each cluster were retrieved for interpretation and label assignment.

3.2.1. General data

While both journals exhibit an upward trend in the number of papers published per period, the rise is steeper in *PUSJ*. Despite the difference in the number of papers published, however, subject matter diversity (number of clusters) evolves similarly in both journals. Not only is the number of clusters the same as in the data overall, but it also exhibits a similar pattern over time (Figure 7).

In the next section, we describe the clusters for each period in each journal with further details only for clusters that have not yet been described or require some additional information. Clusters that remain the same are simply mentioned, without further details.

***3.2.1.1. Evolution of* PUSJ.** In *PUSJ* we found a clear increase both in the number of clusters and in the number of documents per cluster. We will analyze each period in detail.

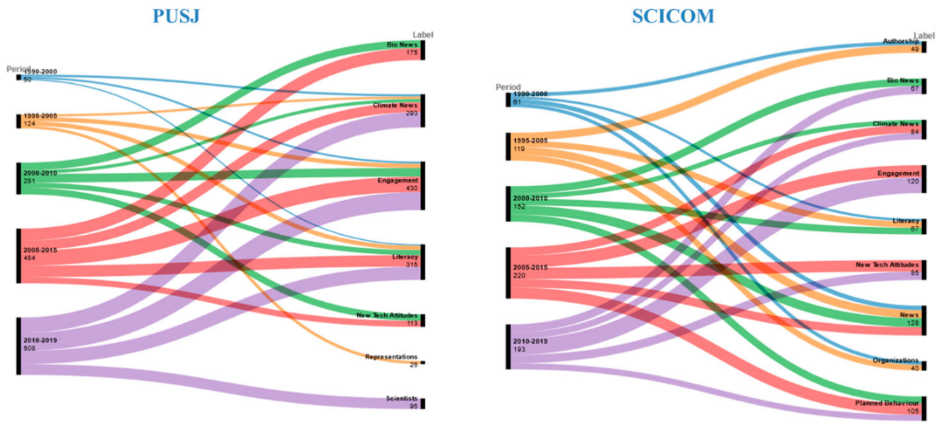

Figure 7. Evolution of clusters in each journal.

- ***1990–2000:*** We found three clusters. The largest cluster is "Climate News" with 20 documents. The second ("Engagement," 18 documents) is where we begin to see keywords associated with citizen science and participation, though they are covert. The keywords are revealed in texts that analyze the limits of the PUS field addressing biotechnology as the main topic. The smallest cluster ("Literacy," 12 documents) gathers texts that measure scientific literacy in specific topics such as nuclear power and climate change.
- ***1995–2005:*** Four clusters. The largest is "Engagement" (39 documents), which gains preponderance in comparison to the previous period but maintains its thematic bias toward "bio" issues associated with health. It is followed by "Literacy" (38 documents), which mainly addresses scientific knowledge in society yet contains some elements that link the cluster to "New Tech Attitudes," focusing on the perception of the risk of emerging technologies. The next cluster clearly inaugurates a hitherto unseen topic, "Representations" (26 documents), which contains texts about cultural representations of science – particularly biotechnology – in different media (press, cinema and school texts). In the general analysis, this cluster was hidden among the more numerous clusters about news analysis. The last cluster is "Climate News," with 21 documents.
- ***2000–2010:*** Five clusters. "Engagement" becomes consolidated as the most important cluster (77 documents) but gains a new perspective: The keyword "democracy" appears for the first time in the analysis of the construction of scientific citizenship. This cluster is followed by "Bio News" (69 documents). "New Tech Attitudes" (59 documents) emerges more clearly, followed by "Literacy" (46 documents) and "Climate News" (30 documents).
- ***2005–2015:*** Five clusters: "Engagement" (136 documents) remains in the same line as in the previous period, but with a new emphasis on nanotechnology issues. Next are "Bio News" (106 documents), which contains some elements that are also present in "Stereotypes"; "Literacy" (101 documents); "Climate News" (87 documents) and "New Tech Attitudes" (54 documents).
- ***2010–2019:*** Four clusters. "Engagement" (160 documents), "Climate News" (135 documents), "Literacy" (118 documents) and "Scientists" (95 documents). The only novelty here is the smallest cluster, whose articles concern the analysis of scientific communication activities performed mainly by scientists. Why are these 95 articles placed

