Does Democratizing Access to Science Imply Democratizing Science? A Case Study of Non-Corporate Spanish-Speaking Science Youtubers

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Abstract

In recent years, access to science content production has been democratized. New actors can make their discourses reach large audiences through popular platforms with no institutional gatekeeping. However, it remains unclear which conceptions of the science-society relationship underlie science content created by non-corporate individuals. To explore how science communication cultures of boosters and critics inform this kind of science content in Spanish, we conducted a qualitative content analysis of a sample of 50 videos from ten YouTube science channels. Our results suggest that more accessible science communication does not necessarily entail a democratized view of science but may reinforce a traditional perspective.

Keywords: Representations of science and technology, public engagement with science and technology, science and media

Context

Science communication on digital platforms: Deinstitutionalization

Science communication has undergone several changes in recent years due to the expansion and diversification of cyberspace. General audiences used to gain access to scientific information exclusively through mainstream media, which played a gatekeeper role by controlling what and how to communicate. Now, given the availability of affordable, user-friendly gear and software, combined with free and easy means of distribution (Finkler and León, 2019), users, even with little or no science or journalism background, can also produce science-related content and reach significantly large audiences (Brossard, 2013; Pascoe, 2018). This user-generated content goes public with no institutional intervention (Brossard, 2013; Geipel, 2017, 2018) and appears in several online media environments—Twitter, Instagram, Tik Tok, YouTube—and a variety of formats and genres—podcasts, memes, microblogging, vlogging, scrollytelling. Additionally, they are more popular than institutional content (Allgaier, 2016; Welbourne and Grant, 2016).

The explosion of formats and broadening of actors in science-content production on digital interactive platforms (Gross and Buehl, 2017) might favor the popularization of scientific knowledge (Bräutigam and Ettl-Huber, 2013; Bubela et al., 2009; Rosenthal, 2020; Shirky, 2011). Moreover, it has been suggested that social media promote an ethos of democratization (Höttecke and Allchin, 2020) and may democratize science by promoting bottom-up alternative framings (Nisbet and Scheufele, 2009). However, science democratization is understood in several ways: from broader access to knowledge (Folguera, 2017) to redistributing epistemic authority between scientists and laypeople to broadening the scope of social control over decisions about science (Kurtulmuş, 2021). It remains unclear what assumptions about science are instantiated in and through these platforms by the new actors involved. Does this broadening of communicators lead to recasting science-society relationships, or, on the contrary, do they bolster traditional views that perpetuate the dominant status of science?

Scholars have posited several models to theorize about science communication's aims, motives, and outcomes. They are frameworks to define, measure, and address the relationship between scientists and the public in the communication process (Metcalfe, 2019; Brossard and Lewenstein, 2010). Perrault (2013) characterizes three general models: Public Appreciation of Science and Technology (PAST), Public Engagement with Science and Technology (PEST), and Critical Understanding of Science in Public (CUSP).

PAST is related to 1980s and 1990s discussions around the 'deficit model,' where communication is one-way. Scholars theorize that science communication's objective in this model is to educate laypeople according to the needs identified by scientists (Durant et al., 1992; Millar and Wynne, 1988). It intends to legitimize science as a reliable source of social benefits, which is worth unconditional support and only works fine if it remains self-governing, i.e., if society stays away from it. The public is conceived as an empty container needing to be filled with scientific knowledge (Nisbet and Scheufele, 2009).

PEST relies on dialogue and promotes a "science-directed two-way interaction between scientists or science communicators and the public" (Metcalfe, 2019 p. 2). Following Metcalfe (2019), this model has multiple aims: to address mistrust of science, discover public opinion about contested science, tailor communication to diverse publics, be more accessible and accountable to the public, and engage citizens in science and technology issues. Several scholars have pointed out that this model does not differ much from the deficit model since it also advocates for science's interests only (Broks, 2006; Metcalfe, 2019; Perrault, 2013; Russell, 2010).

Finally, CUSP appeals to democratic and participatory strategies to encourage the critical understanding of science in public. It recognizes that non-scientists are social actors as valid as scientists in science-related issues (Metcalfe, 2019). Communication in this model encourages non-scientists to oversee and regulate science; it aims to redistribute power regarding science's place in society and the decision-making process (Perrault, 2013).

More fundamentally, Perrault (2013) adds an element frequently assumed in the debates about these models but rarely articulated explicitly. She argues that these models emerge from two cultures in understanding science communication: science boosters and science critics.

Science boosters act as public relations officers who advocate for science and the deficit model. They consider that science communication's success depends on how well the public appreciates science and aligns with scientists' interests. They tend to present science as a set of compatible, riskless, and fixed assertions sharply demarcated from historical, sociopolitical, economic, methodological, and personal contexts.

Meanwhile, science critics promote democratic engagement with science according to a critical understanding of it in public. Science critics' role is to help

people make informed judgments about and have a say in scientific knowledge decisions. It does not imply an anti-scientific attitude but a disposition like other professional critics', such as art and literary critics. Science critics intend to promote appreciation for science with detailed analyses of its advantages and shortcomings. Opposed to boosters, they portray science in a constant interplay with society and as a process of knowledge-making rather than knowledge-finding.

