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Indifferent, Dogmatic or Pragmatic: A Multi-Country Analysis of How Scientists View the Public and Public Engagement

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Abstract

How do scientists view the public and think about public engagement? In this article, we analyze interview data from 205 scientists in the fields of biology and physics from four countries — India, Italy, UK, and the USA — to show that scientists do not perceive the public as a monolithic entity. Three distinct kinds of publics were described by scientists, which we analytically characterize as "indifferent", "dogmatic", and "pragmatic", and discuss in relation to major trends in extant literature. Our analysis showed that the respondents in our sample represented advanced and nuanced understandings of the public. Even though the deficit model still persists, and the preferred mode of public engagement remains science education and mostly (one-way) science communication, the purpose and focus of education and communication differ according to scientists' orientations. We also identify discipline- and country-specific variations that warrant further investigation.

Keywords: Sociology of science; public understanding of science; social trust; imagined public; public engagement in science.

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1 Imagined Publics and Public Engagement in the Field of Public Understanding of Science (PUS)

The domain of the debates around science—society relationships, the domain of Public Understanding of Science (PUS) is almost three decades old (Coates, 2022; Scheufele, 2022). Institutionalized through multiple agencies (e.g., British Science Council), academic journals (e.g., *Science Communication* and *Public Understanding of Science*), government large-scale occasional surveys (e.g., Eurobarometer), and public engagement exercises (e.g., Indian public consultation on Bt Aubergine, NanoNL), the field has taken a central position in understanding and shaping science—society relationships worldwide (Bauer, 2009; Davies, 2013; Wynne, 2014). Building on pre-existing work in PUS, science communication, and sociological research (Horst, 2013), this essay investigates how physicists and biologists from four countries (US, UK, India, and Italy) imagine their public. In particular, we focus on the scientists' perception of the public and how they think about public engagement (Llorente et al., 2019).

Literature has conceptualized the science—society relationship through different theoretical models. For example, Callon (1999) developed a tripartite model that describes the possible ways in which non-specialists (the public) can participate in debates on science and technology. The three types are: (1) the public education model, (2) the public debate model, and (3) the co-production of knowledge model. Similarly, Michael (2002) classified PUS into three main academic/policy trends: (1) traditional PUS, (2) critical PUS, and (3) heterogeneous PUS. These models are based on their diverse conceptualizations of the role of scientists/science in society, understandings of the public, and the mode of public engagement with science.

Both the public education model and traditional PUS (Royal Society, 1986) assume that science/scientific knowledge is unbiased, fact-based, universal, and a superior form of knowledge. Science is considered pivotal to the betterment of the everyday life of people as well as the proper functioning of modern democratic systems (Irwin, 2014). For the public to be better citizens, an appropriate and adequate understanding of science is essential (Michael, 2002; Callon, 1999). Thus, traditional PUS is based on a deficit model (Millar & Wynne, 1988; Ziman, 1991) which imagines the public as a monolithic entity that is "ignorant", "emotional", "irrational", "indifferent", and deficient in "relevant" scientific knowledge (Blok et al., 2008; Burchell, 2007; Besley & Nisbet, 2011). The public's mistrust in science is attributed to lack of scientific education. The major focus of programs under these models is measuring and promoting scientific literacy among citizens through one-way communication (Bauer, 2009).

The public debate model and Critical PUS shifted attention from the "understanding" of science to the "engagement" with science (Hu, 2024; Burri, 2018). This trend contests the traditional one for creating imagined hierarchies between science and society, leading to increasing inequalities.[1] The critical tradition argued that scientific institutions and experts are themselves prejudiced and limited in their assumptions on the inferiority of other knowledge systems and the "ignorant/disinterested" public (Bauer et al., 2007; Callon, 1999). Mistrust in science derives more from the unpredictability of science, and its socially embedded nature and practice, rather than from the ignorance of the public (Miller, 2001). In this view, the affirmation of science as a superior form of knowledge is best understood if considered as part of an epistemic struggle, that is, as an effort by scientists "to distinguish their work and its products from non-scientific intellectual activities" (Gieryn, 1983 & 1999; see also Guston, 2001). Crit-

1. For example, Brian Wynne's path-defining 1992 study investigating the impacts of nuclear fallout in Cumbrian sheep farmers; see also Gustafson & Rice, 2016.

ical PUS and the public debate model assume therefore that all knowledge is context-specific and, therefore, scientific knowledge can only be useful for specific communities when it is contextualized and situated in the local context. What is relevant is therefore to understand the different meanings of science in different publics and for specific social groups (Gauchat, 2011; Michael, 2009; Bauer et al., 2000). As a consequence, science should dialogue with social, cultural and political actors as well as many other knowledge systems. It is only through locally established mechanisms of trust that scientific knowledge gets locally embedded and thus accepted in specific social contexts. The "public" in the dialogue model is not a deficient public; rather, by virtue of being entangled in local, social and cultural settings, it has its own ontologies and epistemologies through which it interprets scientific knowledge (Wynne, 2007; Jasanoff, 2005). In this context of diversity of expertise and complex mechanisms of establishing the validity of knowledge claims, science shifts from deficit to "dialogue" (Stilgoe & Wilsdon, 2009), entering a field marked by discussions, debates, contests, and negotiations (Law & Lin, 2017). Critical PUS argues for dialogue and participatory mechanisms for public engagement with science.

The co-production model and heterogeneous PUS has been gaining increasing recognition through Citizen Science. This approach is aimed at actively involving specific kinds of public in scientific efforts directed towards co-advancing knowledge that concerns them (Bonney et al., 2016). This trend departs from previous ones because it does not postulate a one-way (Traditional PUS/Public education) or a two-way (Critical PUS/Public dialogue) flow of communication between science and society, but is rather based on a model of co-production of knowledge (Callon, 1999). This involves an upstream engagement of people (Stilgoe & Wilsdon, 2009), who participate in scientific research in the form of data collection, analysis, and dissemination of results (Hu, 2024; Cohn, 2008; Silvertown, 2009).