together here? Where can we find them in the general analysis? First, we need to understand that the keyword "scientists" is crucial here. Fifteen of the articles (8% of 201 documents) can be found in the general *PUSJ* cluster labeled "Bio News" (201 articles), where the keyword "scientists" was found to be associated mainly with the role played by scientists as a source of information in news, as in one of the most frequently cited publications in the cluster, "Uses of expertise" (Conrad 1999). Another fifteen articles (8% of 194) can be found in the next general *PUSJ* cluster ("Literacy," 194 documents). This cluster more closely resembles "Scientists" in that it analyses the institutional role of science literacy activities. In any case, the appearance of this specific cluster clearly shows the rise of a topic that was marginal in the past.

***3.2.1.2. Evolution of* SCICOM.** The analysis of *SCICOM* by periods reveals the following characteristics.

- ***1990–2000:*** In this period, we found four clusters: "News" (nine documents), followed by "Authorship" (16 documents), which analyses different forms of academic communication and their internal dynamics. Next is the cluster "Organizations" (15 documents), dedicated exclusively to the use or usefulness of knowledge in health matters. Lastly, "Literacy" (11 documents) addresses knowledge about "public science."
- ***1995–2005:*** Four clusters. "News" (34 documents), "Authorship" (33 documents), "Literacy" (27 documents) and "Organizations" (25 documents).
- ***2000–2010:*** Five clusters. "News" (39 documents), "Bio News" (32 documents), "Planned Behaviour" (31 documents), "Literacy" (29 documents, with the particularity that it includes texts that relate "Literacy" to the "Engagement" cluster, as appears clearly in the 2005–2015 period), and the smallest cluster, "Climate News" (21 documents).
- ***2005–2015:*** We found five clusters. "Engagement" (52 documents), like the analogous cluster in *PUSJ,* is related with nanotechnology issues, but in the case of SCICOM the keyword "democracy" is not present. The next cluster is "New Tech Attitudes" (49 articles), followed by "Planned Behaviour" (48 documents), "News" (36 documents) and "Climate News" (35 documents).
- ***2010–2019:*** We found six clusters. "Engagement" (68 documents) is first, again without the *PUSJ* keyword "democracy." Next is "Climate News Polarization" (40 documents), which contains texts that analyze climate information, but from a slightly different or more specific perspective, endeavoring to account for the polarization of public opinion and explain its causes and dynamics. The next cluster is "New Tech Attitudes" (36 documents), followed by "Bio News" (35 documents), "Climate News" (28 articles) and "Planned Behaviour" (26 documents).

The joint analysis shows that some clusters are repeated, others are exclusive to each journal, and some appear in both journals, but with differences. Let us look at the most important cases.

"Organizations" and "Authorship" only appear in *SCICOM.* They belong to the same reference core, because in the joint analysis these texts appear in a single cluster. In fact, neither cluster ever appears without the other in any given period. The topic of the "Authorship" is also about the disclosure of knowledge, but more specifically in the scientific publishing market. "Climate News Polarization" is a SCICOM cluster about the polarization of society over climate news.

"Organizations" cluster is knowledge transfer and how S&T organizations use knowledge.

As stated above, "Planned Behaviour" is about how people behave with new and sensitive scientific information, with an emphasis on risk-related topics.

Some subjects that are not among the main points of interest in the early years of *SCICOM*, such as "Climate News," "Engagement" and "New Tech Attitudes," acquire greater prominence in the last 10 years. These areas grow at the expense of "News," which is historically predominant in the journal, though more strongly in the earlier decades. "Authorship" follows a similar pattern, prevailing from the 1990s until the mid-2000s. "Organizations," one of the subjects broached exclusively by *SCICOM,* exists throughout the period, although in the earlier years the topics discussed focus more on health.

