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Science dissemination on YouTube in Spanish-speaking countries: Youtubers vs. institutional channels

Divulgación científica en YouTube en países hispanoamericanos: Youtubers vs canales institucionales

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Abstract
YouTube has established itself as a location for the mass dissemination of science that has been widely accepted by the populace. This research sought to analyse science dissemination on YouTube in institutional channels and science YouTube channels in Mexico, Peru and Bolivia. The methodological approach was based on the epistemological premise of pragmatism; hence it was a mixed study of concurrent design. A group of systematised empirical (quantitative analysis) and critical (qualitative content analysis) techniques was used. Seventy-one videos were analysed, i.e., 40,096.28 minutes of recording. These were selected from four channels of science YouTubers and four institutional channels from Mexico, Peru and Bolivia that were selected based on inclusion and exclusion criteria. Differences in behavioral engagement and scope were observed in the Youtuber and institutional channels. Strategies for content- presentation were identified that favour emotional and cognitive engagement but are mainly used by science Youtubers. We conclude that the need exists for science-producing and managing institutions to incorporate the use of these simple and effective strategies for a greater and better dissemination of science on YouTube.

Keywords
Scientific dissemination; YouTube; engagement

Resumen
YouTube se ha configurado como un espacio para la divulgación masiva de la ciencia que ha gozado de una amplia aceptación de la población. Esta investigación tuvo como objetivo analizar la divulgación científica en YouTube en canales institucionales y de Youtubers de ciencia en México, Perú y Bolivia. El abordaje metodológico se hizo sobre las premisas epistemológicas del pragmatismo, por lo que fue un estudio mixto de diseño concurrente. Se empleó un grupo de técnicas sistematizadas empíricas (análisis cuantitativo) y críticas (análisis cualitativo del contenido). Se analizaron 71 vídeos, equivalentes a 40.096,28 minutos de grabación. Estos provenían de cuatro canales de Youtubers de ciencia y de cuatro canales institucionales de México, Perú y Bolivia que se seleccionaron con base en los criterios de inclusión y exclusión. Se observaron diferencias en cuanto al engagement comportamental y alcance en los canales de Youtubers e institucionales. Se identificaron estrategias para la presentación del contenido que favorecen el engagement emocional y cognitivo, pero que son usadas principalmente por los Youtubers de ciencia. Se concluye la necesidad de que las instituciones productoras y gestoras de ciencias incorporen el uso de estas estrategias sencillas y efectivas para una mayor y mejor divulgación de ciencia en YouTube.

Palabras clave
Divulgación científica; YouTube; engagement

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1. Introduction

Science communication is a relevant field of action and study (Lewenstein & Bruce, 2022) because it can serve purposes such as science education (Escobar & Rincón, 2018). The popularization of science involves "bridging the gap between the scientific arena and the rest of the world that, in most cases, is reluctant to enter this type of information" (Morales, 2021: 139). Massarani (2018) noted the use of different terms in the literature to refer to science popularisation, including science popularisation, science communication, non-formal science education and science popularisation. For the purposes of this article, science popularisation and science communication are used interchangeably.

Currently, the exclusivity to decide how to disseminate science has undergone disruptive processes to fulfil the needs of a generation eager to participate, give their opinion, and be part of the solutions. This generation is also characterised by the use of technology. Consequently, the way science is communicated has changed (Gripp & Machado, 2020). New media and formats are emerging; they challenge the socio-cultural and socio-discursive practices of discourse communities and open up access to scientific information to an audience outside the circle of experts, taking advantage of the ubiquity of mobile devices and the versatility of digital social networks.

The transformation of the media and formats for scientific communication has activated the interest of people who research science or expect to do it. Several researchers have been involved in describing the study of scientific dissemination in digital social networks such as Twitter (Denia, 2021; Molina-Canabate & Magallon-Rosa, 2020), TikTok (Neira, Domínguez & Lobo, 2023), Twitch (Buitrago & Torres-Ortiz, 2022b), and YouTube (Buitrago & Torres-Ortiz, 2022a; De Azevedo e Silva y Vieira, 2019; Ojeda-Serna & García-Ruiz, 2022; Vizcaíno-Verdú, De-Casas-Moreno & Contreras-Pulido, 2020).

YouTube stands out among the most accepted media for the massive diffusion of science (Fernández, Menéndez & Fuertes, 2019). YouTube is an excellent resource for learning about science (Dubovi & Tabak, 2020). It is a platform for hosting videos that allows a multimodal dialogical process between people broadcasting content and their audience, who can interact through comments, reactions, and synchronous and asynchronous conversations (chats) (Celik, 2014; Mogo & Trofin, 2015).

Different discursive genres have been identified for conveying information in YouTube. It is worth to mention that, in this study, genres are understood according to Bajtín (1982) and Swales' (1990) framework. For those authors, a discursive genre is a vehicle of communication that arises within discourse communities to fulfil specific rhetorical functions. In sum, it is an oral or written linguistic production comprising certain stereotyping, prototypical linguistic resources and a social dimension (Parodi et al., 2008). Regarding genres on YouTube, authors such as Himma-Kadakas et al., (2018) and Mogo and Trofin (2015) explain that it may be hard to classify genres in this platform due to its dynamism and the speed with which content appears and changes. Himma-Kadakas et al. (2018) identified nine genres of videos on YouTube: advertisements, challenges, tutorials, games, performances, humour, compilations, commentaries and collections. Those genres can appear in various formats, namely: sitting, interview, live, screen sharing, sketch, music video and Vlog, the latter being very common. Considering this variety, YouTube is an attractive platform for the dissemination of science through the creation of content on a channel that represents almost unlimited possibilities for reaching millions of users (Buitrago, García & Beltrán-Flandoli, 2022), as well as offering economic advantages, as it allows the channel managers to monetise if they meet some requirements regarding the number of users and reactions to their content.