Perrault's two cultures provide a valuable framework for studying science communicators' work by narrowing down the models' discussion to communication practitioners and offering operationalizable categories. Although she proposed these cultures based on the analysis of popular science texts, they are helpful to examine other sorts of content involving representations of what science is, how it works, and how it relates to society. The primary purpose of this study is to explore the science-society relationships promoted by non-corporate science communication on a popular platform such as YouTube in light of these two cultures.

Science communication on YouTube

Since its launch in 2005, YouTube has become the second most visited website globally and the most popular video platform. Over two billion logged-in users visit YouTube each month, and every day people watch over a billion hours of video and generate billions of views (YouTube, 2020). One of the success factors of this platform is that it allows users to produce, upload, and share their videos, build communities, and establish dialogues with a variety of audiences (Erviti and Stengler, 2016). Some scholars also see YouTube as a spearhead of participatory culture (Burgess and Green, 2018) since it allows to hear voices other than the institutional ones.

YouTube is used not only for entertainment and commercial purposes but also to disseminate and obtain scientific information and knowledge (Allgaier, 2016; León and Bourk, 2018). Science videos on YouTube are produced by institutions such as National Geographic, BBC, Nature, Royal Institution, and non-corporate individuals (those running Smarter Every Day, Periodic Videos, SciShow, and other channels). These videos can belong to a wide range of genres (Morcillo et al., 2016), some of them with a visible presenter or enunciator, recognized as a YouTuber. There is not a clear-cut definition of the term YouTuber. While some authors state that a YouTuber is any content creator who invests much time into YouTube (creator role) (Holmbom, 2015), others affirm that it is the regular enunciator of the content (presenter role) (Hidalgo-Marí and Segarra-Saavedra, 2017). In the case of non-corporate YouTube channels, both roles often converge in the same individual (Boy et al., 2020). Other authors reserve this label for those who make a living out of the traffic to their content (Aran-Ramspott et al., 2018), which foregrounds the relevance of economic factors in their role as communicators.

Studies conducted in several countries have found that YouTube is widely used as a source to learn about science, especially among young people (Fundación Española para la Ciencia y la Tecnología, 2018; Lebedev and Sharma, 2019;

Rosenthal, 2018; Wissenschaft im Dialog, 2018). In Latin America, most science communication institutions use YouTube as one of their media (Patiño et al., 2017). Despite a lack of studies on YouTube as a science information source in this region, the number of science channel subscribers indicates a highly active relationship with this content. For instance, channels run by non-corporate Latin American YouTubers such as Lumara la bióloga, La ciencia detrás de, Hey Arnoldo Montaño, and El Robot de Platón have more than 28,500, 38,900, 520,000, and 2,320,000 subscribers, respectively.

A growing number of studies address science communication on YouTube (Allgaier, 2018; Breuer, 2012; Geipel, 2018; Welbourne and Grant, 2016). For example, Erviti and Stengler (2016) found that institutions and individuals behind professionally-generated content channels in the United Kingdom have many aims and audiences. Some of them are targeted at the "general public" and aim to widen science engagement; others target specific niches and seek to establish a brand. In turn, Geipel (2018) combined interviews, desk research, and ethnographic fieldwork to study the production process of five non-professional German YouTube science channels. She found that the YouTube algorithm and YouTubers' conceptions of science communication condition each other, and this interplay simultaneously modifies the dynamics of roles, production, and dissemination. The interviewees highlighted that their primary purpose is to entertain and foster curiosity and learning; they did not mention science legitimization or debunking pseudoscientific contents.

Other studies have focused on users' comments on YouTube science videos. Tsou et al. (2014) found that TED talk videos comments on the TED website revolve around the talk content while comments on YouTube discuss the speaker's characteristics. Amarasekara and Grant (2018) noticed that female-hosted channels accumulate more comments per view and significantly higher proportions of appearance, hostile, critical/negative, and sexist/sexual commentary. Shapiro and Park (2015) investigated how people responded to claims about the science of climate change and commented on videos that question this knowledge. They found that argumentative discussions took place in the comments section and that users commented on correct scientific facts with links to other media. Another finding is that most of the comments address general themes rather than the specific content included in the videos. In turn, Dubovi and Tabak (2020) explored whether YouTube's feature of posting comments enables discussion and deliberation among users. They concluded that incongruities between prior individual knowledge and the presented information might motivate users to participate in collaborative deliberation. Their results also suggest that the most active users reached the highest levels of knowledge co-construction, disagreements or counterclaims had the highest probability of advancing collaborative knowledge co-construction, and rude emotional expressions hinder collaborative negotiation.

So far, the study by Boy et al. (2020) is the only one addressing the reception processes triggered by the audiovisual modality of science videos. They developed a typology for TV and YouTube science videos and studied recipients' attention distribution and knowledge acquisition. They found, for instance, that science

videos are much better at conveying factual knowledge (i.e., concepts) than structural knowledge (i.e., logical relations between concepts).