When texts are analyzed by periods, no distinct cluster emerges for "Stereotypes," because the small number of texts and the topic's thematic proximity to other clusters (since stereotypes are generally analyzed in the media) cause it to disappear.

"Representations" is an exclusive though ephemeral cluster that appears in *PUSJ* in the mid-90s. "Scientists," about scientist outreach activities, is also exclusive to *PUSJ.* It appears at the end of the period.

The most prevalent subject in *PUSJ* is "Engagement," which is significantly present after 2000 and even more clearly in evidence after 2005. This cluster is originally related with biotechnological issues, yet with time it incorporates nanotechnology issues as its main topics, with a more democratic criticism of the way science is communicated. Issues related to "Literacy" are addressed more or less uniformly across the entire period; i.e. their relative presence in each subperiod is close to the mean. Subjects associated with "Climate News" and "Bio News," likewise present throughout, are observed to grow in prominence over time.

4. Discussion

We return to the research questions asked at the beginning of the paper.

4.1. Is there evidence to support Bauer (2009) periodization? Or, in the terms of Suerdem et al. (2013), has the field evolved from a perspective associated with the definition of "public understanding" to a discussion of "public engagement"?

The evidence shows that there have been major shifts in PUS topics that match Bauers' description very well, though we can add further information for an even better description. For example, while "Literacy" is the main characteristic of the first period identified by Bauer, the evidence shows that this topic is very much present throughout the entire period in *PUSJ* but remains only until the mid-2000s in *SCICOM.* This too agrees with Bauer's description: Periods are not strictly defined, but rather they overlap. It is not only the presence of a topic that is important, but also its increase. "Literacy" has an overall production increase of over 10% in *PUSJ* in the latest period. When we look more closely at the topics within the "Literacy" clusters, we find that the discussion shifts slowly from “Literacy” to “Attitudes.” In earlier periods these two clusters form a single cluster, while in the latest periods they split into separate clusters: “Literacy” and “New Tech Attitudes.” “Literacy” is more closely associated with measuring scientific culture in laypeople, while “New Tech Attitudes” has more to do with measuring risk. In fact, if we think of them as sister clusters, the whole topic of measuring knowledge and attitudes becomes the main topic of the field, competing for first place with “Engagement.”

In both journals the “Engagement” period, characterized by the “science-in-and-for-society” concept, begins in the early 90s, and its relative increase surpasses the increase in publications. But the question here is whether these “Science-in-and-for-Society” clusters remain homogeneous throughout the thirty-year span. The answer is no. In earlier periods “Engagement” means the analysis of activities very closely confined to specific topics, particularly biotechnology and genetics, and gradually including nanotechnology; in the later periods, the discussion shifts to more general processes of public participation in the democratic dynamics of science communication.

In that sense, it would be interesting to add a new period more clearly featuring the process of the democratization of science communication and also criticizing the entire process of knowledge construction and use. In this new period, a new topic could be proposed, one which was present in earlier periods but gained in emphasis in the run-up to 2010: the role scientists play in science communication. Scientists are present in two kinds of clusters. Some are associated with democratization processes, but there is also the specific cluster that we have labeled “Scientists,” which is related with the analysis of scientists’ representations and scientists’ activity to communicate science, usually through a negative view. This is a very important shift that argues against Bauer’s idea of “angels” as mediators between the public and academia. It could form the grounds for another survey to measure the impact of all science communication programs started in the last decade. Finally, another main characteristic of the new, later period is an increase in the countries that can produce and become involved in the discussion about PUS. While the increase is a natural outcome of the general process of the internationalization of science, it is a notable feature of the last period (Figure 8).