The concept of youtuber encompasses a heterogeneous set of profiles of individuals who manage YouTube channels. These profiles range from people who tell details of their lives on camera or present strategies for video games (people whose audience is quite specific and defined) to those presenting content with concrete contributions to society, such as the dissemination of scientific information for a variety of audiences (Buitrago & Torres-Ortiz, 2022b; Massarani, 2018). These individuals who manage science or technology content channels are also known as Cultubers (Buitrago, García & Beltrán-Flandoli, 2022), science influencers or science youtubers (Buitrago & Torres-Ortiz, 2022b; García, 2022; Zaragoza & Roma, 2020). In this article, the terms 'science youtubers' and its abbreviated version (youtubers), will be used to refer to people whose personally-initiated channels share mainly or exclusively scientific content.

Regarding the popularisation of science on YouTube, researchers have analysed the scientific themes of science youtubers and the credibility that their content represents for university instructors (Vizcaíno-Verdú, De-Casas-Moreno & Contreras-Pulido, 2020). Also, in Spain, García (2022) qualitatively analysed the profiles of Spanish science youtubers and their strategies to present the content, focusing on their strategies to gain popularity and achieve greater engagement with their audience. De Azevedo and Vieira (2019) contrastively analysed the discourse used in two YouTube channels to communicate information related to different scientific topics treated in common, looking for patterns of convergence and divergence in science communication in these two channels.

Besides, Buitrago and Torres-Ortiz (2022b) analysed science outreach on institutional YouTube channels and science youtubers in Spain. They found relevant differences regarding their engagement capacity, that is, variations in the sense of belonging developed by the user towards the channel (Ojeda-Serna & García-Ruiz, 2022).

Ojeda-Serna and García-Ruiz (2022) studied scientific publications on YouTube by universities, museums and Youtubers in Colombia, Ecuador and Peru. They analysed one channel of each type per country and found higher engagement in independent channels than in those managed by universities and museums. These studies have addressed channels of institutions and science youtubers; however, these comparisons did not consider their resources or the discursive strategies as has been done in the study of science communication in other digital social networks (Buitrago y Torres-Ortiz, 2022b). Approaching these issues is helpful to understand strategies and resources potentially associated with the success of the channels.

De Azevedo and Vieira (2019) comparatively analysed two YouTube channels from Brazil and the United States. As previously stated, some research has come close to investigating the differences and similarities between science outreach on institutional channels and science youtubers' channels. However, in Latin America, specifically in countries with different levels of scholarly production, there has been no research to qualitatively and quantitatively analyse YouTube channels from the perspective of the engagement generated by the public and the discursive strategies used for science outreach.

Latin American countries are struggling to increase the quantity and quality of scientific and technological production. International university rankings show poor positioning for most Latin American countries regarding scientific dissemination in indexed journals (De-Moya-Anegón et al., 2021). Consequently, there is a need to enhance interest in science throughout the community. The study of popularisation through media like YouTube would help to propose alternatives consistent with the dynamics and informational preferences of current generations. As Muñoz et al. (2019) stated, the ways to disseminate knowledge contribute to the construction of the social conception of science and the interest that young people may feel in it.

In this context, to study science channels on YouTube would allow an approach to the strategies that are more attractive or trigger more interest in science. A comparative view would allow us to visualise science outreach in countries with different levels of scientific production. Also, it would help to appreciate potential differences between them and, based on the results, to propose strategies that contribute to improving science outreach.

Based on this scenario, we analysed science dissemination on YouTube in institutional channels and science youtubers' channels in Mexico, Peru and Bolivia (three countries with different levels of scientific production according to international rankings) (De-Moya-Anegón et al., 2021). Thus, we sought answers to the following questions: How is science disseminated on institutional YouTube channels and science youtubers in these countries? What tools do they use to present their content to their audience? What is the engagement and reach of both types of channels in the three countries?

The proposed analysis involved the handling of concepts associated with the tools used to generate both reach and engagement. Engagement, in general terms, is the level of attachment or loyalty shown by the user to a brand (Mendia-Valarezo, Morales-Padilla & Moscoso-Parra, 2022). It can be understood as user loyalty comprising the number of likes the channel has obtained (García, 2022; Mendia-Valarezo, Morales-Padilla & Moscoso-Parra, 2022). In the case of a YouTube channel, it is possible to analyse engagement for the channel in general and for each of the videos it disseminates.

García (2022) differentiates three types of engagement: behavioural, emotional and cognitive. Behavioural engagement is a trait that can be quantitatively evaluated. It represents the attraction and loyalty of users as part of a community (Buitrago & Torres-Ortiz, 2022a). Emotional and cognitive engagements are assessed qualitatively and are reflected in the verbal and non-verbal communication between the channel administrator and the audience. These engagements can be noted in the communication among the followers. They reflect the emotional valence in the comments and cognitive efforts based on the video content(Cambronero-Saiz, Segarra-Saavedra & Cristófol-Rodríguez, 2021).

1.1 Discursive genres as a strategy for science popularisation

The literature has evidenced that people posting videos on YouTube use different tools to increase their reach (views) and engagement. The format used to display the content is among these tools. It has been the subject of study by discourse analysts trying to define the discursive genres on YouTube (in Bakhtinian and Swalescian terms), although their dynamism makes this classification a complex task (Himma-Kadakas et al., 2018; Mogo & Trofin, 2015).

