

Is It Truly Scientific? Popular Science Videos on Bilibili

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Nowadays, online video websites are not only for video sharing and watching, but also work as communication channels of special interests such as popular science. With the interactions and participation among the viewers and creators, popular science videos have become an important form of science communication. In HCI and CSCW, previous studies about computer-mediated science communication focused on the perspectives of community and design opportunities in non-video forms. Little is known about the viewer's engagements and the narrations of online video-based science communication. Thus, in this paper we conducted a mixed-method study to investigate the video uploaders, video content, and strategic narrations with viewer's engagements of popular science videos shared on Bilibili, which is known for its collaborative commentary mechanism for videos called "Danmaku". We first created a taxonomy of uploaders of popular science videos on Bilibili. Then we revealed the popular topics and coded a set of sampled videos by 9 content-related features to show the landscape. Finally, we illustrated the correlations between entertaining narration strategies and viewers' engagements via qualitative observations and the Danmaku data. This paper extends the scope of online video-based science communication research to Bilibili, and involves the Danmaku mechanism to the contexts. Our findings enrich the understanding of the viewers' engagements with narration strategies of popular science communicators.

CCS Concepts: • **Human-centered computing** → **Collaborative and social computing**.

Additional Key Words and Phrases: Online video platform; Popular Science; Scientific Communication

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1 INTRODUCTION

The Internet has changed the way of science communication in recent years. Nowadays, scientific knowledge are not only discussed among the professionals in the online spaces, but more and more ordinary people joined the party with their curiosity and enthusiasm towards science [10?]. Videos, as a popular form of online services consumed by billions of people everyday [?], have been acknowledged as a media where science communication activities can be fostered with a board participation of the general public [19, 43, 56?].

With the advancements of the telecommunication and computing technologies, online video websites have been growing rapidly in recent years [50]. At present, YouTube is the second most popular website in the world in terms of network traffic [1]. Besides the high popularity, YouTube is also considered as an important communication channel that enables the information exchanges and interactions between video content creators and their viewers [54].

Science communication is about the process where the scientific knowledge is mediated and exchanged between the scientific practitioners and the general public [6, 12]. At the beginning of the 21st century, Hurd [32] envisioned the potentials of computer-mediated communication (CMC) to be used in the science communication. Up to now, it is not rare that scientists use online social

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media, such as Twitter, to collaborate with their colleagues or share opinions directly to the public [15, 20].

Among the massive contexts, the popular science, as a part of science communication, is a trendy theme on online video websites like YouTube [44, 56]. Previous studies have compared the videos produced by different groups of creators, such as amateur creators v.s. professional video makers [56], and individuals v.s. institutions [19]. In common, the results showed that a number of science communicators on YouTube do not have scientific backgrounds, but the amateur individuals can still gain popularity to be competitive with the scientists or professional video makers. A key point of this phenomenon is the storytelling narration strategies [22, 30, 44] used by these science communicators.

Bilibili.com (a.k.a. Bilibili) is a Chinese video website featured by its “extensive-ACG” culture and the young user groups. Besides the entertaining videos about Animations, Comics, and Games, popular science videos also tend to be popular on this website, especially after a main category named “Knowledge Zone (知识区)” was officially launched in June 2020. Danmaku (弹幕) is another famous feature provided by the website. It is a commentary mechanism that allows viewers to put scrolling text comments to be displayed overlain on the video. Prior work in HCI and CSCW has shown that Danmaku is considered to be a powerful medium which supports viewer interactions and information exchange during video watching activities [27, 40, 61, 62].

In HCI and CSCW, previous work about online science communication primarily focuses on non-video platforms, such as Reddit[35] and Twitter [23]. Also the landscape of video-based science communication along with the viewers interaction behavior are yet explored. Thus, in this paper, we conducted a mixed-method study based on the observations from Bilibili to explore popular science videos in terms of video uploaders (i.e., science communicators), video content (topics and their storytelling strategies), and users’ engagement with the video content.

Specifically, we are interested in the following research questions in this study:

- RQ1: Who are the popular science video uploaders (i.e., science communicators) on Bilibili?
- RQ2: What are the topics and content characteristics of the popular science videos on Bilibili?
- RQ3: How does the Danmaku respond to the storytelling devices?

To answer the research questions, we initially collected the metadata of 213,379 video that were uploaded to Bilibili in July, August, and September 2021. For the RQ1, 514 video uploaders were selected from the top 1500 popular videos (ranked by the number of views). Then, two authors created a taxonomy of science communicators on Bilibili through analyzing the data via the open coding method [37]. The results show that recognizable scientists (1.36%) and semi-professional communicators (5.84%, “popularizers”) are rare in the sample, while nearly half (48.64%) of the uploaders are annotated as “marketing accounts (营销号)”. For the RQ2, a co-word analysis [28] approach was applied on the hashtags from the 213,379 videos in order to reveal an overview of topics about popular science videos on Bilibili. From the inclusion map [28], the largest cluster of topics is centered around the word “Health (健康)”. For the RQ3, the goal is to explore the video content characteristics along with the storytelling strategies. We further selected 111 popular science videos from 37 popular uploaders in 4 categories (the categories come from findings of RQ1), the content of which was then analyzed through an open coding method.

Our contributions to the HCI and CSCW community are (i) A taxonomy of popular science video uploaders on Bilibili and a data set containing 514 labeled uploaders; (ii) Initially involve the online video-based science communication into the research fields; (iii) Investigate the correlations between viewers’ engagements with science communicator’s narrations in depth, and provide implications for future design based on the observations.

2 RELATED WORK

To establish the groundwork for our research, we conduct an in-depth examination of concurrent scientific communication and the narrative strategies used in video-based science communication. Additionally, we reference Danmaku and Commentary on scientific communication videos to have a deeper understanding of the viewer-science video interaction.