Other studies have focused on the content of YouTube science videos. For example, Welbourne and Grant (2016) identified that user-generated content is significantly more popular than professional-generated content, albeit the latter is more abundant. They also found that channels with regular presenters and fast-paced videos are more popular than others. For their part, Morcillo et al. (2016) characterized science web videos, proposing typologies based on technical and narrative aspects that provide an evidence-based description of their distinctive features. In turn, Fernández Beltrán et al. (2019) found that women are underrepresented in the science content of the most popular science channels run by Spanish-speaking individuals and universities in Spain.

Maybe one of the most common research questions when analyzing science videos has to do with their quality in terms of the extent to which these contents align with scientific consensus in a specific domain (Allgaier, 2019; Basch et al., 2020; D'Souza et al., 2020; Haslam et al., 2019; Hernández-García and Fernández Porcel, 2018; Vizcaíno-Verdú et al., 2020; Yörükoğlu and Uzun, 2020). For example, Haslam et al. (2019) reviewed the literature regarding the validity of health information (i.e., accuracy and credibility of content, scientifically correct information, and portrayal of evidence-based practices) contained within YouTube videos. Through the analysis of 58 studies, they concluded that the validity of YouTube videos could range from good to poor within a given health topic, including many deemed misleading or dangerous. Likewise, Allgaier (2019) found that search terms heavily condition the type of content with which one may be confronted. In his study, some general search terms related to climate change led to videos endorsing mainstream scientific positions, while more specific search terms directed to videos challenging mainstream scientific views or presenting outspoken conspiracy theories.

Despite an emerging shift towards diversification, most research into science communication has come from Western, English-speaking countries, especially the US and the UK (Guenther and Joubert, 2017). In line with this tendency, only a few studies have addressed YouTube science videos in Spanish, although they can reach thousands of viewers. These studies have mainly focused on scientific validity (Bortoliero and León, 2017; Hernández-García and Fernández Porcel, 2018; Vizcaíno-Verdú et al., 2020), success factors of popular channels (Martel Cros, 2019), and gender inequality (Fernández Beltrán et al., 2019).

Thus, to the best of our knowledge, research about science communication has widely left aside the conceptions of science-society relationships instantiated in emerging digital contents created by non-corporate individuals, especially in the Spanish-speaking domain. Whether new digital formats of science communication promote the democratization of science or reinforce its traditional view remains unknown. To address this gap in the field and provide some insights, we explored such underlying conceptions in channels of non-corporate Spanish-speaking YouTubers. Our most significant finding is that, in general, these YouTube

channels are inclined to present science, by either actions or omissions, as a homogeneous, everlasting, and riskless body of knowledge involving a few specialized people and unrelated to several contextual dimensions (e.g., economic, political, or personal). Instead of promoting the democratization of science, this democratization of access to science content production tends to emphasize the most traditional views about the relationship between science and society.

Objective

The predominant efforts to identify science content on YouTube that deviate from specific scientific standards or criteria hinder the understanding of representations about what science is, how it works, whom it involves, or how it relates to society. This is not unproblematic because having a gold-standard representation of science may marginalize other ways of understanding its relationship with society and the meaning-making work that popular science videos do. Our aim with this study on non-corporate Spanish-speaking science YouTubers is to explore how the cultures of science boosters and science critics inform science content posted on YouTube and how they frame the relationship between science and society.

Materials and methods

We conducted a qualitative content analysis (QCA) to describe a sample of videos by Spanish-speaking science YouTubers systematically. Given that videos do not explicitly label themselves as science boosters and science critics, we considered QCA a suitable method to describe content that requires some degree of interpretation (Schreier, 2012).

Since our study is exploratory, we do not intend to provide any conclusive or generalizable results but to gain some insights and spot questions that may inspire further studies on how novel science content in popular and interactive platforms, such as YouTube, may shape the science-society relationship.

Sample

Sampling online content via search engines is problematic since the same search terms or strings entered on YouTube by different users do not produce the same results due to algorithm-based individualization—the “filter bubble” problem (Pariser, 2011). To circumvent this problem, we first cleared cache and cookies and then used Tor software to search on YouTube using the string “YouTuber ciencia,” following Allgaier’s (2019) methodological approach.

We filtered the results to obtain channels instead of videos and sorted them by view count. The first 60 videos were recorded top-down. This process was repeated five times, each with a new identity provided by the Tor anonymity network. Thirty-three channels appearing in at least four of the five searches were considered for further screening. Then, we excluded those with non-Spanish content, having an explicit corporate sponsor, or lacking an onscreen presenter. We ordered the resulting 17 channels top-down by their average position in the initial searches and selected the first ten as units of analysis.

We sorted the videos within each channel by popularity and registered the top ten videos under 15 minutes of length. We selected five videos by generating random numbers from 1 to 10 using www.random.org. In this way, we sampled a total of 50 videos and ten channels, five units of coding per ten units of analysis. This sampling was performed in October 2020.