The vlog is the video version of the traditional written blog, but it presents distinctive traits that make it an independent genre. These, in addition to the context, include the discursive resources used to achieve the communicative purpose (De Piero, 2014). The vlog features videos with varying levels of editing quality and complexity. These videos can be recorded indoors (home or office, for example) or outdoors (Dressman & Lee, 2021). The vlog originated with the main purpose of entertaining, although it can reach alternative objectives. It is a particular genre of web production to develop ideas about a topic and elicits interaction with the audience through comments. Despite the differences with the blog, both genres (blog and vlog) share some similarities (presence of title, date of broadcast and reference to the user). Generally, vlogs comprise concise videos that do not exceed 30 minutes (De Piero, 2014).

Another popular genre on YouTube is the 'How to' video, a more popular term for 'tutorial' videos. According to Mogo□ and Trofin (2015), when searching on YouTube with both descriptors separately, there are more results for 'how to'. These videos, made by professionals or amateurs, show ways to perform procedures or solve situations (Mogo□ & Trofin, 2015). In these videos, the presence of a person explaining the content on the screen is not essential; that is because the focus is on the procedures they demonstrate to the audience for detailed observation.

1.2 Tools to increase engagement and reach

In addition to the format and genre used for channels' videos, there are other tools to increase viewing statistics, reach and engagement on YouTube. Among these are video metadata, playlist generation (own or third party), video duration, hyperlinks, calls to action (for instance, react or comment), thumbnails and the rhetorical function of the title (Loperoza et al., 2019). Regarding the latter, titles have been studied in different contexts due to their importance for any discursive genre (Morales et al., 2020, 2022), including audio-visual genres (Bae & Kim, 2019). Titles constitute the first piece of information available for the users (Al-Mazrouei et al., 2022). They may or may not elicit interest in accessing the whole content (Celik, 2014). Consequently, due to the effect they can have on the audience, they are a crucial discursive tool when analysing videos from a YouTube channel.

2. Methodology

The study was a mixed-research of concurrent design, also known as a sequential or parallel design. In this sense, we performed simultaneous procedures for the quantitative information and qualitative data gathering, without one depending on the other (Hernández, Fernández & Baptista, 2014). The corresponding quantitative and qualitative analysis techniques were used. Through their integration, analysis, and discussion, it was possible to comprehensively understand this phenomenon encompassing components for quantitative examination (reach and behavioural engagement) and qualitative investigation (strategies, emotional engagement, and cognitive engagement).

Social Blade was used for the selection of channels. Social Blade provides information on the position of the channels in the global and country rankings. This platform is constantly updated and, due to its reliability, has served as a support tool in previous studies on social networks, including YouTube (Buitrago & Torres-Ortiz, 2022b, 2022a; Cambronero-Saiz, Segarra-Saavedra & Cristófol-Rodríguez, 2021; Loperoza et al., 2019).

The quantitative analyses included reach and behavioural engagement. Then, quantitative information available on the YouTube channels was examined. Descriptive statistics were considered; specifically, we calculated measures of central tendency and dispersion (for video duration), and frequencies (for behavioural engagement and reach). The qualitative examination of the videos considered the form of presentation of the content and audio-visual strategies used to present the content. Additionally, we performed a contextual analysis; it included the comments and reactions to the videos for emotional and cognitive engagement.

2.1 Sample description

The Latin American countries in the sample were selected based on the Ranking of Ibero-American Higher Education Institutions for 2021 (De-Moya-Anegón et al., 2021). This ranking shows the productivity (scholarly publication) of higher education institutions between 2015 and 2019. One country was selected from each of the three groups of the ranking: Mexico from the first group (countries over 60,000 publications), Peru from the second (countries between 1,000 and 60,000), and Bolivia from the third one (countries between one and 1,000). This selection was expected to reflect science outreach on YouTube in countries with large, medium, and low performance in formal scientific publications.

Subsequently, Social Blade and YouTube were used to identify science channels for the three countries. We included four channels per category (institutional and individual) for each country (Mexico, Peru, and Bolivia). Twenty-four channels were chosen (Table 1). This sample size is adequate for the proposed

objectives and methods of the present study. We supported this methodological decision on a literature review that showed successful similar studies with smaller samples, for example, six channels (Buitrago & Torres-Ortiz, 2022b), and two (De Azevedo e Silva & Vieira, 2019).

The sample channels met the following inclusion criteria:

- They were the channels of their type with the most subscribers in their country during the Social Blade search.
- They were labelled as science or technology channels.
- They were active at the time of the research (at least two posts per month).

We selected three videos per channel. The process resulted in a corpus of 72 videos. The main selection criterion to choose the videos was to show the highest number of views on their respective channel between January, February and March 2023. There were no ethical conflicts for the analysis of these channels because the information was open to the public, and the treatment of the information did not harm any of those involved.

Table 1: Channels included for analysis

Country	Institutional channels				Private channels (independent *youtubers*)			
	Name	**NS**	**VT**	**VLM**	**Name**	**NS**	**VT**	**VLM**
Mexico	TV UNAM	499.000	103.957.443	565.278	CuriosaMente	2.880.000	364.425.522	5.524.000
	Universidad Tecnológica de México	75.100	1.015.041.800	38.593.000	MindMachine TV	112.000	13.472.724	151.157
	Conacyt México	35.100	2.716.421	134.335	La ciencia detrás de	43.000	1.606.494	28.904
	El Colegio Nacional	84.100	14.842.647	805	Astrofísicos en Acción	61.500	2.988.823	17.270
Peru	Concytec Perú	18.800	3.198.818	27.111	El Robot de Platón	2.650.000	386.715.281	5.278.000
	INGEMMET Perú	11.700	1.272.601	9.944	Dr. Luis Antonio Pacora Camargo	578.000	62.352.660	762.635
	Universidad de Ingeniería y Tecnología	13.200	11.035.199	121.758	Profesor HibiTo	22.900	1.282.986	8.842
	Inia Peru	131.000	25.286.018	243.680	Humberto Higinio	370.000	49.539.882	509.519
Bolivia	Agetic Bolivia	7.530	1.529.299	34.297	@marcelopardo	205.000	20.694.240	412.925
	UMSA	1.880	147.758	11.256	Kiketeenseña	35.500	2.182.732	34.180
	Univalle Bolivia	4.220	1.615.778	2.909	Urckari	614,000	117.471.701	4.067.000
	UTP de Santa Cruz	1.200	629.910	1.495	You Tops	232.000	32.790.387	6