Types/trends — constructed as ideal types — are not to be considered as displacing one another over time, but rather as co-existing. Literature signals how they vary in their adoption depending on disciplinary differences and on the type of knowledge produced, where the need for democratization of science is less or strongly felt (Dickinson et al., 2010; Burri, 2018; del Savio et al., 2016; Lewenstein, 2016).

Within existing literature, most studies are devoted to understanding the public's view of science, while few focus on scientists' view of the public (Bauer & Jensen, 2011; Poliakoff & Webb, 2007; Burri, 2018) and how this may impact the public understanding of, and engagement with, science. Because of this, some debates remain unsettled. In particular, research shows mixed results about the attitudes of scientists towards the public, their role in policymaking, and the influence of the media on public opinion. In terms of the persisting prevalence of the deficit model, Besley and Nisbet's (2011) analysis of two large-scale surveys conducted in the UK and USA suggests that the dominant understanding among scientists about the public is still that of "ignorant/indifferent" individuals. Dietram et al. (2017) confirmed the findings of the above study, that the main motivation for scientists to participate in public engagement is to provide scientific information to the "ignorant/lay/deficient/indifferent" public. While other studies confirm that the deficit model is still the most preferred model of science—society interaction (Schmid-Petri & Burger; 2019; Simis et al., 2016), Kessler et al. (2022), in their recent large-scale survey, observed that the notion of deficit in lay people has been changing, just as it has been abandoned as the preferred model in public engagement (Burri, 2018; Koizumi & Yamashita, 2021; Stilgoe et al., 2014). In addition, there is little research on how these different models of science—society engagement appear in practice. Are these models and their corresponding elements, such as different public perceptions and modes of engagement, evenly distributed in the way scientists actually think, or do they appear in combinations not entirely corresponding to the models? This aspect calls for further investigation.

The present article contributes to this debate by suggesting, through empirical evidence, that although the deficit model is still the most widely adopted by scientists, they in fact attribute different meanings to it, depending on nuanced views of the public and about the role of one-way communication.

Besley and Nisbet (2011) also highlighted the limitations of survey methods for generating a nuanced understanding of how different publics are imagined and co-produced during science—society interaction. They show how survey methods based on the "deficit model" prevent an understanding of the processes through which values and meanings are ascribed to science, society, public, politics, and media (Davies, 2022). The limitations of survey methods in understanding trust as both an individual and a socially shaped attitude have also been highlighted by a few recent sociological studies (Eyal et al., 2024; Möllering, 2024). Scholars have argued that trust must be studied through the actions and practices of actors (Eyal et al., 2024; Möllering, 2024). In PUS literature, the two dominant ways of understanding trust are surveys (individual attitude and rationale) and mechanisms of public engagement (actions to build trust) (Davies, 2022; Besley & Nisbet, 2011; Wynne, 2006; Law, 2009). Yet, studies on scientists' perceptions of the issue of public trust are limited. Even though Kessler et al. (2022) found that scientists' approaches toward public engagement are based on mental models shaped by individual experiences and knowledge, neither their study nor similar ones specifically discuss how scientists perceive their publics, what they think about public trust in science and scientists, or the impacts of these perceptions on science—society engagement.

Our study engages with geographical and disciplinary diversity in science to provide insights into how scientists imagine their public (cf. Maranta et al., 2003) and how these imaginations influence the perception of science—society relations (see Besley et al., 2018; Landström et al., 2015; Koizumi & Yamashita, 2021), thus contributing to PUS literature on this topic.

2 Data and Methods

Data for this study are derived from a larger project in which quantitative surveys and qualitative in-depth interviews were conducted with scientists (Mauceri, 2016). While the present study is based on the analysis of qualitative data derived from the in-depth interviews, for the sake of clarity the complete research design is briefly sketched. Online surveys were rolled out to 22,840 physicists and biologists at 233 universities and research institutes in four countries (India, Italy, the UK, and the US) between May–September 2021. Ultimately a total of 3,442 completed surveys were collected (AAPOR Response Rate of 15.2%). Along with the surveys, the project team conducted a total of 205 interviews with scientists in physics and biology departments in the four countries between July–December 2021. Most of these interviewees were recruited from survey respondents who gave permission to be contacted for an interview. An additional 24 were recruited via "snowball sampling" techniques — either from contacts of academic scientists interviewed for the study, or personal contacts from members of the project team. The 205 in-depth interviews conducted were carefully balanced across disciplines and countries, with an even representation by gender. We selected scientists primarily along six different career levels (Post-graduate Student, Postdoctoral Researcher, Research Scientist, Junior Faculty, Mid-level Faculty, Senior Faculty). Additionally, we aimed to interview approximately equal numbers of postgraduate students and postdoctoral fellows. We also strived for a balanced representation across junior, mid-level, and senior faculty positions. In terms of demographic composition, the majority of our respondents were Caucasian, while approximately one-quarter were of South Asian descent. Table 1 summarizes key demographics of the in-depth interview sample.