Table 1 shows the ten channels in the sample. The number of subscribers ranges from 40,000 to 6,210,000, the average view count per video from 6,599 to 2,465,538, and the creation year from 2012 to 2018.

Table 1. YouTube channels analyzed

Channel	**Creation year**	Subscribers	Number of videos	Average view count per video
Curiosidades con Mike	2015	6,210,000	469	2,465,538
QuantumFracture	2012	2,790,000	196	1,074,108
El Robot de Platón	2013	2,380,000	493	665,315
Antroporama	2017	771,000	52	565,808
Date un Vlog	2016	2,030,000	469	367,277
CdeCiencia	2014	1,450,000	349	343,693
La gata de Schrödinger	2018	543,000	85	341,636
Deborahciencia	2017	45,000	40	31,157
Ciencias de la Ciencia	2016	191,000	321	24,530
CERNtripetas	2016	40,000	115	6,599

Note. Data retrieved on November 7, 2021.

Content analysis

A coding frame with 14 categories was constructed for QCA. One addressed the prevailing field of knowledge in the video, according to the OECD classification (OECD, 2007), and thirteen operationalized Perrault's cultures of science boosters and science critics (see Table 2). For the latter, one of four codes could be assigned to the video:

Code 01. This code links the category to the science booster culture: The video's content depicts science, by mention or omission, as a set of compatible, riskless, and fixed assertions sharply demarcated from historical, sociopolitical, economic, methodological, and personal contexts.

Code 02. This code links the category to the science critic culture: The video's content frames science as a human practice embedded in historical, sociopolitical, economic, methodological, and personal contexts, with social benefits as well as risks, interests, and even biases.

Code 03. This code links the category to anti-scientific attitudes: The video's content delegitimizes science as a kind of knowledge because of its risks, heterogeneity, provisionality, cross-sectoral links, methodological biases, among other factors.

Code 98. This code, also identified as “other,” is chosen when none of the previous options describes the video.

Two coders independently analyzed the content of each video, including its visual, audio, and text presentation. One holds a BSc in biology, pursues an MSc in STS studies, and has an eight-year career in science communication, and the other holds a BSc in chemical engineering, an MSc in biotechnology, and has a seventeen-year career as a full-time professor. Before coding all the videos, coders performed a pilot phase with 10 % of the sample (five videos) to check coding consistency and adjust the coding frame so that categories and codes were interpreted similarly, as suggested by Schreier (2012). After having coded all the sample, both coders discussed one by one their interpretations of those videos with different codes in the same category and agreed to choose one code. Code frequencies were calculated using Microsoft Excel.

Table 2. Categories included in the coding frame for qualitative content analysis

Category	Description
Field of knowledge	Academic discipline mainly addressed in the video, ascertained by identifying the primary subject matter, practices, techniques, questions, and concepts to which the content of the video refers, according to OECD classification
Actors involved	Social actors involved in the production of scientific knowledge according to the content of the video. They comprise scientists, entrepreneurs, activists, politicians, corporations, ONGs, citizenry.
Compatibility between scientific findings	Coherence among the scientific ideas/findings presented in the video. Compatible ideas/findings do not counteract each other, while incompatible ones do
Provisionality	Possibility for a statement, theory, or hypothesis to be replaced or modified. The content of the video may imply that scientific knowledge is provisional because it presents that either an idea has changed or might change.
Riskiness	The possibility of something risky happening because of scientific knowledge, e.g., unexpected side effects of drugs or radioactive contamination associated with nuclear power
Position of science about other kinds of knowledge	How scientific knowledge relates to other knowledge, such as practical or traditional knowledge
Role in public decisions	The role of science in public decision-making promoted by the content of the video
Funding	Relationship between funding and issues related to scientific knowledge development (choice of research topics, data collection, analysis, research communication, application, or uses)
Methodological and material context	How science is presented in the video content, i.e., as a body of knowledge or as the process whereby that knowledge is developed, including methods, techniques, and instruments
Sociopolitical context	Relationship between sociopolitical issues (e.g., social movements, political regimes, public policies, geopolitical conditions) and scientific knowledge development (choice of research topics, data collection, analysis, research communication, application, or uses)
Scientists’ personal values and beliefs	Relationship between scientists’ personal values and beliefs and scientific knowledge development (choice of research topics,

	data collection, analysis, research communication, application, or uses)
Historical context	Relationship between historical events and scientific knowledge development (choice of research topics, data collection, analysis, research communication, application, or uses)
Corporate interests	Relationship between corporate interests (e.g., for-profit, power, market advantages) and scientific knowledge development (choice of research topics, data collection, analysis, research communication, application, or uses)
Scientists' personal rivalries	Relationship between personal rivalries among scientists and scientific knowledge development (choice of research topics, data collection, analysis, research communication, application, or uses)

Results

The QCA shed some light on how science is communicated on YouTube. Results are presented by category and channel regarding the number of videos or code percentage/frequency. Although the sample size and the number of categories did not allow statistical tests of independence between variables, our findings provide valuable insights to explore science-society relationships promoted in this kind of content.