2.1 Science Communication and the Dialog Model

As defined by Burns, O'Connor and Stocklmayer, the concept of contemporary *science communication* is “the use of appropriate skills, media, activities, and dialogue” to have personal responses on Awareness, Enjoyment, Interest, Opinions, and Understanding (i.e., “AEIOU”, the vowel analogy) of science [12]. Thus, science communication can potentially involve everyone from the society as long as they engage with the activities related to science, distinguishing from the concept of *scientific communication* which focuses on the communication among the scientific practitioners [57].

In the era of social media, scientists are used to utilize online platforms to either communicate with their colleagues or directly talk to the general public. By observing Twitter, a prior study theorized the communications between scientists to two different types of participant into two models namely “preaching to the choir” (Inreach, within professionals) and “singing from the rooftops” (Outreach, to public) [15]. Another study on Reddit also indicated the situation that both of the scientists and ordinary people are actively engaged in a online forum-based community [35]. In addition, social studies of science conceptualizes the interaction between science and the public in such a way that the concept of expertise is extended to non-scientific actors [14], which is congruent with the latest trend of social studies on public understanding of science [8]. The researchers described the phenomenon where scientists adequately collaborate with the non-experts as trend of shifting from the *deficit model* to the *dialog model* [18, 51]. The *deficit model* describes science communication as a unidirectional transmission where the knowledge is passed from the scientists to the public, assuming there are “deficits” to be filled. However, the model has been challenged as it neglects the public’s engagement to the science communication [42]. The *dialog model*, on the contrary, emphasizes the bidirectional interaction between the scientists and the public [46]. It has been described as a move from public comprehension of science to public engagement with science, which may be described as a more open, egalitarian, and participatory approach to science [7, 9, 33].

Although several research has been undertaken on individual instances of science communication as well as the role of traditional mass media in these disputes [7, 34, 60]. A lesser amount of attention has been dedicated to the investigation of more contemporary modalities of communication or to efforts to understand how media such as video sharing platforms, social media, and other similar sites contribute to science communication [38]. To bridge this gap, we explored more on how science is communicated through video and how viewers may engage and interact with it.

2.2 Video-based Science Communication and Storytelling

In past few years, video has become in relevance as a means of communicating science to the general population [22]. Decades ago, science communication videos have been used to educate and inspire a broad range of viewers [5, 49]. Norman [47] mentioned that videos may visually move individuals to places and conditions they would never encounter otherwise, and Wright [58] also suggested that the video may transport an viewers to an issue to care, which is an important benefit of using video for scientific communication. Researchers have begun an investigation into why scientific videos have acquired such widespread attention, and have discovered many

probable causes relating to the video content [10, 21, 44, 55, 56]. Simultaneously, various research have begun to study the narrative component of scientific video and its influence on viewership [22, 30, 36]. Storytelling has been leveraged as a tool to enhance students' engagement, and their motivation to learn [31, 45] for a long time. The usefulness and impact of narrative have been shown in several studies [26] and have been effectively used to scientific communication with viewers [16]. There are various advantages to leveraging story, including attracting attention, increasing engagement [25], and influencing a point of view [17, 24]. Although these factors may increase the risk of misleading viewers because narratives are rarely rejected [3, 41], researchers continue to recommend that scientific communicators possess the ability to "deliver a succinct, intriguing, and entertaining narrative that communicates content" in order to engage and win over public audiences [48]. Additionally, numerous studies have demonstrated that increasing viewer engagement with a narrative can increase its persuasiveness [29, 52, 53], implying a strong relationship between narrative and viewer engagement. In light of this, our research was driven by the need to better understand how viewers engage with the narrative portion of scientific communication videos.

2.3 Danmaku Commentary Mechanism

Danmaku ("弹幕") is a mechanism where the watchers can put their text comments onto the video frame, so that the other watchers can see these comments scrolling or floating over the video when playing. The literal meaning of the word "Danmaku" is bullet curtain, which means each piece of text comment looks like a bullet, so that a huge number of such bullets (texts) combining together can form a curtain covering the video frame. Although the Danmaku originates from Japan, now it has become an iconic feature of a popular Chinese online video website Bilibili [39].

Commonly, people also call a single text comment as "a piece of Danmaku" or "a Danmaku". A Danmaku is associated with a certain time point of the video, and normally it will be initially rendered on the left side of the video frame, then moving towards the right side until disappear (i.e., fully outside of the frame). However, a Danmaku can also be fixed to a certain position of the video frame and lives for a limited time. Color and font size are customizable by the author.

Danmaku differs from the traditional forum-like commentary systems by its anonymity and asynchronization [40]. Specifically, on Bilibili, the author of a Danmaku is not accessible to any other watchers and the display order of a Danmaku is decided by its relative timing within the corresponding video's timeline, while the realistic creation date of a Danmaku is hidden during the playback. As a result, the Danmaku mechanism forms a "Pseudo-synchronized" video-watching and communication experience [59]. From a watcher's perspective, watching a video with Danmaku is like watching with other people together.

In the HCI research area, previous works [4, 40, 59] have addressed that the Danmaku mechanism has explicit potentials to mediate the interactions among the users of online video websites. Even the specific usage and preference of Danmaku have variances for different types of videos [61, 62], Danmaku can usually promote the interests of users and encourage their engagements. So far, there are researches about Danmaku in particular application fields such as knowledge sharing [59] and crisis communication [27]. But there is no study about scientific communication. Thus in this study, we'll try to fill this research gap.

3 METHODS

A mixed-methods approach is applied in this study. For both of RQ1 and RQ2, we used open coding [37] qualitative analysis to code the video uploaders and the video content. In RQ2, a computational method named co-word analysis [28] is applied to address the overall topics of the popular science videos on Bilibili. For the RQ3, we combine qualitative analysis with basic

natural language processing techniques to show the correlated patterns between video content and Danmaku. The overview of methods and the corresponding data is showed in Figure 1.