Table 1. Demographics of interview sample

Country (institutional affiliation)	**Frequency**
India	50
Italy	52
UK	51
USA	52
Discipline	
Biology	100
Physics	104
Other	1
Gender	
Female	96
Male	107
Other	2
Race/Ethnicity	
Black, African, Caribbean	2
Caucasian, White, European	136
Central Asian / Arab	1
East Asian	3
Hispanic or Latino/a	6
Middle Eastern	1
Multiracial	1
South Asian	55
Career Level	
Masters / Ph.D. student	51
Postdoctoral fellow	50
Junior Faculty	35
Mid-level Faculty	25
Research Scientist	13
Senior Faculty	30
Other	1
Total	205

The initial quantitative survey was aimed at examining well-being among scientists and did not include questions about public trust in science. However, considering the changing social contract of science (Funtowicz & Ravetz, 2018; Guston, 2000), we included questions during the follow-up in-depth interviews to examine scientists' views on (a) the public, (b) the public's understanding of and trust in science and scientists, and (c) what would help improve public trust in science. As is well known, during in-depth interviews (Bryman & Burgess, 1994), it is common for a particular theme to surface not necessarily as a direct response to a specific question, but at any point throughout the conversation (Deterding & Waters, 2021; Savin-Baden &

Major, 2013; Sbalchiero & Tuzzi, 2017; Strauss & Corbin, 1990). This phenomenon is particularly notable when respondents introduce topics that were initially scheduled for discussion later in the interview. The spontaneity of these thematic introductions highlights the dynamic nature of in-depth interviews, emphasizing the need for flexibility in addressing subjects as they naturally unfold. To discern how scientists perceive and imagine the public and public engagement with science, it was necessary to identify the portions of text that addressed our specific subject of interest and contained a thematic list of keywords (Neuendorf, 2016). For these reasons, we arranged a two-step analysis. The first step focused on analyzing the interviews using Reinert's topic detection method (1983). As will be illustrated subsequently, this application led to the identification of three distinct orientations within our corpus. The second step complemented the automated analysis with an interpretive, qualitative analysis of the reworked corpus (Silverman, 2006), allowing us to interpret narrative accounts of scientists within each orientation in light of the theoretical debates discussed in the previous section. Since all the authors participated in conducting interviews, a back-and-forth between our field diaries, interview data, and content analysis enabled us to navigate the extensive qualitative data gathered during this study.

Reinert's method (1983 & 1993) — implemented in the R-based version of Iramuteq (Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires) (Ratinaud, 2014; Ratinaud & Marchand, 2015) — is based on the automatic classification of portions of text that contain certain words in order to identify topics by considering the semantic contexts of words that co-occur in the same portions of text. As the topics are composed of "words", the quotations that contain them provide a lens through which we can identify and understand the meaning of these "words in context" wherever they appear. This approach allows for a nuanced exploration of how specific words are employed in different situations, contributing to a more comprehensive understanding of their contextual significance. A keyword search helped to identify relevant portions of the text. To this end, a frequency vocabulary of the interview corpus was constructed, and words were selected based on their relevance to the research focus. This resulted in the following list of keywords: "perception", "view of science", "people understand", "perception of science", "public thinks", "population", "public opinion", "public trust", "communication", "mistrust", "distrust", "trust science", "communicating science", and "public engagement". This selection enabled us to focus on portions of text containing relevant content for the purposes of the analysis and to build a thematic corpus related to the research objective. The final corpus was composed of 1,516 portions of text (Table 2), and the lexicometric measures clearly indicate that a statistical analysis of textual data is plausible for these corpora, considering that the ratio between hapax (words that appear only once in a corpus) and type (different words) is less than 50% (48.8%), and the TTR (Type-Token Ratio) between type and tokens (total occurrences) is less than 20% (7.4%) (Lebart et al., 1998).

Table 2. Lexicometric characteristics of the analyzed corpus

	Corpus
Number of texts	1516 portions of text
(N) word-tokens	68726
(V) word-type	5074
(V1) hapax	2477
(V/N)*100 = Type/Token Ratio	7.4%
(V1/V)*100 = Percentage of hapax	48.8%

The pre-processing phase involved normalization (which consisted of replacing uppercase with lowercase letters, and removing punctuation, numbers, and stop words, as they are not significant in terms of content), lemmatization (by grouping together inflected forms of words), and the identification of relevant multi-words expressions, i.e., informative sequences of words repeated at least three times in the corpus (for example, "public trust", "public opinion"). The pre-processing phase focused on increasing the amount of information conveyed by sequences of words, and it helped to reduce redundancy and provide homogeneity among words through lemmatization (Sbalchiero, 2018). The outcome of the classification is a set of topics, i.e., semantic classes, that group together words relevant for interpreting each class, thereby enabling the identification of three major semantic areas, which we interpreted as orientations. Finally, we assessed the degree of association between these classes and the modalities of other variables, namely country and scientific discipline.

3 Results

3.1 Scientists' Views of the Public and Public Engagement in Science: Distinct Orientations

Results reflect a multiplicity of themes and semantic contexts (fig. 1), including the issue of information, communication, and trust in science (see the word "trust" above the center of the graph and the other associated words nearby). Words such as "controversial", "problem", and "misunderstand" point to contingent factors that, for scientists, affect the public's view of science. Similarly, words such as "skepticism", "negative", "misinformation", "polarize" positions, and "conspiracy" refer to negative factors generating distrust in science. The role of the pandemic (bottom right of the center of the graph, close to "influence" and "impact") is especially connected to "uncertainty", "suspicion", and "doubt".[2]

In the next paragraphs, the three semantic areas will be presented, showing significant correlations with variables such as country and scientific discipline, and will then be interpreted through the lens of PUS literature.

In the Correspondence Analysis (CA) graph (Greenacre, 2007; Lebart et al., 1984; Murtagh, 2005), each semantic area points to a distinct orientation of scientists towards the imagined public. Orientation 1 is characterized by the keywords "trust in science", "public opinion" and "understand science". Orientation 2 revolves around keywords such as "ambivalences", "doubt", "confusion", "confidence", and "hopes", all based on the "experience" of the public with science. Orientation 3 refers to "public perception" and the role of "communication". To compare and contrast the presence of each orientation for the different variables available, we can observe the association, in terms of general prevalence, expressed by the modalities of the variables: if an orientation tends to be more present in the texts of some groups of scientists, then it means that these scientists have used the words characterizing that orientation (fig.2).