Fields of knowledge

The prevailing fields of knowledge in most videos were natural sciences (46 %) and engineering and technology (26 %), followed by social sciences (10 %), other (8 %), medical and health sciences (6 %), and humanities (4 %). None of the videos was coded as agricultural sciences (see Figure).

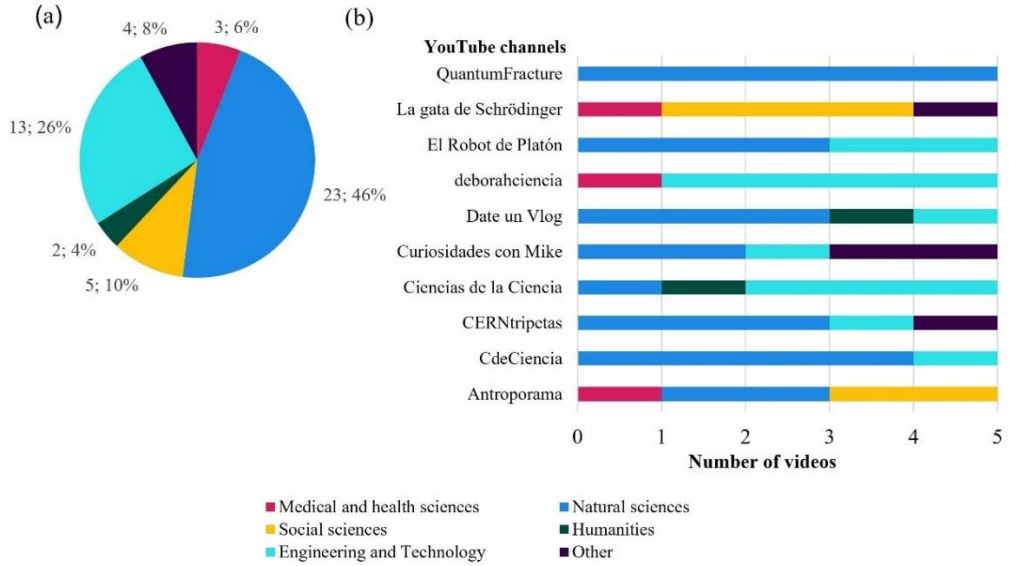

Figure 1. Field of knowledge frequency (a) in the whole sample and (b) by channel.

Nine of the ten YouTube channels addressed 2-3 fields of knowledge. All the videos sampled in the remaining one (QuantumFracture) were coded as natural sciences. The four least frequent fields of knowledge were present in 2-3 channels. Only four videos fell out of the established field of knowledge categories. One belongs to the channel CERNtripetas and revolves around an anecdote of the YouTuber that, according to coders, does not address any subject matter or question within the established fields. Another belongs to La gata de Schrödinger and critiques some influencers whom she considered pseudoscientific. Two belong to Curiosidades con Mike and present dissections of fictional creatures with artificial internal body organs; these fictional settings were not related to any subject matter or question within the established fields.

Science communication cultures

In the whole sample, 79.0 % of the codes assigned correspond to “Science booster,” 20.0 % to “Science critic,” and 1.0 % to “Other.” None of the categories was given code 03, corresponding to anti-scientific attitudes (see Figure 2).

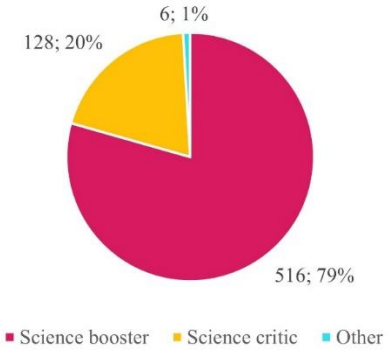

Figure 2. Percentage of codes in the whole sample belonging to each science communication culture proposed by Perrault (2013) or the category “Other.”

The channel with the highest frequency of science-booster codes is Antroporama (93.8 %), and the one with the lowest is Ciencias de la ciencia (61.5 %). The average frequency of codes per channel was 79.4 % for science boosters, 19.7 % for science critics, and 0.9 for other. Only two channels were given codes 98, Curiosidades con Mike (7.7 %) and CERNtripetas (1.5 %) (see Figure 3).