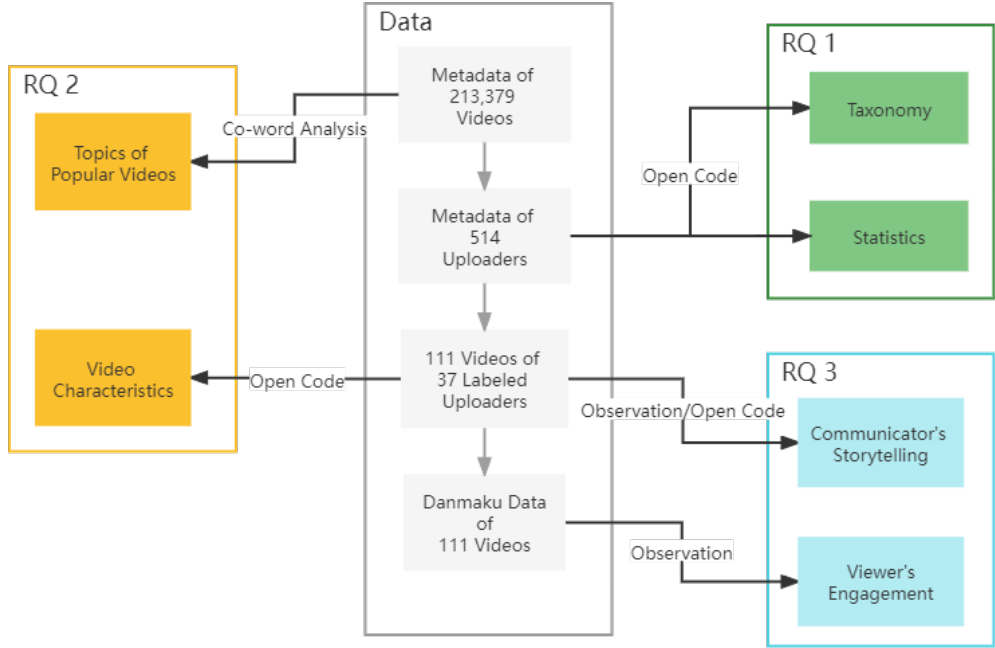


Fig. 1. Methods Overview

3.1 Data Collection and Selection

At the beginning, we collected the meta information of all the "Science and Science Popularization (科学科普)" videos which were uploaded to Bilibili in July, August, and September in 2021. The "Science and Science Popularization" is a sub-category that is managed by Bilibili under the "Knowledge Zone (知识区)" main category. Although the uploaders are able to choose the target category when uploading a video, the operation team of Bilibili will continuously correct the misplaced videos, so that most of the videos in the "Science and Science Popularization" sub-category can be seen as relevant to our study. As a result, the meta data of total 213,379 videos were fetched. Technically, considering the efficiency of data collection, we built a web crawler based on Python3 standard libraries to fetch the most of the data. All the data collected and used in this study is visible and publicly accessible from the Bilibili's website by desktop computer.

For each video, we got its authorship (i.e., author and mid), descriptive texts (i.e., title, tag, and description) and the numerical information (i.e., duration, play, and favorites). The details of these meta information are showing in Table 1.

To answer the RQ1, we firstly need to select uploaders following 2 principles: (1) The uploader should be popular; (2) The number of selected uploader should be suitable for qualitative coding by two researchers. From the original video meta data, there are 43,622 unique uploaders recognized by counting the "mid". Then we ranked the video by the number of video plays ("play") and select the top 1500 (< 1%) videos leading to 514 unique uploaders. As those uploaders contributed at least

Table 1. Video Metadata

Attribute Name	Description
title	The title/caption of a video
author	The user name of video uploader
mid	Refers to “member id”, which is the unique id of the video uploader
tag	Hash tags that are assigned to the video
description	A short text provided by the uploader about the video
duration	The length of a video in sec.
play	How many times the video has been played
favorites	How many times the video has been marked as favorite

one popular video (Top 1% in terms of plays), we thought they are relatively more popular than the others among the observed data set. Once the uploaders were selected, we use the web crawler fetched their publicly visible detailed data including name, gender, sign, the number of followers, and the uploader’s video list (with id and category of each video). The details of the uploader’s meta data is showing in the Table 2.

Table 2. Uploader Metadata

Attribute Name	Description
mid	Refers to “member id”, which is the unique id of the video uploader
name	The user name of a video uploader
gender	A value from: male, female, or unknown
sign	A customized text displayed with profile, usually be used for short self-biography
follower	The number of followers
video list	All the videos that are uploaded by the user, with the video id and category information

For the RQ2, we firstly selected 37 uploaders from 4 categories recognized in RQ1: *Scholar/Researcher*, *Popularizer*, *Doctor/Physician*, *Marketing Account*) as the former 3 categories are recognizable individual uploader and the *Marketing Account* is dominant in terms of the population. Except the *Scholar/Researcher* that only has 7 uploaders, for each of the other 3 categories, the top 10 uploaders with relatively high population of followers are selected. As a result, the population of purposely sampled uploaders is 37 (i.e., 7 + 10 + 10 + 10). Next, we take the 3 most popular videos that were uploaded before Oct 1, 2021 from each of the 37 uploaders resulting in 111 videos to be used for qualitative open coding for investigating the video content.

For the RQ3, as we aim to figure out the most typical storytelling narration strategies among the observed data set, 9 videos were selected. The videos are reviewed from Bilibili website so that no extra data was collected in the process.

3.2 RQ1: Who are the popular science video uploaders (i.e., scientific communicators) on Bilibili?

To investigate the uploaders of popular science videos on Bilibili, we applied a qualitative analysis approach by 2 researchers to recognize the categories and build a taxonomy from the 514 selected uploaders. The uploader’s profile web page (Figure 2) and the captured meta data are used as the evidences for coding.