2. While individual words can take on different meanings depending on the context, our analysis does not rely solely on isolated words. Instead, we examine them within broader thematic areas. Specifically, the words we discuss are correlated because they frequently co-occur in the same sections of text. This co-occurrence reveals semantic contexts that inform our interpretation. For example, the word "problem" consistently appears in discourses referencing contingent factors that shape the public's perception of science. These semantic associations enable us to attribute the word to a particular orientation, reflecting broader textual and thematic dynamics rather than its standalone meaning.

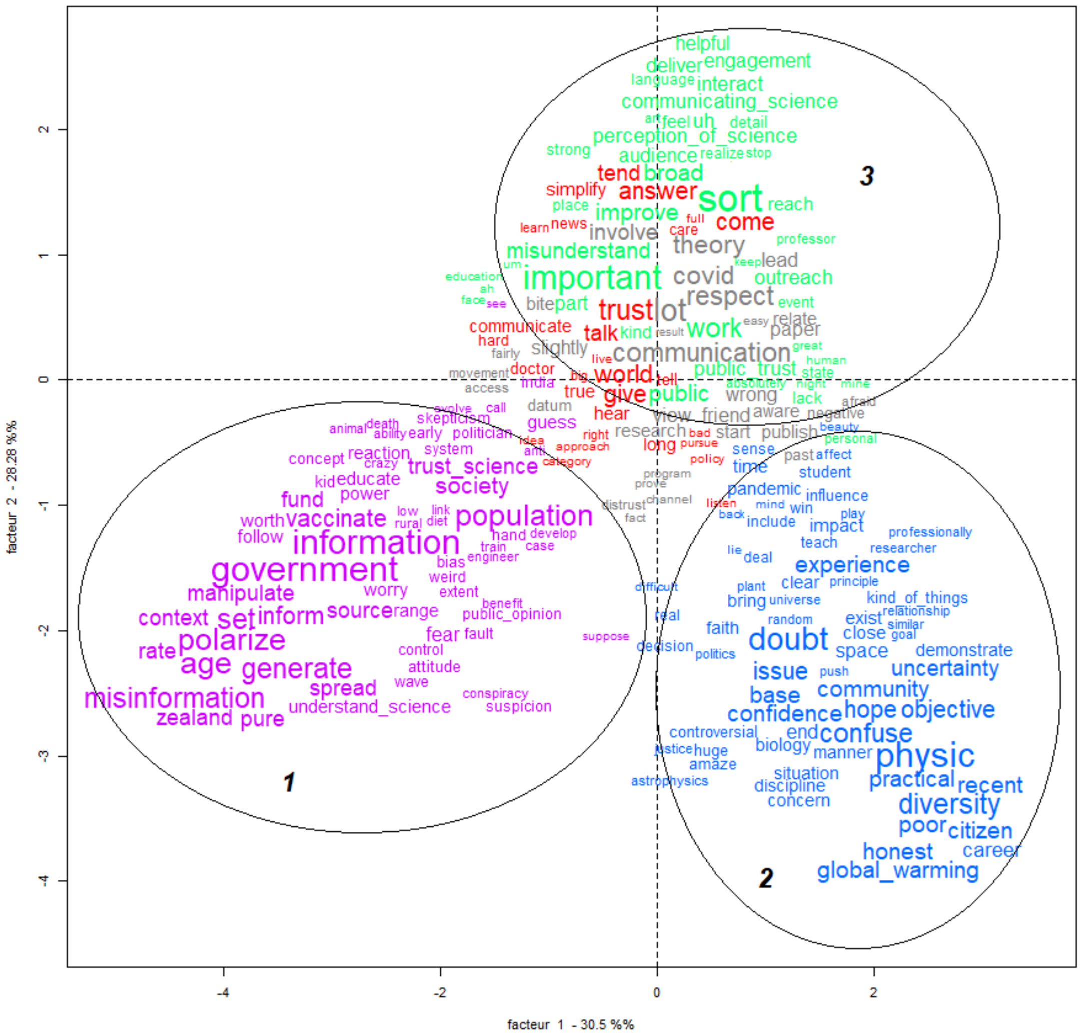

Figure 1. Sub-corpus. Principal Factorial Plan (CA), Topics and Words (size of the words is related to the contributions of χ^2 of words x topics)