Note: NS (Number of subscribers), TV (Total views), VLM (Views during last month). This was the updated information on YouTube channels when data collection was performed. The names of the channels and institutions have been copied verbatim.

2.2 Instruments and procedures for information collection and analysis

We developed a matrix displaying variables and categories for the quantitative and qualitative approaches, respectively (Table 2). This matrix was the cornerstone for data collection.

Table 2: Matrix used for the elaboration of the sheet for content analysis

Type of analysis	Variable	Concept	Indicators
Quantitative	Behavioural engagement	Level of attachment that a user shows to a brand (Mendia-Valarezo, Morales-Padilla & Moscoso-Parra, 2022). Attraction and loyalty of users as part of a community (Buitrago & Torres-Ortiz, 2022a).	Number of comments. Number of reactions (likes and dislikes).
	Channel reach	Range of people showing interest in content (Buitrago y Torres-Ortiz, 2022a).	Number of views.
	Duration	Length of videos uploaded to the channel.	Average length of videos per channel.
Type of analysis	**Category**	**Concept**	**Sub-categories**
Qualitative	Strategies for content presentation	These are the ways used by channel managers to present their content. These strategies cover thematic organisation and format, strategies associated with resources, and discursive strategies used to deliver content to their audience.	Genre the video fits into (Himma-Kadakas et al., 2018). Link to other author's sites (Loperoza et al., 2019). Access to additional or complementary information (Loperoza et al., 2019). Thumbnails (Loperoza et al., 2019). Rhetorical function of the title (Bae & Kim, 2019; Loperoza et al., 2019). Aesthetics (Hunicke, Leblanc & Zubek, 2004).
	Emotional and cognitive engagement	They constitute verbal and non-verbal communication between the channel manager and the audience, and audience communication with each other. It represents the emotional valence in the comments and cognitive efforts based on the video content (Cambronero-Saiz, Segarra-Saavedra & Cristófol-Rodríguez, 2021).	Type of reactions. Type of comments. Content of the comments.

Note: own authorship, based on the cited authors.

The matrix presented in Table 2 was the foundation for the research instrument, namely, the content analysis sheet. This sheet was designed to record the information in a digital format. This sheet and the matrix were evaluated by experts in discourse and content analysis. After the assessment, they stated its validity as they found that the matrix and the instrument efficiently covered all the issues to respond to the research objectives.

Two researchers analysed the videos independently. To prevent biases associated with the reliability of data collection and to give scientific rigour to the study, researchers were trained for the use of the matrix, as recommended in the literature both for quantitative (Villasís-Keever et al., 2018) and qualitative (Bedregal et al., 2017) instruments. In this sense, we studied each variable and category, and their indicators or subcategories to ensure that both researchers managed the same criteria for processing information. Then, independently, each analysed four videos similar to those in the sample. The results were cross-checked by an external expert who found a complete coincidence of criteria. Then, there was no need to go back to the sample or to the theory to settle differences in criteria.

3. Results and discussion

A corpus of 72 videos was proposed; however, one channel from Bolivia (a country with few scientific channels) only submitted two videos that met the inclusion criteria. Then, the corpus finally consisted of 71.

3.1 Quantitative characterisation

Seventy-one videos (40,096.28 minutes of footage) were analysed. Table 3 summarises the information on the average duration for each type of channel (youtuber - institutional) by country and the results of the quantitative analysis of behavioural engagement and reach. Table 3 indicates that the youtubers' channels show higher behavioural engagement, even though some institutional channels exceed them regarding views (e.g., Mexico and Bolivia). Bolivia is the country with the lowest engagement for youtubers' channels. In Peru, on the other hand, science youtubers channels showed higher reach and engagement than institutional ones. This finding is similar to previous studies addressing these two types of channels in Spain (Buitrago & Torres-Ortiz, 2022a; Ojeda-Serna & García-Ruiz, 2022). It seems to confirm that the number of views does not necessarily reflect the engagement and growth of the channel. It is worth mentioning that, between reach and engagement, the latter is more relevant because it represents the loyalty of the target audience, who not only eventually view content but also subscribe to and follow the channel's production, making it grow in the rankings.

Table 3. Video length, behavioural engagement and channel reach sorted by type and country

		Lenght in minutes				*Behavioural engagement*			Reach
Country	**Type of channel**	**Min**	**Máx**	**Mean**	**SD**	**C**	**Likes**	**Dislikes**	**Views**
Mexico	*Youtuber*	4,38	13,13	7,9	2,9	2.947	62.679	0	870.578
	Institutional	0,20	59,12	22,9	23,9	43	843	0	40.014.569
Peru	*Youtuber*	1,50	71,06	27,9	21,2	8.707	196.387	0	2.766.460
	Institutional	0,10	161,49	19,2	45,3	17	660	0	153.295
Bolivia	*Youtuber*	2,15	20,37	12,6	6,5	3.111	9.758	0	239.388
	Institutional	0,10	45,03	6,0	13,3	39	181	0	666.686

Nota. SD: Standard deviation; C: comments.