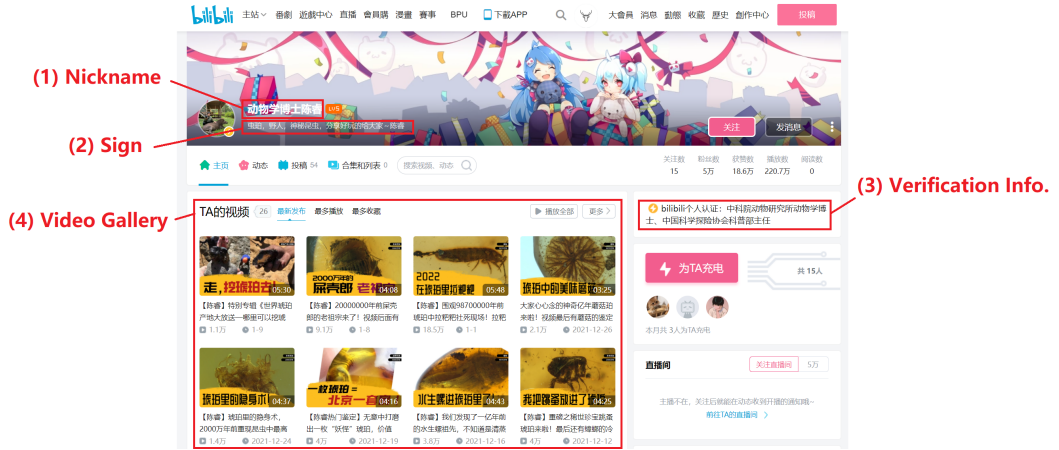


Fig. 2. Uploader Profile

On the uploader's profile page, the name, sign, verification information and video gallery are mainly considered by the coders. The name (Figure 2 (1)) is a customizable nickname. The sign (Figure 2 (2)) is a customizable short text displayed under the nickname. Uploaders usually make it a brief biography showcasing their interests or identifications. The verification information (Figure 2 (4)) is a service officially provided by Bilibili. It allows the account to be equipped with verified caption and description displaying in the profile once the owner made an application to Bilibili with proof of their real-world identifications. For example, in the sample picture (Figure 2 (4)), the uploader is verified with his title of "Doctor of Zoology of the Chinese Academy of Sciences, Director of the Department of Science Popularization in the China Adventure Association". In this paper, the verification information is considered to be a credible evidence to determine the category of uploader, although not all the uploaders have such a verification information. The video gallery (Figure 2 (5)) area listed all the videos of the uploader with thumbnail, title, date, and the number of plays.

During the annotation process, the science professionalism is the first feature to be evaluated. The second is the individuality, which refers to whether the uploader is an individual or group/organization. At the beginning, the 2 coders have looked through the entire sample set for common senses. Then they individually coded the first 50 (10%) of the samples to recognize potential categories. Next, a consensual version of recognized categories was conducted from discussion. Based on consensus, the coders continued to code the rest of samples respectively. The inter-rater reliability of raw code results of 2 coders has been evaluated by Cohen's kappa score [13], which resulted to 0.908. Thus, a final consensual code result was conducted by one coder (1st author). The result is also used in the subsequent RQ2 and RQ3.

3.3 RQ2: What are the topics, content characteristics and storytelling devices of the popular science videos on Bilibili?

3.3.1 Co-word Analysis. To reveal the topics of all captured videos, we implemented the algorithm of inclusion map in co-word analysis [28] using Python3, and then applied the algorithm to the hash tags from the 213,379 videos whose meta information were fetched.

The inclusion map is an approach based on the word frequency and it is used to highlight the central topics within a domain that is represented by a collection of words [28]. On Bilibili, a hash

tag is a key word corresponding to the topic of the video, and each video can be assigned with more than one hash tags. Therefore, when all the hash tags from a set of videos are combined together, we can obtain a collection of key words that is exactly fitting for the co-word analysis algorithm. Thus we can investigate the major topics of the videos from the output of the algorithm.

During the pre-processing, we purposefully excluded 3 kinds of tags: defaults tags, event tags, and non-science tags, since our goal is to show the science related topics rather than other noises. The default tags refer to the two tags namely “Science (科学)” and “Science Popularization (科学科普)”. As all the captured videos are belonging to the “Science and Science Popularization” sub-category, they are all assigned with at least one of the two tags by default. The event tag are a bunch of tags assigned by Bilibili indicating whether a video is associated with a special event or not. The event tag is irrelevant to the video topic in general. The non-science tags include tags which are too general to represent certain messages, such as “Knowledge(知识)”, or tags which are irrelevant to science such as “How to run an online shop (如何开网店)”. In summary, there are 163 tags were removed and 83,112 unique tags remain.

Before running the co-word analysis algorithm, we further ranked the 83,112 unique tags by the frequency among all observed videos and take the top 500 to be the major key words, resulting to the count of the last word is 125. Then following the inclusion map algorithm we calculated the scores of all the word pairs, and select the top 100 pairs as the final result. The “pyVis” library [2] is used for visualization.

3.3.2 Open Coding for the Video Content. To investigate the video content characteristics, we conducted another open coding [37] process on the selected video set (N=111, see the previous *Data Collection and Selection* section for details) by two authors. The code used here are partially borrowed from the prior study conducted by Huang and Grant [30], combining with our own heuristics that are identified from our iterative observations. The details of the code can be found in Table 4.

3.4 RQ3: How does the Danmaku respond to the storytelling devices?

For the 111 selected videos, we further investigated their storytelling narrations by segment the timeline into multiple fragments and coded each of the fragment.

Inspired by the literature review, we proposed five elements of interest that constitute the main contents in science videos, namely *Serious Content*, *Infotainment*, *Acting*, *Interaction*, and *Commercial*. *Serious Content* refers to neutral-emotion, serious-attitude, and rigorous contents that contain objective facts and arguments; *Infotainment* refers to jokes, funny words, memes, and punchlines; *Acting* refers to exaggerated and apparent acting through which the author deliberately amuse the audiences; *Interaction* indicates that the author is orally encouraging audiences to send Danmaku, choose from window prompt, comment, subscribe, and like/favorite the video; *Commercial* refers to contents sponsored by profitable enterprises;

Our interest in partitioning *Serious Content*, *Infotainment*, and *Acting* is driven by the intuitive senses of what the contents are about after watching these videos and motivation of investigating the quality of science knowledge offering in the video-intermediate context. Interest on *Interaction* comes from videos that astutely utilize Danmaku and window prompt as unique devices to interact with and draw attention from audiences. *Commercial* advertising, yet another content presumably irrelevant to and may affect science communication offering, was also annotated.