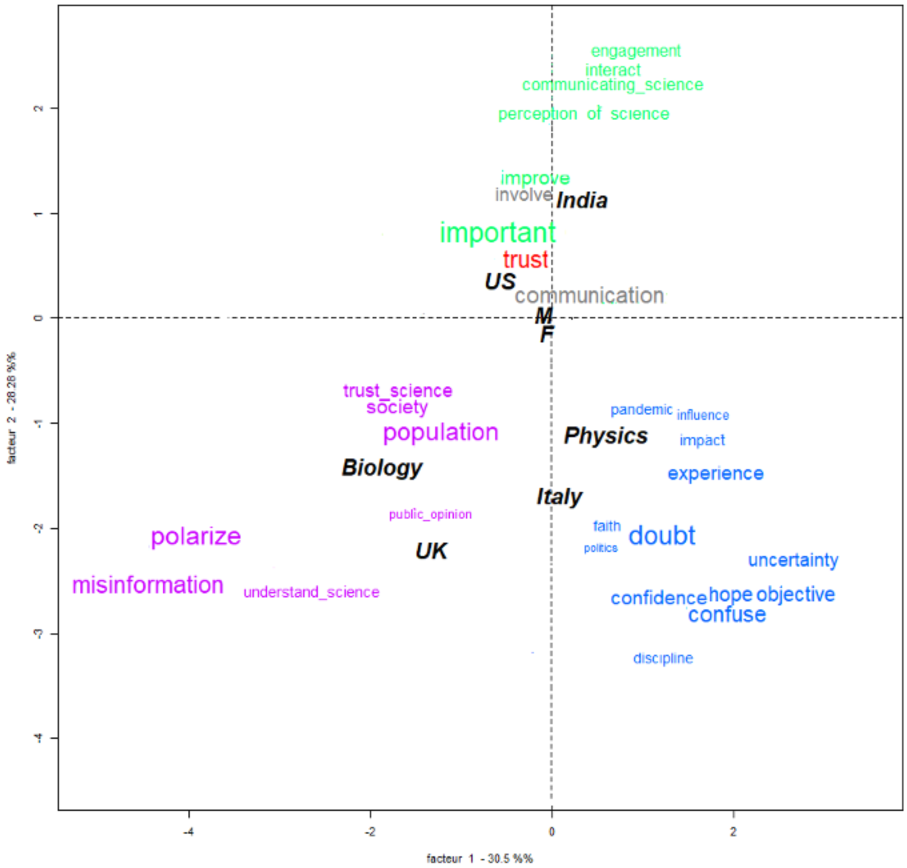

Figure 2. Sub-corpus. Principal Factorial Plan (CA), Topics and Variables (Gender, Country, Discipline)

Orientation 1 (purple, bottom left) is characterized by a consideration of the public as mostly skeptical, holding to their beliefs firmly even though they are formed mostly through external factors such as politics, religion, and the media. In this view, the formation of public trust undergoes a process of polarization: among the most significant words, we find, in fact, "polarize", "government", "misinformation", "trust science", and "public opinion". The main causes of this "dogmatism" are attributed not directly to scientists but to other factors (e.g., misinformation, the role of media, lack of education). That means that the public does not always trust science and scientists because of other social factors that lead to polarization, information manipulation, and conspiracy. While there is no gender-based orientation, Orientation 1 is more likely to be present among biologists and, by comparing countries, among European and UK scientists.

Orientation 2 (blue, bottom right) is not associated with a particular country, tends to prevail among physicists, and is characterized by a consideration of the public that takes a position toward science and scientists based on their experiences. In this case, they underline that "uncertainty", "confidence", and "doubt" are not based on negative or positive preconceptions about science and scientific knowledge, but are based on the experiences the public might have with science. The main cause of "uncertainty" or "confidence" is not attributed to external factors, but to the concrete experiences of people with science.

Orientation 3 (green, top center) is not associated with a particular discipline, tends to concern non-European contexts, with a slight prevalence in India, and is characterized by a vague conception of the public. These scientists don't always have a clear idea of what the public thinks about them and about science; they say they don't know if the public is interested in science at all. So, if in some ways they are undecided about how the public perceives them and science — whether in a positive or negative sense — for these scientists, the communication of science can be crucial in shaping the perception of science: they are convinced that communication plays a central role in the public's perception of science as an instrument to build social trust in science.

3.2 Scientists' Perceptions of the Public: "Indifferent", "Dogmatic", and "Pragmatic" Publics

By jointly analyzing what was previously discussed, we can describe the different orientations that, with a classificatory effort, correspond to ideal-types (in the Weberian sense) and can be interpreted as follows. We characterized "Orientation 3" as an "indifferent" public because, here, scientists believe that the public is uninterested in scientific knowledge (good or bad) altogether. We define "Orientation 1" as a "dogmatic" public because, here, scientists associate the public's view of science with (external and internal) factors that lead to strong opinions and positions about scientific knowledge and innovations. We categorize "Orientation 2" as "pragmatic" because — whether it is characterized in terms of ambivalence, doubt, confusion, confidence, positive attitude, or hopes — scientists imagine that the public forms its view of science based on their own experiences.

"Indifferent" Public

The indifferent public squarely fits into the traditional model of PUS. Scientists think of the public as "ignorant/indifferent", arguing that it needs to know more about science in order to improve its positive perception of science. According to the scientists in our sample, knowing more about science would improve the quality of everyday life for the public and make it more appreciative and respectful of what scientists do, thus improving the public image of science and public support:

> "I don't think the public has respect for science. I don't think they understand how science is done. [...] the motivations of people who do it" (Biologist, Female, USA).

> "[The] public does not understand science. This is something that we must accept. They understand a simplified version of it, and this does not need to change. I am talking about people who would require a scientific input to make a decision, any decision. They do not need to understand the details. They just need to understand this is dangerous: Please, take your vaccines; and that is probably enough" (Physicist, Male, India).

"Dogmatic" Public

Scientists in this category view the public as having its own strong opinions on certain issues that differ from scientific positions. These opinions, according to the scientists, are shaped by factors that include socialization, political and religious influences, as well as the media. The role of mass media as a source of misinformation appeared repeatedly during our interviews.

> "We have got the same types of people [...] they're basically anti-vaccine, anti any kind of control measures [...] I suppose, my feeling is that these people spread what we call misinformation, these crazy ideas, conspiracy theories, that type of thing. I think they must have always been there in society, but I guess that social media is facilitating it" (Biologist, Male, UK).

> "People are starting to question [scientific advice] because of the availability of information with the internet and then it kind of went too far" (Physicist, Female, UK).

As per the scientists in this orientation, the public becomes dogmatic about their opinions as a result of two interconnected factors. First, the public is not deficient in information but rather lacks the "right" scientific information to make their decisions. Scientists defined "right" in terms of the sources of information, as well as the level of trust the public has in these sources. Second, in situations of uncertainty, people want information from a source that is consistent, approachable, and available for debate and discussion. People often associate science with unchangeable truths, and when scientific information changes (in cases of uncertainty) without proper engagement and discussion with the public, they turn to sources that are more consistent and approachable.

> "How could you expect the public when they're in the middle of a public health emergency to understand scientists, when one day they say wear masks, and one day they say them don't wear masks. They're saying things that are demonstrably not true" (Biologist, Male, UK).