Yet, what are the consequences of the coexistence of “Literacy,” “Attitudes” and “Engagement”? It may be better to think of PUS more as musicians tuning up before a concert, where each musician concentrates on his/her own sound, rather than as an orchestra, where all the musicians play together. “Literacy” strategies can adapt to and be implemented in several contexts, while “Engagement” activities may include some moments associated to “Literacy.”

4.2. Which topics are of most interest, and how do they relate to one another (Smallman 2014)? Are there any new topics not reported in previous studies based on PUSJ?

Bauer and Howard (2013) analyzed the itinerary of *PUSJ* based on the articles it publishes, and they divided its history into two periods, 1992–2001 and 2001–2010. The authors classified articles into “themes” and “topics and sciences,” deploying a methodology developed by Suerdem et al. (2013) to conduct a lexicographic analysis of 465 *PUSJ* abstracts. Based on the co-occurrence of words, they identified a series of topics that defined the core interest of the papers published in the journal over two decades.

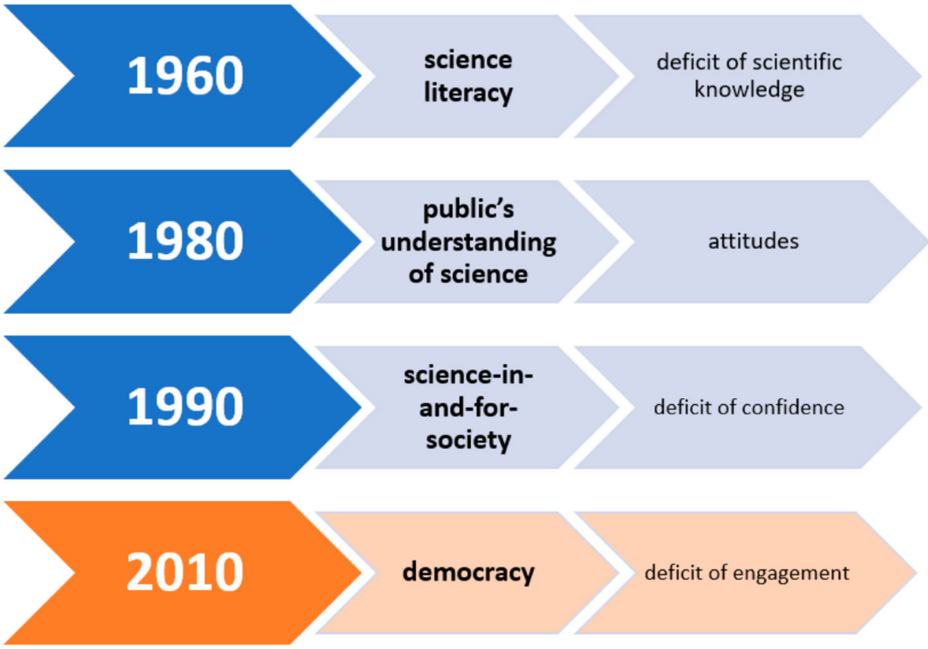

Figure 8. Periodization of the field of the public understanding of science.

Strikingly, these authors also organized the data essentially around seven topics. Some concurred with, or could be likened to, the subjects identified here, such as "public engagement" or "public perception," whereas others were exclusive to each analysis. They observed environmental issues to be stable with a slight decline in the more recent periods. In our study stability lasts approximately through 2005, after which environmental issues receive fresh impetus, emerging as one of the subject areas most frequently addressed in *PUSJ* and the one most frequently discussed in *SCICOM*. Interest in these matters is not confined to the journals we analyzed but can be found in any number of fields of knowledge. A review of the papers and journals listed in the Web of Science showed that these topics have grown exponentially after 2005. Indeed, the 2015 edition of Journal Citation Reports includes a new subject category denominated "Green and Sustainable Science and Technology," covering journals dealing with climate change, renewable energies, green nanotechnology and the environment, which together account for 80% of the output after 2010 (Clarivate Analytics 2021).