Videos length is considered one of the most relevant viewing and marketing strategies on YouTube. Consequently, experts recommend that videos should be brief and that the first 15 seconds should attract the audience's attention (Loperoza et al., 2019). However, except for Mexico, all YouTubes' channels show a longer average length than institutional channels. It seems to confirm the need to analyse the way they present their content in order to understand why they generate more engagement even with longer videos.

The presence of the youtuber on the screen is a differentiating element that can influence engagement for Youtubers and institutional channels. In the latter, this presence tends to be less frequent, and generally, they do not have a permanent image of the channel. On the contrary, those who appear on the screen are, for example, guests, lecturers, and students in institutional advertising. Their presence lacks continuity that can generate engagement with the audience. On YouTube channels, even when the person is not visible on screen to prioritise their content (e.g., in 'know how' videos), the audience can identify the same broadcaster in each video. Besides, this person usually interacts verbally with the audience.

Analogous to Buitrago and Torres-Ortiz (2022a), we found that videos from science youtubers' channels receiving more reactions were those dealing with controversial topics (e.g., UFOs, Evolution of species), practical content (e.g., use of tools and construction techniques), and current issues (e.g., presence of viruses and genetic codes). For institutional videos, the most viewed were those related to administrative processes (e.g., enrolment and admission processes) and important events (e.g., student fairs and scientific congresses). However, as noted above, although institutional videos had a high reach, engagement was low in all three countries.

3.2 Qualitative characterisation

In general, there were differences in the strategies used by independent youtubers and institutional channels. This finding for Mexico, Peru and Bolivia is similar to that observed in previous studies for Spain and Colombia (Ojeda-Serna and García-Ruiz, 2022). These are discussed in detail below.

3.2.1 Prevailing genres

Most of the channels of individual youtubers presented their videos in the vlog genre, whereas the institutional channels used other genres named by Himma-Kadakas et al., (2018); for instance, sketches and interviews in a formal setting. The vlog has been reported in the literature as being used by more successful and popular YouTube channels (Sabich & Steinberg, 2017), including channels of science YouTubers (Buitrago & Torres-Ortiz, 2022b).

As De Piero (2014) highlights, the vlog was born with the intention to entertain, so it does not seem an isolated fact that youtubers prefer it to share content in a fun and entertaining way that elicits empathy in the audience. Despite its success and popularity, it is striking that institutional channels are not using this genre to generate greater reach and engagement. However, no studies have been found to discuss or analyse the reasons why youtubers and institutional channel managers choose a format or genre.

The structure of the vlog genre can be variable, as with other genres, but generally, it starts with the introduction of the topic and has a build-up and a closing. The opening and closing may contain short segments (clips) consistent across all broadcasts and segments within the content. We observed, as in Celik (2014), that science youtubers use the opening and closing to empathise with their audience, appeal to their sympathy and invite them to respond and subscribe.

Finally, a distinguishing feature of the vlog observed in some of the science youtubers' videos is the use of direct cuts. These are cuts made during editing to shorten the content and remove unwanted parts of the recording (De Piero, 2014). They enable youtubers to edit and incorporate additional content, such as images, gifs, and memes, without it being perceived as inappropriate or unexpected.

3.2.2 Linking to other author's sites and access to additional or complementary information

The presentation of links to other sites of the channel's owner was a frequent feature for science youtubers and almost zero for institutional channels in the three countries. This finding has partial similarities with Pattier's (2021) findings for science youtubers in Spain. In addition, we observed that youtubers tend to mention scientific evidence to support their content. In the institutional channels, this was only seen when interviewing experts or playing videos of papers and conferences.

The difference in the use of this strategy between the two types of channels seems to depend on their goals. Independent youtubers aim to monetise, so they appeal to a transmedia expansion in other networks. This strategy enhances the increase of followers (Hidalgo-Marí & Segarra-Saavedra, 2017). In addition to promote themselves and inviting the followers to also follow them on other social networks, science youtubers provide links to endorse all their channels with similar or complementary content. In this way, they aim to maintain the interest and increase their reach and engagement on all their channels and digital media. This strategy was observed, for example, in Plato's Robot channel (*El Robot de Platón*). The owner of this channel has diversified his content into three different science channels on YouTube and a science blog outside this social network.

3.2.3 Rhetorical function of the title and use of thumbnails

The analysis included the rhetorical function of the title of the videos and the thumbnails. These are part of the VSEO strategies (VSEO standing for "Search Engine Optimisation" applied to the positioning of video content) recommended in the literature (Loperoza et al., 2019). In the corpus, two types of titles were observed: Informative and stimulating.

An informative title contains information about the genre or the content of the text (Bae & Kim, 2019). In the corpus analysed, it refers to information about the genre to which the video belongs. For example, lecture, podcast or interview, as seen in [1] and [2] or directly about the content like in [3] and [4]. At the end of each example, we have indicated the code to identify each video [1]. All the examples have been written verbatim in their original language.

[1] "RobóTICas V3 - Niñas de 7 a 10 años (Clase 1 MAÑANA)" (BI2303)

[2] "Plenaria: Innovación social en la era de la recuperación" (PI1301)

[3] "Bombarderos de sexta generación sustituirán a los B-2 Spirit en EEUU" (BY2002)

[4] "Caracterización celular, molecular y genómica del cáncer para el desarrollo de inmunoterapias" (MI703)

Stimulating titles generate curiosity and interest in the reader. This interest is usually triggered by a question, as shown in [5] and [6], or by a statement that does not inform or describe the content of the video but gives 'clues' to it in an eye-catching form, as illustrated in [7]. It is important to emphasise that these titles are eye-catching, but they do not engage in fallacies or mislead the audience. They only stimulate their curiosity.