The lack of "right" scientific information provided through approachable media makes them the subject of manipulation by politics and mass media, leading to polarization of views on contentious issues such as vaccines, nuclear energy, and GMOs.

> "You can produce all the great data in the world that you want, but it will be less influential to the people who watch those YouTube videos or Facebook posts than a David Icke type person saying something that the person wants to hear in an eloquent way" (Biologist, Male, Italy).

> "People have always had mad ideas, and we say, like, people are easily led if they got it from a man in the pub. They have sat in a pub and some guys [say something]; we have got this expression, like, 'You heard it from a man in the pub' " (Biologist, Male, UK).

"Pragmatic" Public

As per the scientists in this orientation, public understanding of science is shaped by individual experiences. Positive and negative encounters with specific scientific knowledge or advice, and with technological artifacts or applications (such as medicine, pesticides, etc.), shape people's perceptions and opinions of specific scientific artifacts, events, and issues. There is no indifference toward science due to a lack of connection, or rejection of science due to inconsistency. Rather, the public contextualizes and uses science according to their needs in a pragmatic way. This means that public trust in science is partial, conditional, and contingent on socio-cultural factors. For example, scientists argued that people will follow scientific advice (such as going to a doctor if they are sick), but, at the same time, they may also follow advice from other knowledge systems (such as home remedies or praying to God) to counter the uncertainties of scientific knowledge, especially when that knowledge directly affects their lives and beliefs.

> "People trust scientists who maybe work in technology, and don't trust scientists that, or don't necessarily trust scientists who are working in something that is controversial and maybe new. So, it's like people accept that scientists understand the ins and outs of the electronics of the television, for example. But when you bring in something like climate or vaccination, or any of the other slightly more controversial topics, suddenly science becomes this thing that is a bit more questioned by some groups in the public" (Biologist, Female, UK).

> "Most science that is done is still abstract, and how great you've discovered whatever, not going to change my life. But the closer it gets to someone's life, so that vaccines, there's understandably probably more of a hesitance to trust it" (Physicist, Male, USA).

Table 3. Scientists' understanding of the public and public engagement

Orientation	Indifferent Public	Dogmatic Public	Pragmatic Public
Challenge	Lack of access to any kind of scientific information	Access to scientific information polluted with misinformation and biased sources; lack of understanding of authentic sources.	Access to scientific information from authentic sources but lack of complete trust in scientific authority
What shapes public understanding of science	Disconnect/distance with science	External factors (media, religion, politics)	Personal experiences and localized knowledge
Remedy	Improved access to science, better communication	Improved access to and capacity in recognizing authentic sources of science	Dialogue, discussion, and involvement of public in decision-making
Role of science education in building trust	Provide scientific information to improve decision making	Prevent misunderstanding by appreciating the contextual and contingent nature of scientific knowledge	Empower the contributing citizen by building capacity for appreciating the scientific method beyond individual experiences
Country based orientation	India and USA	UK	-
Discipline based orientation	Biology and Physics	Biology	Physics

Orientation	Indifferent Public	Dogmatic Public	Pragmatic Public
Relation with academic trends	Primitive deficit model/Public education model, except the blame for deficit is attributed to scientists rather than the public. Public is a passive receiver of scientific knowledge	Advanced version of deficit model where the blame for deficit and lack of trust is put of the education system. The public is a passive receiver of scientific knowledge.	A combination of public dialogue and co-production model. The public is recognized as a contributor to scientific development in different forms.

3.3 The Problems and Solutions for Science-Society Engagement

Indifferent Public

Similar to traditional PUS and public deficit model, the scientists in this orientation believed that science is crucial for the shaping of our societies. As a result, an understanding of science among the public is very important to ensure their well-being.

> "I think scientists do a bad job of selling how beneficial science is to the general public [...] the public doesn't understand how much — the discoveries of science shapes the modern world today" (Biologist, Male, USA).

These scientists often attributed the lack of interest in science among the public to inadequate communication strategies between scientists and the public. Many believe that this public's lack of interest in science is an obvious issue and that the public should not be blamed for it. For these scientists, ensuring that science is understood and valued by the public is the responsibility of scientists.

> "I do not think this needs to change. What needs to change is scientists' presentation of the simplified version. If [the] public is not understanding science, I think at the end is the scientist's fault. I think [the] public is not meant to understand science" (Physicist, Male, India).

Many scientists associated with this orientation emphasized the need to cultivate public communication skills among scientists for better science—society engagement. Here, a lot of emphasis is placed on making science accessible to people by improving the simplicity and visualization of scientific discourse, as well as working on the communication skills of scientists:

> "It is very rare for someone with the right background to disseminate the information effectively. [Now] it is getting better. Like there's more emphasis put on science communication now. But years ago, I mean, well, up until this point, scientists have been very, very poor communicators for the general public. They will talk to each other and it makes sense to them but when they try and like when the general public hears their conversations, it is just [...] it's another language. There are efforts now to make it easier or to facilitate how this information is distributed to the public so that people can understand but it's an ongoing process" (Biologist, Female, Italy).

Many scientists emphasized that the presentation, content, and language of communication with the public ought to be simple, interesting, and appealing to the public interest and their day-to-day life.

> "So, I think having scientists communicate right things that aren't just scientific articles. We train scientists now to translate science, to write more digestible versions of our work sometimes. You see that with, like, *Science Direct*, right […] sometimes those get picked up, and next thing you know, it's Jimmy Kimmel saying something about it" (Biologist, Female, USA).

> "This kind of science has to be taught at a slow pace and be associated with things that people know already" (Physicist, Male, UK).

Here, the role of aesthetics (in presenting science in an appealing, attractive way) becomes crucial for science communication activities:

> "I really like being able to convey the importance of science and how useful it is in our everyday life […] it is so important educating people in a certain way […] You need to make it more pleasant and accessible for everyone; to make people understand the usefulness of science" (Biologist, Female, Italy).