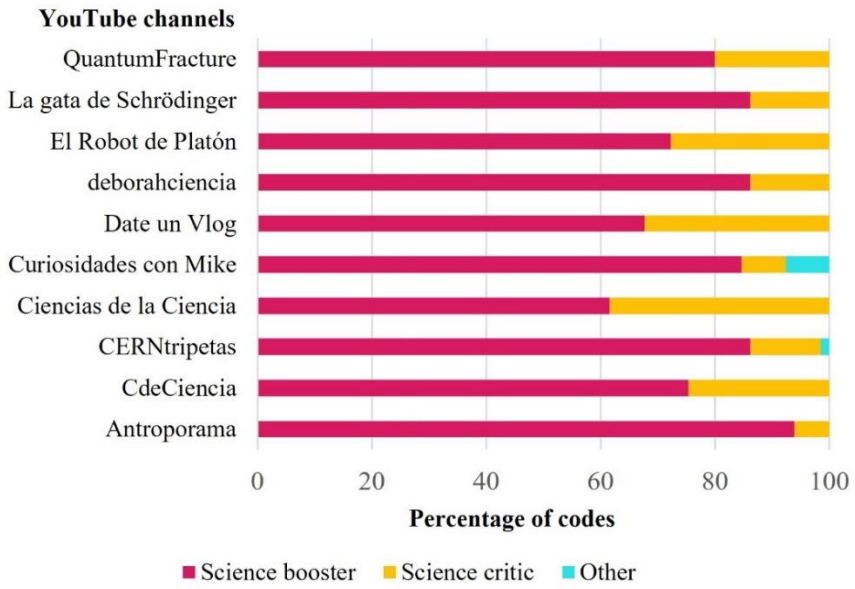

Figure 3. Percentage of codes by channel (*n* = 65) belonging to each science communication culture proposed by Perrault (2013) or the category "Other." *No videos were coded as anti-scientific.

The frequency of codes related to science booster culture was higher than those related to science critic culture in all fields of knowledge, being the difference lower for Engineering and Technology and Humanities (see Figure 4). Besides, three of the four videos coded as 98 were not in any of the established fields of knowledge; the other was coded as Engineering and Technology.

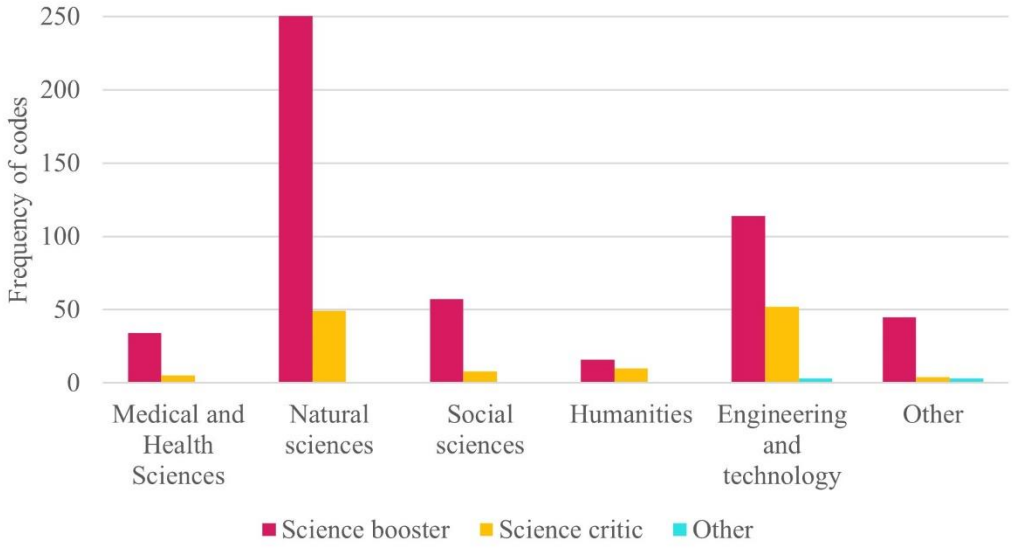

Figure 4. Frequency of codes by field of knowledge belonging to each science communication culture proposed by Perrault (2013).

Concerning the other 13 categories, only in the category “Methods and material context,” most videos (72 %) were coded as science critics, and the other two categories, “Historical context” and “Provisionality,” have a relatively higher percentage of videos coded likewise (40 %). Conversely, the remaining ten categories exhibit a percentage of videos coded as science booster above 82 %, reaching 98 % and 100 % in the case of “Science role in public decisions” and “Personal rivalries,” respectively. Two videos in each of three categories (“Actors involved,” “Internal compatibility,” “Position of science”) account for the six codes unrelated to science booster or science critic (see Figure 5).