We annotated timestamps of the starts and ends (thereby duration) for each content element mentioned above in each sample video (N=37). First, two authors both conducted a trial coding for the same set of 37 videos (each from an individual uploader) in the sample pool of 111 videos. As a result of the almost inevitable local differences when annotating the exact timestamps, we did not

measure inter-rater reliability; but the two results manifested authentic consistencies in terms of content partitions and labels. Next, the authors discussed the differences, merged them, and made the criteria more concrete and comprehensive. One author then annotated the rest of the sample videos (N=74), referring to these new standards. Then, we identified the vital and distinctive styles and elements involved in these science videos to answer RQ3.

4 FINDINGS

4.1 RQ1: Who are the Popular Science Video Uploaders on Bilibili?

4.1.1 Taxonomy of the Uploader. To directly answer the question of “Who”, we need to figure out the categories, i.e., taxonomy, of video uploader on Bilibili. From a open coding [37] approach conducted by 2 authors, there are 11 categories recognized from the 514 selected uploaders. The definition and population of each category are listed in the Table 3.

Scholar/Researcher is the first and most important category in terms of science. They are the uploaders who have explicit identification information on their profile pages with title, institution, and research specialization. Only 7 out of 514 (1.36%) of uploaders belonging to this group. Their research specializations include marine geology, neuroscience, experimental physics, Chinese pharmacology, and biology. A noticeable finding is that all of them used their real name (or at least one of last name or first name) in the account’s nickname.

Popularizer is a category to describe the uploaders who showed some degree of scientific background or full-timely working on science popularization, although they may recognized from different disciplines. To be detailed, one kind of popularizer includes self-employed popular science writer and the workers hired by government-funded science popularization organizations. Another major kind is research students who have yet fully qualified as scientists. Finally, less but recognizable, engineer is also merged into *Popularizer* as they do have solid professional background but isn’t typical scientists.

Doctor/Physician specifically refers to the medical workers, the majority of this category are doctors, very less are nurses or others relevant. Although clinical medicine and healthcare related topics are relevant to medical science, we distinguish this category out because the medical workers hold an appreciable amount (66, 12.84%) in the selected data set with explicitly different characteristics comparing with other categories in terms of the video themes.

Grassroot are the ordinary people who do not appear any evidence of scientific background or experiences. But they can still be easily recognized as individual rather than organizational uploader.

The name *Marketing Account* is translated from the Chinese word “营销号”, which refers to a kind of content creators that are featured with the batch production of relatively low-quality contents on UGC platforms. Usually there is no visible information about their identity and purpose. Their videos do not centered with a stable theme but usually follow trendy topics. Since previous years, the Chinese government have tried to moderate the marketing accounts as they’ve been accused of involvement with plagiarism and spreading misinformation [?]. However, in our selected data set, nearly half (265, 51.56%) were still assigned to the ‘Marketing Account’ category with no doubt.

Self Media refers to new media groups and personal podcast channels who are not fully focusing on science popularization and communication. Most (>50%) of their videos are non-relevant to science topics (i.e., not in the “Science and Science Popularization” sub-category).

Commercial Institution and *Non-profit Institution* are institutional uploaders who works as an official information delivery channel to their corresponding organizations. For example, companies, universities, departments of the government.

YouTuber refers to the uploaders that are officially managed by the YouTube channels with the same name. Their videos are uploaded to YouTube and Bilibili respectively, as YouTube is not accessible from the mainland China. But the Bilibili version may be modified to meet the censorship requirements. Also, Chinese subtitles would be provided if the language originally used in the video is not Chinese.

Transporter/Fansub Group is the non-official uploaders who transport videos from the websites out of mainland China to Bilibili. Typically, YouTube and Niconico Douga are targeted as the sources. These uploaders are usually managed by self-organized online communities. Some of their transporting operation might be authorized by the original authors, but most are not.

Unavailable Account are accounts which were in invalid status (deleted or banned) when we tried to access the profile pages, since the original video meta information is about videos in July, August, and September but we did the qualitative code in later October. *Transporter/Fansub Group* and "Marketing Account" are usually risky to be banned because they can easily got involved with plagiarism and copyright issues.

In the following analysis, we excluded 5 categories as they are not considered sufficiently relevant to the research questions. *YouTuber* and *Transporter/Fansub Group* are excluded as their videos are not native. The institutional accounts (*Commercial Institution* and *Non-profit Institution*) are also removed as they do not stand for individual science communicator. *Unavailable Account* is excluded naturally as their data is incomplete. As a result, 449 out of 514 (87.35%) uploaders left while 65 are dropped.

4.1.2 Statistics of Uploaders. In terms of the popularity of uploader, we selected the number of followers and the age of account for comparison among the categories. Because the number of followers is an indicator reflecting the popularity of the account (i.e., uploader) [11], while the age of account is a counter factor to the number of followers as the longer an account exist, the more chance it can gain followers. As the age of account is not directly accessible, we approximate its value by count the days from the time of first video uploaded to a certain end point (i.e., Dec 1st, 2021), since the "video list" information of uploader is available (see the Method section for details about the data). For example, if the first video is uploaded in Nov 30, 2021, then the age of the account should be 1 day.

The cumulative distribution function (CDF) curves for the uploaders belonging to each of the 5 categories: *Scholar/Researcher*, *Popularizer*, *Doctor/Physician*, *Grassroot*, *Marketing Account*, and *Self Media*. As showing in Figure 3.