For the indifferent public, the issue of trust is deeply entangled with the absence of a shared vocabulary of communication between the scientists and the public. In comparison to the traditional deficit model understanding, where the blame for the lack of communication is placed entirely on an uneducated and undifferentiated public (Callon, 1999), in our case, this blame was mostly taken up by scientists. Science is generally seen as beneficial to society, and to ensure that the public enjoys these benefits, scientists have to put effort into making science understandable, accessible, and interesting to the public. Along with improving scientific literacy, the modes for public engagement with science proposed within this orientation are one-way science communication events where scientists give information to "deficient", "lay" people.

Dogmatic Public

For the scientists in this orientation, the problem with the science-society relation is not just the lack of accessible information. It is more about misunderstood images of science, the scientific process, and scientific institutions. Scientists argue that the epistemic authority of science is contextualized by ensuring that efforts are made to let the public know the "true" nature of science which is contingent and changing.

> "We just got to really talk to people more, and I think [there should be] an emphasis on what the scientific process means and why it's acceptable and is good that in science what is defined as the truth changes over time based upon having new evidence. And why that, yeah, why that's a good thing rather than a bad thing" (Physicist, Male, UK).

The role of "right" information and education is considered important in this orientation, not just in terms of providing scientific literacy but also as a mechanism of building trust among the public for scientific knowledge. The mechanism of public engagement, in this orientation, relies on increasing platforms where the public can find "right" and "trustworthy" scientific information to make informed decisions.

As per Critical PUS, the public does not trust science because of the lack of embedding of science in the social and contextual factors within which knowledge is appropriated and trusted. Regarding mechanisms of public engagement, while Critical PUS argues for the social and cultural contextualization of science and advocates for a two-way communication and dialogue between different knowledge systems and forms of expertise, the scientists in our sample once again prescribed mostly science education, and more rarely, dialogue and debate. When dialogue was suggested, it was mostly to understand the fears and doubts of people in order to devise a better education strategy for developing scientific thinking:

> "Science is not a monolith, a source that people go to drink from; it is clearly something that is built up, and, in fact, the whole of society builds it up, not just scientists. And so, I think that in the dissemination of science, in order to approach the 'no vax', it is fundamental, first of all, to listen to their fears and doubts, whatever they may be, and gradually educate them in scientific thinking. In other words, the important thing is to think, the scientific method. It's more a philosophical question in the end than a technical one, in my opinion" (Physicist, Male, Italy).

The role of science education in this case is associated with building the capacity, mostly in schools and universities, to understand the contingent nature of scientific findings, and to maintain trust in science in situations of uncertainty (such as during a public controversy):

> "We should be communicating to our students how science works, not just what the facts are, but how science works. How you propose hypotheses, test hypotheses, revise your hypotheses. There is no truth, there is no proof of anything in science. It's continually revised" (Biologist, Male, UK).

Based on the understanding of the scientists' views in this orientation, we found that they too associate with a version of the deficit model that is more nuanced compared to the indifferent public. Despite the connection with the Critical PUS tradition in terms of contextualizing science and encouraging some form of dialogue to understand public opinion, the dogmatic orientation also relies on educating the public. Here, the blame for a dysfunctional science—society relationship is placed on science education systems that create a misguided image of science as a system that produces certain, fixed facts. As a result, situations of uncertainty lead to a crisis of trust, where people end up engaging with other sources that are more consistent and approachable. The proposed solution to this challenge is building capacity among the public (likely through schools) to understand the complexity and contingency of science, which will eventually build trust in the right sources of information.

Pragmatic Public

For scientists in this orientation, the problem with the science—society relationship lies in the non-recognition (among scientists) of the ways in which scientific knowledge fits into the public worldview. Scientists in this orientation, therefore, question their epistemic authority and accept public skepticism of science as valid. According to these scientists, the pragmatic public is more knowledgeable about the everyday purpose and use of scientific knowledge and, consequently, public engagement — where different actors talk to each other — was designated as important.

> "There are people who are thinking in a different way, who think truth can be attained in other ways. And I think our compass should be — I don't know — we could call it justice. If someone doesn't share my ideas, yet they want to obtain similar goals, why should not we collaborate, even though our underlying theories are fighting each other?" (Biologist, Male, Italy).

> "I think it's also important for the public to be engaged with scientists and in meaningful conversation and not talking past each other" (Biologist, Male, USA).

In line with heterogeneous PUS which argues for a multi-directional engagement that takes into account the diverse networks through which sense-making and trust around knowledge are built, and Citizen Science which suggests implementing strategies of co-production of scientific knowledge, scientists who held this view adopted a more open view of public engagement involving dialogue and debate and, even more rarely, co-production:

> "I believe wholeheartedly that when I say, 'get the public engaged in science', I don't mean just teaching it to them. They should be involved, but they should have ownership in that involvement. Science should serve the community, not the other way around. And to do that, we need to get the community into the labs, into the universities, and saying: 'These are our issues; this is what we need'. It's so often just left to the scientists to decide what it is that they're going to study. But how do you know that you're solving a problem that is a real problem, or that you're solving it in the right way, if you're not asking the people who this is meant to help?" (Physicist, Male, UK).

4 Conclusion and Future Directions

This article examined how scientists imagine their public, public trust in science and scientists, and, consequently, how they envision public engagement with science. Our analysis of interview data gathered from four countries shows that scientists do not see the public as a monolithic entity. Based on their own experiences and engagement with the public, scientists envisioned different kinds of publics, which could be broadly characterized as "indifferent", "dogmatic", and "pragmatic". The scientists based their responses on multiple experiences, ranging from active, individual interactions with family members and local communities, to science outreach events organized by their universities, to understandings developed through following media and political debates on scientific issues. According to our respondents, events of crisis and controversy, such as the COVID pandemic, become major sites where scientists' opinions of the public are shaped, and vice versa. These events are seen by scientists as "make or break" moments for scientific disciplines, where ensuring public trust through engagement is critical. Scientists employed metaphors like the "Sputnik moment", "Chernobyl disaster", and "GMO controversy" to explain how the pandemic provided an opportunity for scientific establishments (especially in virology and vaccine development), to build greater trust in science by ensuring effective science communication.