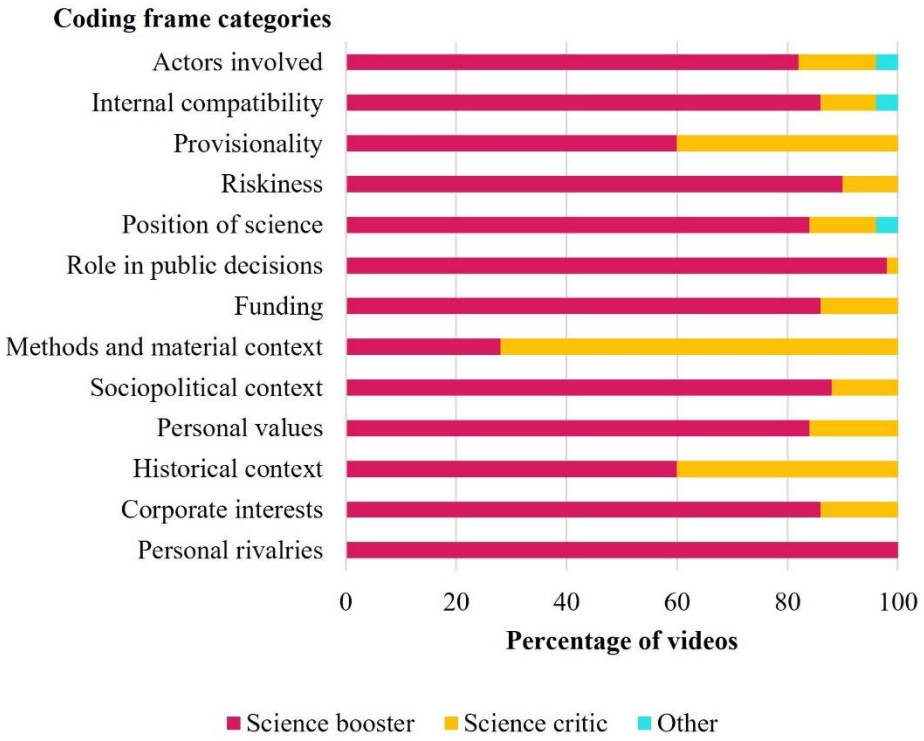

Figure 5. Percentage of videos (*n* = 50) by theme belonging to each science communication culture proposed by Perrault (2013) or the category “Other.” *No videos were coded as anti-scientific.

Discussion

It has been shown that particular ways of presenting an issue can significantly affect people’s attitudes, behaviors, and opinions (Chong and Druckman, 2007; Druckman, 2001). The current tendency in science communication literature is to present the field as undergoing a sort of democratic turn, as if most people were naturally inclined nowadays towards the democratization of science in society and what is going on in platforms such as YouTube would be evidence of this perspective. This study provides an initial approach to reconsider this way of presenting the issue by focusing on how Spanish-speaking non-corporate science YouTubers channels frame science, that is, which science-related aspects are

selected and made more salient than others to promote a particular view of what science is, how it works, whom it involves or how it relates to society.

The most significant finding is that the YouTube channels studied lie at the booster side of the science communication cultures. Easy access to new technology does not show a fundamental transformation in the communicative intention of a new generation of science communicators. The videos tend to present science, by either actions or omissions, as a homogeneous, everlasting, and riskless body of knowledge involving a few specialized people and unrelated to several contextual dimensions (e.g., economic, political, or personal). This depiction of science fails to account for how it is a part of society and not a different domain, and how scientific knowledge conditions and is conditioned by social factors or which risks it entails. The videos reinforce the view of science as an enterprise not conditioned by contextual factors, not even clearly connected to any specific contextual factor.

In this sense, the content analyzed in these channels, reaching thousands to millions of people, perpetuates science's dominant images and status by neglecting that society can have a say therein. For instance, out of the 50 videos, only one suggested that science deals with public decisions, and six mentioned sociopolitical aspects. As Perrault puts it:

> Ultimately, all of this matters because science is a god term—perhaps *the* god term—of our time, and god terms must be subject to critical scrutiny if their rhetorical power is to be kept in proportion to the benefits they actually offer. (2013, p. 17, emphasis in the original)

Thus, platforms such as YouTube have contributed to democratizing access to science communication due to the absence of editorial gatekeeping and distribution networks at almost everybody's hand (Carpentier et al., 2013; Rosenthal, 2020). However, our results suggest that novel communication formats do not necessarily entail a framing that contributes to democratizing science, one that, in terms of Nisbet and Scheufele, may "promote dialogue, learning, and social connections and that allow citizens to recognize points of agreement while also understanding the roots of dissent" (2009, p. 1771). The use of these new formats may be described instead as putting old wine in newer, fancier bottles, as it reproduces the traditional image of science.

Science communication seems to be understood here as an expositive or didactic enterprise devoted to making concepts, hypotheses, and theories more familiar, comprehensible, and acceptable for a broader range of people, without intending to increase their critical thinking. In countries considered democratic, as almost all those in the Spanish-speaking domain, such an understanding turns out problematic; it does not bring to the fore the mutual conditioning between science and society, nor the importance of citizen intervention in science-related public issues (Meyer, 2016). Science boosterism, on the contrary, might hinder efforts to regulate science-related issues because it represents science as an institution that flawlessly works when it receives a blank check from society. The issue, in the end, is that this way of communicating science, with its seductive appeals to democracy due to the wide use of technology, becomes functional for antidemocratic attitudes

interested in concentrating the power over science and its decisions on small groups or elites.

This type of democratized access to science communication seems neither to tackle the established epistemic authority directly nor to broaden the scope of social control over decisions about science. On the contrary, it might even help perpetuate the prevailing image of science as an elite's black box releasing factual knowledge because of the new formats' high potential to reach and engage people (Himma-Kadakas et al., 2018; Yuste, 2015). Science's role would be to release factual knowledge, and the public's one would be to provide silent support. That is, albeit these YouTubers are not dependent on institutions, their far-reaching discourses (on average, more than 1,600,000 subscribers and ~580 thousand views per video) appear to be aligned with the deficit views of science communication, like most of the other science content (Meyer, 2016; Simis et al., 2016).