We can see the impressive rise of "Engagement" as a main topic, followed by "Climate News," and the continuous importance of "Literacy." New topics coalesce: "Scientists," containing thematic clusters related to the analysis of scientists' involvement in science communication activities, and "Planned Behaviour," analyzing people's feelings about sensitive scientific information. The same could be said for "Organizations" and "Authorship," both of which faded out of PUS around 2000 but are very important in social studies of science nowadays.

4.3. Have case studies come to dominate the field?

This is a very tricky question. A mere case study is one thing, whereas the use of cases to exemplify or generalize processes is something quite different. Our data do not allow us to confirm one or the other, but we are willing to support the latter. We see cases misused on a daily basis in our work, but in this particular analysis the theoretical growth of the field is deeply indebted to all the cases we read.

4.4. Has the discussion of different aspects of PUS become more international over time?

In the first decade (1990–2000), we find some European countries along with Canada, the United States and Australia. In the next decade we see the rise of China, South Africa and South Korea, along with India, Brazil and Argentina, and in the last decade, articles from a greater number of European countries (Belgium, Greece), Nordic countries (Norway, Finland), Asian countries (Singapore) and Latin American countries (Mexico). Clearly, this is an indicator of the spread of PUS issues around the world, and yet, when we weigh the number of papers from each country with both the total science publications from each country and the total publications in each journal, we find nothing actually surprising. Internationalization follows the same general dynamics in PUS as in all scientific fields. A close look at the data shows that throughout the period the UK and India published less on PUS than they did on average in all disciplines.

4.5. Is there evidence that the language shift that Suerdem et al. (2013) identified reflects a conceptual change, or is it simply a change in terminology? Is there a "conceptual consolidation" of the field? (Smallman 2014)

Although we consider that the analysis of these journals affords a very good representation of the interests of the field and its evolution, we do not believe that our methodology can answer this question clearly. However, we see a convergence of topics between the two journals, a network of shared references and a consolidation of groups throughout the period. In our opinion, all these results are indicators of field consolidation.

5. Final words

SCICOM and *PUSJ*, the journals selected for analysis, are indisputable benchmarks in the field, as revealed by earlier studies on the number of citations, impact and their relationships with other social sciences, and especially science communication journals (Leydesdorff and Probst 2009; Bauer and Howard 2013). Although Bauer and Howard (2013) acknowledged *SCICOM* and *Science, Technology & Human Values* to be direct competitors, the latter is not included here, for it widely out-ranges the field of PUS and would introduce too much noise in our data corpus.

Analyzing the metadata in papers by using bibliographic coupling affords a number of advantages relative to tools deployed in other scientific fields or disciplines (Arora et al. 2013), research subjects or journals (Suerdem et al. 2013). In particular, it precludes the often-uncritical adoption of database categories (WoS categories in this instance). Database classifications stem from criteria that are not wholly explicit and are structured around the journal as the unit of analysis. The present methodology, in contrast, can be used to descend to the paper level, affording a subject classification more in keeping with field research (Rafols and Leydesdorff 2010; Levin, Jensen, and Kreimer 2016).

Our study finds that "Literacy" is a persistent cluster and that the "Engagement" and "Scientists" clusters have grown in importance. Moreover, a new or more refined hypothesis could be proposed to discuss the "science-in-and-for-society" hypothesis: Current studies on the communication of science reveal a closer relationship between academia and the general public in a somewhat larger group of countries than in previous decades, but the group of countries still remains very small within the general context. Nevertheless, the nature of these close relationships continues to focus on science literacy, with an accent on climate and health issues and the analysis of the role that scientists play or could play in this process. We have traced the rise and fall of a small cluster that we have called "Authorship" and also "Organizations," a topic that boasts few papers despite its importance and the fact that it is closely related to the way science spreads. Together, all these data reveal science communication dynamics that leave out many controversial issues raised by less visible stakeholders, such as the role of science assessment in the development of R&D that can be better aligned with regional and local issues. This conclusion aligns well with the wider dynamic that has long characterized science in peripheral countries, associated with utility problems and local agendas.