In this article, we analyzed the typology of publics and public engagement that has constituted a three-decades-long debate in the field of PUS (Bauer et al., 2007; Miller, 2001). The analysis showed that, in terms of understanding the diversity of publics, respondents in our sample demonstrated advanced and nuanced understandings of the public. The categories of "indifferent", "dogmatic", and "pragmatic" publics share features from the three dominant trends of PUS in a complex and messy way. Compared to the existing PUS and science communication literature — that is majorly produced in the Global North (Wynne, 1992; Bauer, 2009) — the categorization of "indifferent" public by the scientists emphasized the lack of access, both physical and ideational, to science education. Similarly, the categorization of "dogmatic" public was associated with the deficit model (Simis et al., 2016), in terms of encountering an opinionated public that needs science education and communication. In addition, while these two orientations served to safeguard (indifferent) and contextualize (dogmatic) the authority and epistemic boundaries of science (Gieryn, 1983), the third orientation (pragmatic) accepted civic epistemologies and public skepticism as valid (Jasanoff, 2005). Simultaneously, all three orientations demonstrated explicit and implicit tendencies towards the deficit model of public engagement (Stilgoe et al., 2014). Many scientists in our sample resorted to science communication and scientific literacy/education as their main prescriptions, except in the case of the "pragmatic" orientation, which highlighted co-production, as seen in Citizen Science initiatives (Bonney et al., 2016; Silvertown, 2009).

The aims of scientific education and communication, however, differed across the three orientations. For "indifferent" publics, the purpose of scientific communication and education was to provide a "deficient" public with information about science, in line with the deficit model and Traditional PUS. Aesthetic factors must be mobilized to communicate complex scientific information to the public in simple ways. Interestingly, in this characterization of public engagement, scientists argued that the responsibility for effective communication also falls on scientists, who should work towards improving public engagement by enhancing their own communication skills and devoting more time to such (often institutionally unrewarded) activities. In our data, this orientation toward understanding the public was mostly observed among scientists from India and the USA. For "dogmatic" publics, the role of science communication and education was twofold: to provide the "right", "trustable" information in moments of crisis, and to build intellectual capacity among the public regarding the uncertain and contingent nature of scientific information, as a long-term educational endeavor. Here, the frequency of information provision, the platform, and the format in which information was shared were considered crucial factors in building public trust. These factors become even more central in science communication during moments of uncertainty and emergency, such as the pandemic, which led to a crisis in public trust in science, due to the uncertainty of knowledge production (Ballo et al., 2024; Pandey & Sharma, 2022). The "dogmatic" orientation in our data sample was predominantly represented by scientists from the UK. For the "pragmatic" publics, science education emphasized building capacity for logical thinking. For these scientists, subjecting individual experiences to rigorous scientific evaluation is important for maintaining trust in science, in line with the idea of empowering the contributive citizen. These citizens can eventually participate in the co-production of scientific knowledge along with scientists.

The association of different views of the public and public engagement among scientists from different countries points to the role of distinct national political cultures and civic epistemologies that shape science—society engagement (Jasanoff, 2004 & 2005; Entradas et al., 2020; Kessler et al., 2022). Nevertheless, we should note that scientists in our sample continue to focus on one-way science communication/scientific education, in line with Traditional PUS (Simis et al., 2016), and less frequently on a two-way dialogue (Critical PUS) or multi-way/multi-format interactions (Heterogeneous PUS), which entail direct involvement in data collection, analysis, and communication. However, the data also show that clear-cut theoretical categorizations become messily entangled in practice, as scientists present more nuanced understandings of the public and science education (in the "indifferent" and "dogmatic" orientations), primarily in relation to the deficit model. Similarly, the co-production and dialogue aspects of public engagement were coupled with the understanding of the public associated with the "pragmatic" orientation. In relation to the question of trust, in all three orientations we found issues that are not commonly discussed in the literature. For example, scientists discussed the misrepresentation of science and the scientific method within education systems, which creates unrealistic expectations and thus fosters distrust in science. Likewise, the recognition of public skepticism as a plausible aspect of civic epistemology in the "pragmatic" orientation points to reflexivity among scientists regarding public positions on trust.

This study has several limitations. First, due to the research design being primarily focused on work and well-being among scientists, public engagement constituted only a section of the in-depth interview portion of the study. As a result, we can only identify significant orientations. Further work is needed to gain deeper insights into these orientations and their relationships with the socio-cultural, economic, and historical factors shaping the science—society relationship. Similarly, follow-up research should be devoted to assessing, through representative surveys, the distribution of the three types among the broader population of scientists.

Despite these limitations, our findings have important implications for the sociology of scientific knowledge in general, and for the fields of science communication and PUS in particular. As our sample consists of scientists from biology and physics in four countries (UK, USA, Italy, and India), this study addresses a topic that is under-analyzed in the sociology of scientific knowledge and STS, which have mainly focused on science in action and scientists' narratives about their work rather than their views of the public, thus encouraging further investigation on the topic. The study may also serve as a heuristic for determining future trends and directions in science communication and PUS research and policy (Nisbet & Scheufele, 2009). For example, it raises a critical concern about the impact of PUS research: while the field has developed and experimented with nuanced approaches to public engagement over the past three decades, we found a lack of interest among scientists in incorporating these approaches into their vision and practices of public engagement. Whether the field of PUS/science communication should focus more on scientists as the subject of analysis and intervention rather than the public in public engagement activities remains an open question for future research.

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