Opposed to the rest of the contextual dimensions, most of the videos (70 %) lie at the science critics' side regarding the methodological and material context of science, that is, the artifacts, techniques, or methods that enable it. In this regard, the channel Curiosidades con Mike stands out because, besides having the highest number of subscribers (6,210,000) and the highest average view count per video (2,465,538), it has a clear focus on hands-on activities such as experiments, or dissections of toys and objects created for that purpose. Therefore, it foregrounds the idea that knowledge is mainly built through empirical approaches, even with this content proposing a fictional pact, as it has been shown to transform cultural ideas about science (Tabas, 2019). It is also noticeable that this channel concentrated most 98 codes in the sample, which the fictional settings in some videos might explain.

Addressing science methodological issues in science communication has been proposed to portray science as a process of knowledge-making rather than knowledge-finding and, therefore, as a human practice beyond a set of concepts and propositions (Dijk, 2011). However, further studies are required to ascertain how science is presented in methodological terms: whether there are one, several, or no methods, how they vary according to the field of knowledge, what the role of theory and experience in science is, among others.

Regarding fields of knowledge, the categories established in the coding frame covered almost all the diverse content, given that one of them could describe the field of knowledge in 95 % of the videos. Although the resolution of this classification frame might be considered not so high (i.e., it could not be told which natural sciences or engineering subfields appear in the sample), it is detailed enough to examine which subject matters and questions are more frequent in the videos with the highest view counts when a search is performed using a string related to "ciencia."

In this case, most of the content fell into "natural sciences" or "engineering and technology." New media does not seem to stray far from legacy media as a similar trend has also been found therein (Schäfer et al., 2019). This asymmetry with other

fields could result, not exclusively, from an algorithm bias towards these fields of knowledge related to the label “ciencia,” an actual lower quantity of videos in other areas, or a tendency to view videos addressing these fields instead of others. In any case, it suggests a strong association between science and technology, as well as a conception of “ciencia” limited to what has been called “hard sciences” — physics, astronomy, chemistry, biology, and mathematics. Such a conception is worth debating since considering anything “scientific” has consequences for whether it obtains numerous societal benefits, ranging from tangibles such as grant to intangibles such as the high degree of esteem accorded to scientists. Further research is necessary to determine whether this field bias holds for more videos on YouTube under the label “ciencia.” Nevertheless, the evidence collected so far suggests a very narrow conception of what science is about and the knowledge it produces.

The tendency towards science boosterism was present in all fields of knowledge, apparently to a lesser extent in Engineering and Technology and Humanities, but these results may arise because of a limited sample size. Additional studies are needed to establish whether these differences are representative of science communication on YouTube.

Future research should also address the limitations of this study. Our sampling method, for example, focuses on those channels with the highest view counts, that is, those with higher exposure, leaving aside lower-audience science communication such as that occurring in niches. Addressing not-so-popular channels may help understand those conceptions of science circulating in non-mainstream settings. Another shortcoming is the resolution of the coding frame, which allows ascertaining the saliency of categories in a channel or a whole sample but not within a single video (e.g., only one mention of science’s relationship with its context is enough to code a video in one way and not the other). Thus, further investigation is needed to understand better how categories are discursively addressed.

It remains unstudied how science content on digital platforms relates to communicators’ backgrounds and personal, social, and cultural effects. Do YouTubers’ views of science arise unconsciously or intentionally? Do different science framings elicit differential interactions with audiences? To what extent does a popular science channel constitute a role model for users becoming producers? We hypothesize that fostering epistemological discussions among science-content producers about science and its relationships with society may enrich perspectives. These perspectives will help us better understand whether framing specific cases of science communication in a particular culture, either booster or critic, responds to explicit agendas on the YouTubers part (for instance, an attempt to counteract anti-scientific attitudes) or to views uncritically taken for granted by them as part of their society’s accepted science discourses. This study has not asked the YouTubers directly about these issues, which are relevant for a more comprehensive view of the aims pursued in their science communication experiences. Future research should address these topics as well.

Conclusions

This article explored the relationships between science and society promoted by channels of non-corporate Spanish-speaking YouTubers. Our findings suggest that science communication content created without institutional gatekeepers and presented in novel formats seems to be informed by the same pervasive view of science as a body of knowledge rarely connected to diverse contextual dimensions. In other words, this study points out that democratized access to science communication does not necessarily entail a democratized view of science, as sometimes suggested or implied.

Therefore, deinstitutionalized science communication seems to share the same views of science prevailing in legacy media. YouTubers tend to be science boosters instead of science critics; the primary inclination is not to challenge science's status quo despite having a stage to rouse public discussions among large audiences. What is their level of political awareness? How are their views of science shaped? Have they been exposed to STS-related discussions? Does a science communication practitioner's closer relationship with science communication theory diversify their content? Is there any connection between their boosterism and a conscious attempt for counteracting anti-scientific attitudes? The answers to these questions will help better understand how traditional views of science have been perpetuated and how they inform these new media and platforms. This knowledge may also contribute to figuring out alternative strategies for democratizing science.

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