For the CDF curves, the trends of each category are similar, but a rank can be clearly presented. Overall, *Self Media*, *Popularizer*, and *Scholar/Researcher* are the top 3 on the number of followers, while *Grassroot* is the most lagging one (Figure 3 (1)). *Self Media*, *Popularizer*, and *Grassroot* exist longer than the others and *Scholar/Researcher* is the youngest category (Figure 3 (2)). Thus, *Scholar/Researcher* is quite competitive as they have relatively more followers within the shortest time. And the 'Grassroot' exists relatively longer but they only got the smallest number of followers comparing to other categories. *Self Media* and *Popularizer* have larger population of followers, which also take longer time. *Marketing Account* and *Doctor/Physician* are always in the middle.

With the meta data of videos, we counted the number of videos per uploader (Figure 3 (3)) and the number of plays per video (Figure 3 (4)) for each category of uploader. On average, each uploader in *Doctor/Physician* has uploaded about 71 videos to Bilibili during the July, August, and September 2021, which is extremely higher than all the others. Both *Scholar/Researcher* and *Popularizer* uploaded about 13 videos within the 3 months, nearly one video per week. The average count of *Marketing Account* is about 25 which refers to a frequency around 2 videos per week. *Grassroot* only 4.67 videos, about 1.5 videos per month. The largest amount of videos leads to the

Table 3. Taxonomy of Uploaders

Category/Code	Definition	Population	Proportion
Scholar/Researcher	Individual scientist, scholar, or researcher with explicit title and institution information	7	1.36%
Popularizer	(1) Individuals whose major job is about science popularization. (2) Research students that have yet fully qualified as scientists. (3) Individuals who have some degree of professionalism other than science, e.g., engineer	33	6.42%
Doctor/Physician	Medical workers from recognizable hospitals or clinics	66	12.84%
Grassroot	Individuals who are non-professional or unidentifiable as any kind of professionals	28	5.45%
Marketing Account (营销号)	No identifiable information provided in the profile page, owning a huge number of videos in very similar style but do not have a common theme	265	51.56%
Self Media	Identified with studios, groups that mainly produce news, entertaining videos. Most videos are uploaded into the non-science categories	50	9.73%
Commercial Institution	Business companies, brands, or mobile applications, etc.	27	5.25%
Non-profit Institution	Governments, the china communist party (CCP), universities, or other non-profit organizations & institutions	13	2.53%
YouTuber	The official accounts on Bilibili held by recognizable YouTube channels	10	1.95%
Transporter/Fansub Group (字幕组)	Self-organized studios or groups who capture the videos from the websites which are not accessible in the mainland China (e.g., YouTube, Niconico Douga), and then re-upload those videos to Bilibili. Some of them also provide translation with subtitles (usually from English or Japanese to Chinese) to the captured videos	5	0.97%
Unavailable Account	Accounts which have been deleted or banned when access during qualitative coding	10	1.95%

lowest average plays per video for *Doctor/Physician*. The videos owned by *Scholar/Researcher* and *Popularizer* are more popular over other categories.

4.2 RQ2: Topics and Content Characteristics of Popular Science Videos on Bilibili

4.2.1 Video Topics Overview. In the inclusion map of co-word analysis, topics are presented as clusters in which each node represents a key word. The connections among nodes indicate the correlations based on co-appearances while the layout and the lengths of edge do not stand for specific meanings. In our result (Figure 4), there are 21 clusters found from the top 100 words. We translated the visualized tags into English. There are 2 tags ("Starship" and "Harry Potter")

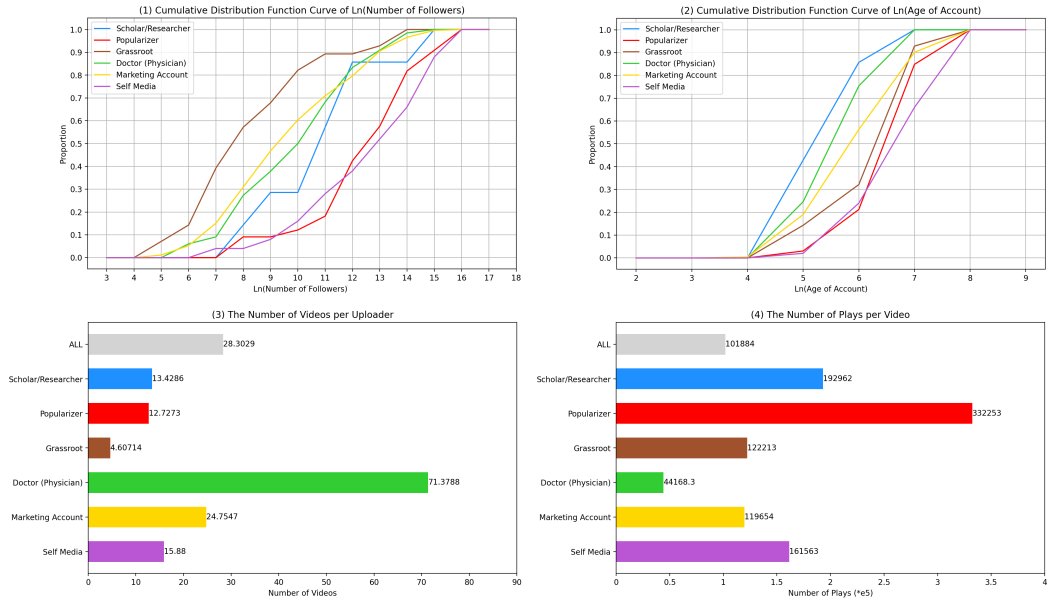


Fig. 3. Cumulative Distribution Function Curves of The Number of Followers And Age of Account

originally have both English and Chinese version, we added a star mark ("*") for distinguishing. In order to summary and interpret the visualization, we assigned these clusters into 5 groups by their related knowledge domain .