[5] "¿California era una isla?" (MY101)

[6] "¿Podría Pasar "The Last of Us" en la Vida Real"? (PY903)

[7] "Virus zombie y más descubrimientos "virales" en 2023" (MY301)

The title has an effect on VSEO. In this sense, the literature recommends that in addition to informing about the content, it should be attractive to users (Loperoza et al., 2019). As found by Buitrago and Torres-Ortiz (2022a) for YouTube channels in Spain, a difference was observed between the titles of institutional channels and youtubers from the three countries analysed. Institutional channels use mostly informative titles, while youtubers' channels (with the exception of Bolivia) show more stimulating titles that generates curiosity and expectation in the user about what they will find in the video.

Sometimes, stimulating titles are combined with thumbnails as strategies to increase the visibility of the videos (Loperoza et al., 2019). These thumbnails also showed a pattern in our corpus. In institutional channels, they are mostly formal while, in Youtubers' channels, they are informal, colourful and eye-catching in combination with stimulating titles.

3.2.4 Aesthetics

Aesthetic experiences encompass different features associated with how enjoyable videos can be for the audience. These traits can be a sense of fantasy, credibility, camaraderie, and discovery, among others (Hunicke, Leblanc and Zubek, 2004). Our analysis showed that the aesthetics differ for both types of channels and these differences are consistent for the three countries. In institutional channels, formality and institutionalism predominate, but in the youtubers' channels, sympathy and entertainment are outstanding, as previously observed by Bernad-Mechó and Girón-García (2023). We observed humour as a strategy to elicit sympathy, but the goal was to get the user to the semantic field of knowledge. Irony, exaggerations and references to popular culture are some strategies observed in videos of individual youtubers. These modes of humour were identified by Bernad-Mechó and Girón-García (2023) as very frequent in science dissemination.

In the corpus analysed, the vlog format (preferred by most Youtubers) tends to generate aesthetics of emotional closeness in the audience. A comparable finding was reported by Buitrago and Torres-Ortiz (2022b) in a study of science outreach on Twitch. They showed that people who communicated science in a vlog format easily engaged with users.

A similar result was observed by Sabich and Steinberg (2017). They noted that the prevailing rhetorical strategy in youtubers channels is to stimulate the generation of aesthetics associated with contact and affection to produce engagement in their target audience. Similarly, our results are in line with the study by Zaragoza and Roma (2020) because they also found that a discourse able to generate emotions from empathy and affection produces engagement and determines the success of science channels.

3.2.5 Cognitive and emotional engagement

Engagement, both emotional and cognitive, can be observed in the comments of the channel's users (Cambronero-Saiz, Segarra-Saavedra & Cristófol-Rodríguez, 2021). In general, all the institutional channels received very few comments, unlike the youtubers' channels, as evidenced in Table 3. In this analysis, five categories of comments emerged. These reflected the types of engagement and the strategies that triggered them. Each category is explained and exemplified below with comments by users copied verbatim.

1st category: Comments related to the presence of guests on the channel.

This category appeared mainly in youtubers' videos and was present in two institutional channels (one comment in one video from each channel). We noted that pleasure was elicited in the audience by inviting other well-known youtubers as guests, making winks, cameos and references to them. These actions do not go unnoticed; they are also exciting and make viewers want to watch new videos in anticipation of new surprises of the same kind. Among the comments, some people expressed pleasure

and greeted the gests, as can be seen in the following examples of comments on videos showing a youtuber from another country [8], or someone from another local channel was invited to discuss a topic [9]:

> [8] "Ese cameo inesperado del panconjamonismo no me lo esperaba, saludos a Aldo Bartra de el robot de platón…" (MY101)
>
> [9] "Muy interesante Aldo, no conocía al entrevistado, pero me ha parecido que presentaba muy buenas explicaciones. Buscare su canal. Muchas gracias por su labor y mucho ánimo con su canal!" (PY902)

Guests from other channels may respond to the strategic background of the Youtuber since showing quality followers who reflect engagement may evoke it in others (Fernández, Menéndez & Fuertes, 2019), Consequently, interaction with owners of other channels with strong engagement is beneficial to maintain the interest of the audience.

2nd category: Comments on the content and its presentation.

Science youtuber channels received more comments than institutional ones. Among all the categories, remarks on the content and its presentation were more frequent, especially on the channels from Mexico and Peru. These comments show that youtubers present their content in an entertaining, but scientifically rigorous way. They choose appealing topics, even those associated with everyday life, which generates engagement with the audience. The examples [10] and [11] illustrate those comments.

> [10] "Perfectamente explicado para el público en general, sin abusar de tecnicismos" (PY901)
>
> [11] "Es tan agradable escuchar opiniones sensatas sobre los Ovnis, usualmente las personas se dejan llevar por el amarillismo y sus emociones nerviosas son contagiosas. Gracias" (PY902)

These excepts above show appreciation for receiving information on interesting scientific topics transmitted in a discourse close to the audience. This interaction reflects what Nichols and Petzold (2021) suggested. They stated that, for non-scientists, the discourse of science itself is strange, opaque, and alienating. This discourse distances them from the scientific community and reduces their interest in listening to what they have to say; therefore, using a discourse that is closer to the audience is appreciated and generates engagement.

Examples, demonstrations and analogies to present content are strategies used by science youtubers. They generate emotional responses from users as perceived in comments [12] and [13].

> [12] "Me encanta todo lo que aprendo con ustedes, y particularmente bonito el ejemplo del faro" (MY402)
>
> [13] "Buenísimo el vídeo Maestro, esas herramientas están espectaculares sobre todo la pinza amperimétrica muy completa, mil gracias por tomarte el tiempo…" (PY1202)

Humour is another strategy. It is used even to discuss serious topics with content based on scientific sources. This strategy generates engagement with the audience. Comments [14] and [15] are examples of the audience's reaction to humour.