Acknowledgements

We gratefully acknowledge the valuable contributions of a number of experts in the area, in particular Dr Carina Cortassa (Centro REDES, Universidad de Entre Ríos), who helped build and validate the labels.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was conducted under the project entitled "Detection of new research and innovation fronts. Analysis of knowledge flows in the scientific domain, industry and society" [ref.: CSO2014-51916-C2-1-R], funded by Carlos III University of Madrid Department of Library and Information Sciences. This study was also carried out with funds provided by the Ministry of Science and Innovation Rámon y Cajal call [RYC2018-024894-I].

Notes on contributors

Luciano G. Levin is a researcher at the University of Río Negro and CONICET. (Argentina) where he leads the postgraduate degree in STS. He works in sociology of science in particular analyzing the way in which scientific knowledge is produced and used.

Daniela De Filippo is a researcher at the INAECU Institute (www.inaecu.com). Her activity includes the design and application of methodologies for the study of the scientific activity of institutions, disciplines, journals and researchers. She is involved in the development of the IUNE Observatory for monitoring the research activity of Spanish universities (www.iune.es).

ORCID

Luciano Levin http://orcid.org/0000-0001-7209-805X
Daniela De Filippo http://orcid.org/0000-0001-9297-9970

References

Arora, S., A. Porter, J. Youtie, and P. Shapira. 2013. "Capturing New Developments in an Emerging Technology: An Updated Search Strategy for Identifying Nanotechnology Research Outputs." *Scientometrics* 95: 351–370. doi:10.1007/s11192-012-0903-6.

Bauer, M. W. 2009. "The Evolution of Public Understanding of Science – Discourse and Comparative Evidence." *Science, Technology and Society* 14 (2): 221–240.

Bauer, M. W., N. Allum, and S. Miller. 2007. "What Can We Learn from 25 Years of PUS Survey Research? Liberating and Expanding the Agenda." *Public Understanding of Science* 16 (1): 79–95. doi:10.1177/0963662506071287.

Bauer, M. W., and S. Howard. 2012. "Public Understanding of Science – a Peer-Review Journal for Turbulent Times." *Public Understanding of Science* 21 (3): 258–267. doi:10.1177/0963662512443407.

Bauer, M. W., and S. Howard. 2013. *Public Understanding of Science: Compiled Bibliography, 1992–2011*. London: Sage. https://journals.sagepub.com/pb-assets/cmscontent/pus/pus_book_v6_AG-1471428484300.pdf.

Bauer, M., and I. Schoon. 1993. "Public Understanding of Science Mapping Variety in Public Understanding of Science." *Public Understanding of Science* 2 (2): 141–155. doi:10.1088/0963-6625/2/2/004.

Blondel, V., J. -L. Guillaume, R. Lambiotte, and E. Lefebvre. 2008. "Fast Unfolding of Communities in Large Networks." *Journal of Statistical Mechanics: Theory and Experiment* [Internet]. 2008 (10): P10008. http://stacks.iop.org/1742-5468/2008/i=10/a=P10008.

Bowen, J. P., and A. Borda. 2009. "Communicating the Public Understanding of Science: The Royal Society Website." *International Journal of Technology Management* 46 (1–2): 146–164. doi:10.1504/IJTM.2009.022682.

Bucchi, M., and B. Saracino. 2016. "'Visual Science Literacy': Images and Public Understanding of Science in the Digital Age." *Science Communication* 38 (6): 812–819. doi:10.1177/1075547016677833.

Clarivate Analytics. 2019. *Journal Citation Report*.

Clarivate Analytics. 2021. *Web of Science. Categorias de Web of Science: notas de alcance*.

Conrad, P. 1999. "Uses of Expertise: Sources, Quotes, and Voice in the Reporting of Genetics in the News." *Public Understanding of Science* 8 (4): 285–302. doi:10.1088/0963-6625/8/4/302.