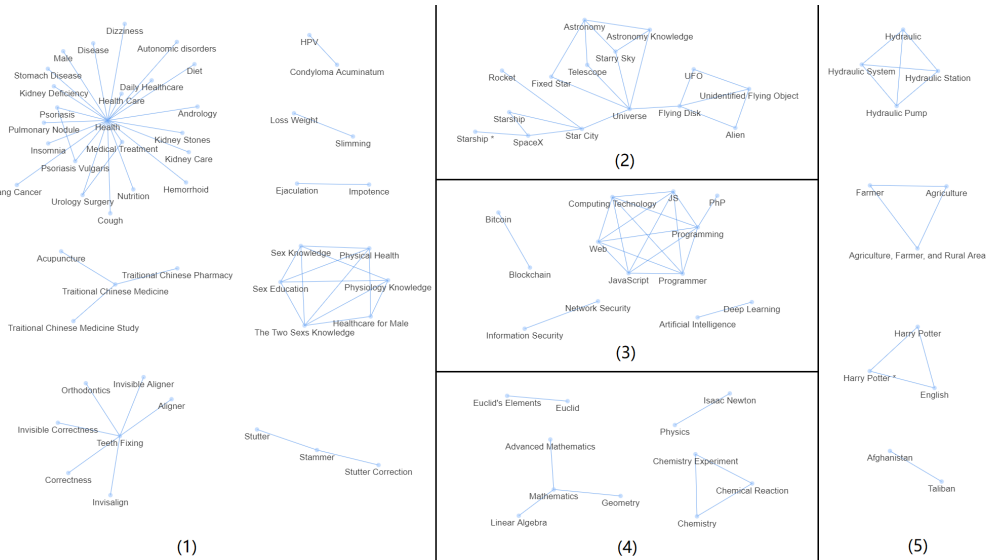


Fig. 4. Inclusion Map of Video Tags

The topic about *Healthcare* can be highlighted with the first group (Figure 4 (1)). The largest cluster is centered with the key word "Health" and it is surrounded with the names of disease or

symptom. Besides, there are 3 middle-size clusters indicating the topics about “Traditional Chinese Medicine”, “Sex Knowledge”, and “Orthodontics” respectively. Minor clusters are about some specific topics of healthcare such as “HPV” (i.e., Human Papilloma Virus) or “Loss Weight”. “Universe” is the most important word in the second group (Figure 4 (2)) where only one cluster exists, because it connects 3 components together. “Astronomy”, “SpaceX”, and “Unidentified Flying Object (UFO)” are centered the components respectively. We describe the topic of the third group (Figure 4 (3)) as *Computer Science*. The most conspicuous cluster is about Web development featured with words like “Programming” and “JavaScript”. Three isolated word pair properly reflect other popular topics in computer science: Artificial Intelligence, Block chain, and Information Security. The fourth group (Figure 4 (4)) consists of topics in *Classic Science*: mathematics, physics, and chemistry. There are 4 clusters without common theme assigned into the fifth group (Figure 4 (5)).

4.2.2 Video Content Features by Open Coding. As mentioned in the *Methods* section, we considered 9 video features to be coded by 2 authors. The Dramatic Question, Narrative Point of View, Use of Voice, Insight are referenced from the prior study [30]. Besides we added 5 new features Subtitle, Background Music (BGM), Screen Size, Reference, and the Science Subject as they are annotated by the 2 coders from observations. Details about the coded features are listed in Table 4.

Table 4. Coded Video Feature

Feature	Definition	Possible Values	Original
Dramatic Question	Whether a dramatic question is asked at the beginning of the video or shown in the title for increasing the attraction	None, Implicit, Explicit	No
Narrative Point of View	The narrative point that used by the communicator for storytelling	None, 1st (Me), 2nd (You), 3rd (He/She/It), Mixed	No
Use of Voice	How the video combine the voice and frame	None, Speak on Camera, Voice over Visuals, Mixed	No
Insight	Any high-level insight or conclusion highlighted by the communicator	None, Implicit, Explicit	No
Subtitle	Does a video originally contain a subtitle	None, Ordinary, Entertaining	No
Background Music (BGM)	How the music is embedded to the video content	None, Ordinary, Entertaining	Yes
Screen Size	Either the video is scaled for watching on desktop or mobile devices	Desktop, Mobile	Yes
Reference	Any academic references provided by the communicator in the video	None, Yes	Yes
Science Subject	Which science disciplines does a video fit for	Non-Science, Current Event Comment, Life Science, etc.	Yes

The result of qualitative code by 2 authors is shown in Figure 5. We count each feature by the uploader’s category produced in RQ1 to further explore the difference among these science communicators.

From the coding results, total 68 videos explicitly raise a *Dramatic Question* either at the beginning of narration or in the titles. 22 videos suggest the question implicitly, and the rest 21 videos do not