> [14] "Me encanta el sentido del humor de Aldo, hace que sus vídeos sean tan cómodos de ver por así decirlo y no se haga pesado…" (PY903)
>
> [15] "Ando algo preocupado, ...desde que te conozco (tus vídeos) entre a menudo a ver tus cortos de divulgación científica como amante de la ciencia que soy. Me cuestiono ahora si lo hago solo por eso o por tu sentido del humor. Ya lo dije una vez y lo repito ahora: que grande eres!" (PY903)

This finding is in line with Bernad-Mechó and Girón-García (2023). They found that humour in popular science channels helps to generate empathy in the audience and increases their engagement. This treatment brings the audience closer. The followers respond emotionally with words, smiley faces, thumbs up and other expressions of liking and affection. Celik (2014) also observed comments using these combinations. Communicating through emoticons expresses a greater emotional charge that

the audience wants to convey to the youtuber. As Cheng (2017) states, a simple smiley face can make a message friendlier and give it a kinder tone. Furthermore, emoticons capture attention faster than text and convey emotion effectively (Cheng, 2017). These graphic expressions interspersed in comments are a written version of the bodily expressions and suprasegmental features used in speech acts that can be ways in which subjects position themselves in social life and in the language life, and that varies across cultures (Cheng, 2017; Sisto, 2015).

These strategies of content presentation create an emotional bond with the youtuber. The youtuber is seen as an authority disseminating content and is considered a close person. The audience feels free to interact and empathise with that individual. Similarly, sharing information about the youtuber's personal projects develops a sense of trust, friendship and affection in the audience. The comment [16] is an example of this type of engagement. It was a reaction to the reappearance of a youtuber who shares the conduction of a channel with other people. Finally, it is also observed in [17] when a youtuber announces that he will take a break from the channel for a few days as he has started a new academic project that will demand some time.

> [16] "She's back. The Karen of the Science is back!! Enhorabuena!!" (MY302)
>
> [17] "felicidades de verdad extrañare tus videos este tiempo que te tomes para abrir segunda temporada pero que la divulgación no pare y a compartir como siempre (aunque casi no comente)" (MY203)

The literature has associated these emotional links with behaviour and discourse at two crucial moments in the discourse: opening and closing (Celik, 2014).

3rd category: Questions related to content.

Youtubers' videos triggered the audience's interest through their explanations. Also, they enhance confidence in the audience to ask questions about the content. They do it in a relaxed and emotional way, as can be seen in [18] and [19]:

> [18] "Aldo, déjame preguntar: además de la interacción gravitacional ¿Cómo los cambios en la superficie de la tierra tendrían un efecto (así sea pequeño) sobre la duración del día?" (PY901)
>
> [19] "Saludos ing, gran video como siempre, podria ser una solucion colocar una columna en diagonal? es decir conectar la columna del piso superior con la inferior con una columna inclinada?" (BY1701)

These types of comments become recurrent when the youtuber answers the questions. Sometimes, they write the answer or respond verbally in a subsequent video. In both cases, they keep the engagement because the followers know that they will get answers to their inquiries.

4th category: Personal extensions to the content

Clearly, the topics discussed in the channels are appealing to the viewers. In several occasions, they relate the content to their everyday lives. Some people add comments to complement what is said in the video, as seen in [20] and [21]. Other users comment by adding examples from their own experience, as seen in [22], showing that they have understood of what is explained in the video. In this way, users demonstrate cognitive engagement with the channel.

> [20] "Que buen revisado, yo comence en astrofotografia con un mak 90 parecido pero de la marca skywatcher, lo compre barato y este venia con una montura altazimul motorizada," (MY402)
>
> [21] "Recomiendo mucho el libro 'Privacidad es poder' de Carissa Veliz, ahí describe a detalle cómo nos roban información y hasta influyen en nosotros a través de las distintas" (MY202)
>
> [22] "Seguro tengo mucha oxitacina, porque duermo muy bien y me quedo dormido muy rápido." (MY303)

5th category: Suggestions or requests for new content.

Users of the youtubers' channels freely requested new videos with content of their interest (see examples [23] to [25]). In some channels, the youtuber answered these requests. This practice occurs on the part of the audience because, as with the questions on the topics discussed, the youtubers review them

and, in some cases, develop content based on the comments.

> [23] "Muy interesante. Me gustaría que comentes sobre los quasars. Saludos desde Costa Rica" (MY301)
>
> [24] "Hola Humberto podrías hacer un video sobre el GM328? Tbm llamado tester de transistores" (PY1203)
>
> [25] "¿Podrías hacer las curiosidades sobre todos los continentes, también?" (BY1901)

We noticed that emotional and cognitive engagement with the audience generates reciprocity in the youtubers. The comments and reactions of the followers encourage them to continue producing and transmitting content that meets their needs. Celik (2014) compares these comments to a variant of textual applause or a kind of cheers manifested in the Internet language. According to Celik (2014), this language is characterised by abbreviations, modified spelling, slang and even multilingualism, and depending on the findings reported in this study, emoticons.

In short, we analysed the five categories of response in the youtubers' channels, the strategies (discursive, content presentation and use of tools) that generate them and the engagement they reflect. We summarise them in Table 4.