Davies, S. R. 2008. "Constructing Communication: Talking to Scientists About Talking to the Public." *Science Communication* 29 (4): 413–434. doi:10.1177/1075547008316222.

Entman, R. 1993. "Framing: Toward Clarification of a Fractured Paradigm." *Journal of Communication* 43 (4): 51–58. doi:10.1111/j.1460-2466.1993.tb01304.x.

Gómez, I., and M. Bordons. 1996. "Limitaciones en el uso de los indicadores bibliométricos para la evaluación científica." *Política Científica* 46: 21–26.

Grauwin, S., W. Beslon, E. Fleury, S. Franceschelli, C. Robardet, J. B. Rouquier, and P. Jensen. 2012. "Complex Systems Science: Dreams of Universality, Interdisciplinarity Reality." *Journal of the American Society for Information Science and Technology* 63 (7): 1327–1338. doi:10.1002/asi.22644.

Grauwin, S., and P. Jensen. 2011. "Mapping Scientific Institutions." *Scientometrics* 89 (3): 943–954. doi:10.1007/s11192-011-0482-y.

Irwin, A., and B. Wynne. 1996. *Misunderstanding Science? The Public Reconstruction of Science and Technology*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511563737.

Jensen, P. 2011. "A Statistical Picture of Popularization Activities and Their Evolutions in France." *Public Understanding of Science* 20 (1): 26–36. doi:10.1177/0963662510383632.

Kessler, M. M. 1963. "Bibliographic Coupling Between Scientific Papers." *American Documentation* 14 (1): 10–25. doi:10.1002/asi.5090140103.

Levin, L., P. Jensen, and P. Kreimer. 2016. "Does Size Matter? The Multipolar International Landscape of Nanoscience." *PLoS ONE* 11 (12): e0166914. doi:10.1371/journal.pone.0166914.

Leydesdorff, L., and C. Probst. 2009. "The Delineation of an Interdisciplinary Specialty in Terms of a Journal Set: The Case of Communication Studies." *Journal of the American Society for Information Science and Technology* 60 (8): 1709–1718. doi:10.1002/asi.21052.

McNeil, M. 2013. "Between a Rock and a Hard Place: The Deficit Model, the Diffusion Model and Publics in STS." *Science as Culture* 22 (4): 589–608. doi:10.1080/14636778.2013.764068

Nelkin, D. 1995. *Selling Science: How the Press Covers Science and Technology*. New York: Freeman, ISBN: 9780716725954.

Poliakoff, E., and T. L. Webb. 2007. "What Factors Predict Scientists' Intentions to Participate in Public Engagement of Science Activities?" *Science Communication* 29 (2): 242–263. doi:10.1177/1075547007308009.

Rafols, I., and L. Leydesdorff. 2010. "Science Overlay Maps: A New Tool for Research Policy and Library Management." *Journal of the American Society for Information Science and Technology* 61 (9): 1871–1887. doi:10.1002/asi.21368.

Roland, M. C. 2007. "The Changing Paradigm of Science Communication: Challenges for Researchers from a "Deficit{"} Model to a "Democratic{"} Model." In *Communicating European Research 2005*, edited by M. Claessens, 65–69. Dordrecht: SPRINGER.

Smallman, M. 2014. "Public Understanding of Science in Turbulent Times III: Deficit to Dialogue, Champions to Critics." *Public Understanding of Science* 25 (2): 186–197. doi:10.1177/0963662514549141.

Suerdem, A., M. Bauer, S. Howard, and L. Ruby. 2013. "PUS in Turbulent Times II – a Shifting Vocabulary That Brokers Inter-Disciplinary Knowledge." *Public Understanding of Science* 22 (1): 2–15. doi:10.1177/0963662512471911.

Villarroel, P., V. H. Valenzuela, G. Vergara, and C. Sepulveda. 2013. "Public Understanding of Science in Chile: Adaption of Instruments and Measurements." *Convergencia* 20 (63): 13–40.