Table 4. Strategies used by science Youtubers and the type of engagement they generate with their audience

Strategies	Engagement they elicit	Audience reaction reflecting that engagement
Humour: jokes, presence of images, funny gifs or memes, as the content is presented.	Emotional	Closeness, liking the content and the person presenting it.
Invite other youtubers: interviews, joint analysis, winks, cameos or other.	Emotional	Sympathy, respect for the presenter of the channel.
Examples and metaphors.	Cognitive	Interest in the content, recognition of the youtuber as a knowledgeable and empathetic person who is interested in sharing knowledge with others.
Speech without excessive technicality.	Cognitive and emotional	Learning and affective closeness with the person in charge of the channel, who understands that non-scientists need to know about science in a simple way, without losing scientific rigour.
Respond to subscribers (in comments or in new videos).	Cognitive and emotional	People show interested in learning more about the topic. People stay tuned to the channel, expecting a response to their comments and new videos with the content they expect
Share personal information about the owner of the channel (academic interests, projects, other).	Emotional	Empathy and sympathy. People identify and also develop a sense of admiration. Credibility grows when the Youtuber shows evidence that is constantly preparing to offer better content

Strategies	Engagement they elicit	Audience reaction reflecting that engagement
Vlog format (presence of the Youtuber in an informal setting, which can be their home or office, even outdoors).	Cognitive and emotional	Users like to watch the Youtuber; the vlog format creates a sense of intimacy. The relaxed presentation of this content with visual and audio-visual elements that eventually appear, stimulates interest and makes it possible to reach people with different learning styles.
Addressing scientific issues related to everyday life.	Cognitive and emotional	Interest in learning about a topic relevant to the subscriber's immediate reality. Sympathy for the youtuber's interest in sharing this type of interesting information.

Note: Prepared by the authors on the basis of the analyses carried out.

These strategies were observed in science youtubers channels, as opposed to institutional ones. We noted in the literature that Latin American institutions trying to increase scholarly production face structural, organisational and budgetary weaknesses in fulfilling this task (Massarani, 2018). It would be appropriate to investigate the policies and plans for science dissemination in these institutions and to know why they have not focused on improving the engagement and reach of their YouTube channels.

Finally, we noted that in youtubers' channels, the discourse was joyful; however, it did not lack scientific rigour and did not fall into the vulgar language to seem more accessible and authentic. This finding is similar to Pereira Pereira, Moura and Fillol's (2018). However, some youtubers use sarcasm and humour 'dosed' and interspersed in some content to create a sense of closeness and authenticity. On the other hand, institutional channels maintain a formal discourse only, as observed by Buitrago and Torres-Ortiz (2022b) in science popularisation channels on Twitch.

Even when the strategies used by youtubers lead to engagement, other variables may also influence it. These strategies are related to the functioning of YouTube's algorithm (Bishop, 2018; Bryant, 2020). Future research should address this issue and also focus on the perceptions of youtubers in this regard.

4. Conclusion

This study allowed us to characterise science dissemination on YouTube in institutional and science youtubers' channels in Mexico, Peru and Bolivia. We saw differences between the strategies used for science outreach on youtuber and institutional channels. In all three countries, youtubers' channels outperformed institutional ones regarding reach and engagement. Bolivia showed youtubers with the lowest engagement and reach. Although these three countries differ in formal scholarly production (publications in indexed journals), they share the same weaknesses in science dissemination through institutional YouTube channels.

A YouTube science channel aims to disseminate information based on scientific evidence in an entertaining way for users. In this way, it is possible to stimulate interest in science and research, which is much needed in Latin American countries, even those with the highest scientific output. Successful science youtubers are paving the way for science communication to attract the audience's interest. In this study, we have observed simple and effective strategies that institutions could replicate to contribute to the massive communication of scientific knowledge. These strategies (summarised in Table 4) help to increase engagement and reach; besides, they do not depend on high investments that may impede their implementation.

In our opinion, the institutions managing and producing scientific information (universities, research groups, government agencies, among others) in Mexico, Peru and Bolivia should become more active in using YouTube for scientific outreach. It would make it possible to attract young people's attention to the different branches of science, bearing in mind that these are generations with different tastes, habits and needs. For these generations, ubiquity and immediacy are part of their culture, so the media and forms of communication used must respond to these characteristics. It does not mean neglecting formal scientific production and publication; on the contrary, it means to disseminate science through various sources to motivate the population towards it. This promotion could positively impact formal scholarly production in the medium and long term.

This positioning in science outreach on YouTube is necessary for institutions, especially nowadays, because misinformation permeates and tries to control all spaces. Science institutions in Mexico, Peru and Bolivia should take advantage of the potential of YouTube and the strategies that have proven successful in non-institutional channels for science outreach. The main weakness observed in several institutional channels analysed was using this network only to promote their events.

Research agencies and departments should improve these channels to motivate interest in scientific knowledge and to show their institutions as a generator and disseminators of knowledge in the international arena. Further research is needed to know why these institutions have not adopted these strategies to strengthen their YouTube channels for science communication, institutional outreach, and to enrich their brands as benchmarks in science. Finally, there is also a need for research addressing the perspective of the owners of these channels, to understand their motivation and evaluate the intentionality behind each of the strategies observed in their channels.

5. Contributions

Contributions	Author
Conception and design of the research	Author 1
Literature review	Authors 1 y 2
Data gathering	Author 1
Critical and analytical appraisal of information	Authors 1 y 2
Revision and approval of versions	Authors 1 y 2

6. Founding

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7. Conflict of interests

The authors declare no conflicts of interest.

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Notes.

1. The videos were coded as follows: first letter of the country, first letter for channel type (YouTuber-Institutional), a number to indicate the channel position in the corpus (from 1 to 24) and a two-digits number indicating the position of the video for each country (01 to 03). For example, MY101 is a Mexican channel (M), from YouTuber (Y), is the channel number 1 out of the 24 included (1), and is the first video from that channel in the corpus (01).