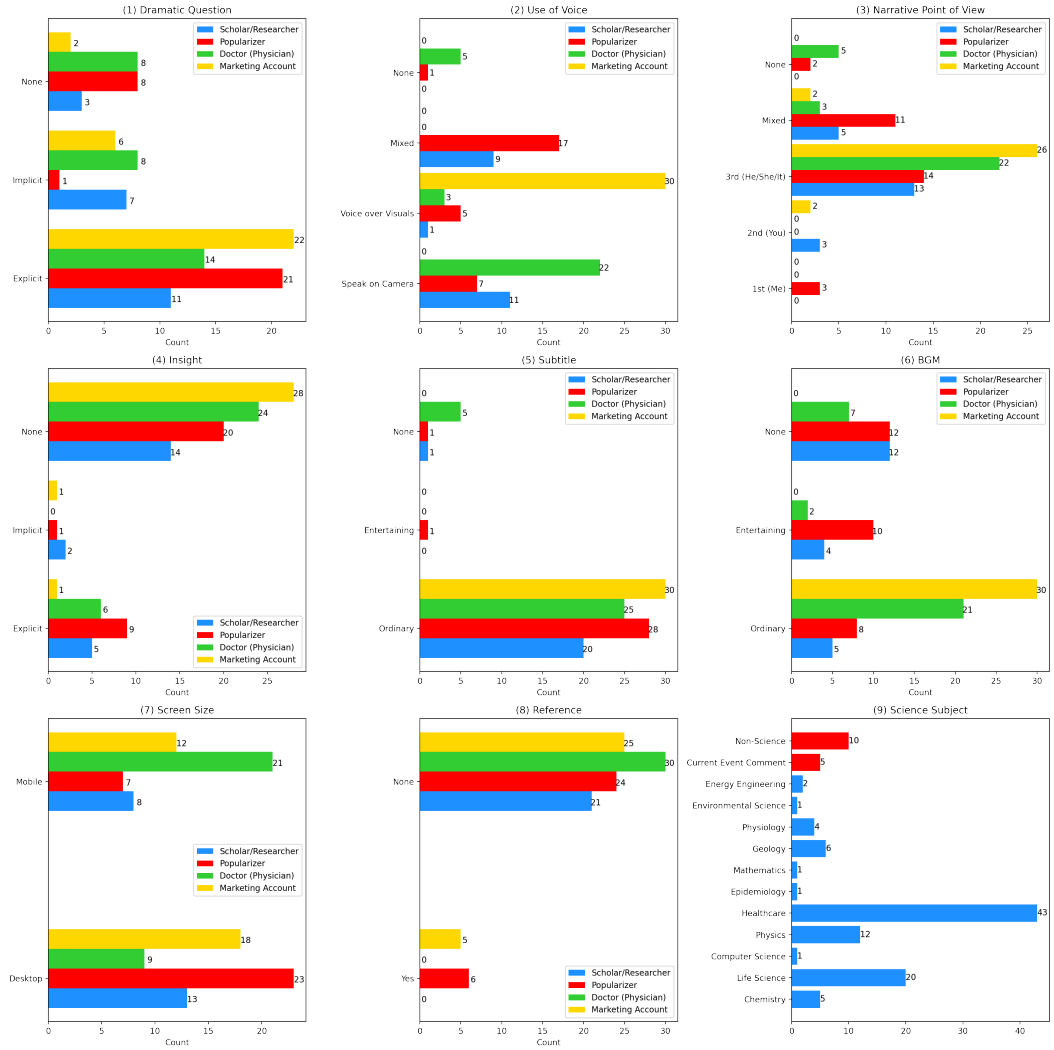


Fig. 5. Video Content Coding

have such a component. Comparing to other groups, uploaders of *Popularizer* (21/30) and *Marketing Account* (22/30) are more likely to use this strategy in their videos.

The observation of the *Use of Voice* diverged a lot for different uploader categories. All the *Marketing Account* adopt the "voice over visuals" mode, which means there is no communicator showing up but only a voice speaking aside the frames. Most (22/30) of uploaders in *Doctor/Physician* category prefer "speak on camera" mode, meaning the communicator always looks at the camera and talks to the audience like a face to face situation. *Scholar/Researcher* and *Popularizer* are the most advanced uploaders who are observed to use the mixed voice communication strategies. Their videos usually consist of substantial montage operations, animations, and role playing scenarios. Very few videos (6) are annotated as None because they are recordings without narration.

As for the *Narration Point of View*, the majority of videos choose the 3rd person narration as the common goal of popular science video is about demonstration of some scientific concepts or phenomenons. However, uploaders of *Scholar/Researcher* and *Popularizer* contribute 16 (5 + 11) videos with the mixed narration point of views. This also results from their complicated video patterns. In the narrations, the communicator switch their role purposefully. For example, they initially use a tone of 1st person to throw the dramatic question and share their own experiences, then switch into the 3rd person perspective to interpret the scientific knowledge. And then the 2nd person perspective is used to invite the audience to respond to the discussion topics. (We'll explore the typical narration strategies in observed popular science videos in deep in the next section).

Insight stands for a point of view that is normally inducted and generalized from the fundamental facts [30]. In our observation, only a minor set of videos (21) have provided explicit insights while the most videos do not show any clue about this.

Different from YouTube, Bilibili do not have a mature functionality to generate real-time *Subtitle* for videos. In the sampled video set, most of videos (103/111) are embedded with native subtitles. We consider a subtitle to be entertaining when it is purposefully modified with non-standard spelling/usage of characters or mismatched to the voice in order to foster the entertaining atmosphere. Although, this phenomenon is rare with only 1 video produced by a uploader of *Popularizer*.

Background Music (BGM) is also marked as either Entertaining, Ordinary, or None. In our observations, less than 1/3 (31/111) videos do not have BGM, and 64 videos are simply made with an ordinary BGM, which means only one piece of music is played from the beginning to the end. In few videos (16), the BGM is purposefully manipulated to fit the narration in order to enhance the attractiveness.

Screen Size is a easily noticeable feature as 43.24% (48/111) of sampled videos is made for the Mobile scale (18:9) while the rest is in a Desktop scale (16:9). This feature implicitly indicates the video target audience's watching preferences that watching from either mobile devices or desktop/laptop computers.

Reference is critical to the credibility of a popular science videos, since it is also a norm in the scientific contexts. From the result (Figure 5 (8)), only 10% (11/111) uploaders provide clear references list. Even the uploaders of *Scholar/Researcher* category do not appear to make references list for their videos.

Finally, we annotated the *Science Subject* of the 111 videos. The results shows the most frequent discipline is healthcare with 43 videos. This situation can be supported by the outcome of RQ1 where the *Doctor/Physician* uploaders submitted extremely more videos (71 per uploader) over the others. Life science and Physics get the 2nd and 3rd position as popular fields that are covered by the sampled videos. Also, there are 10 videos delivering non-science information such as life skills, and other 5 videos make comments or criticisms to popular affairs.

4.3 RQ3: How does the Danmaku respond to the storytelling devices?

4.3.1 Temporal Arrangement of Entertaining and Serious Narration. We investigated the temporal arrangement of entertaining and serious content in these videos; the result implied an alternating pattern where serious and entertaining content usually appear in turn repeatedly. In the best practices, serious narration do not proceed for long and must be interrupted by amusing *Infotainment* or exaggerated *Acting* after some amount of time; the entertaining content each proceeds for a shorter time, even one second in some cases, but appears rather frequently. We also saw such entertaining 'stimulus' distribute evenly throughout video playing. Finally, *Acting* usually are much less than *Infotainment* but present longer in these videos. Examples are on Figure 6. The alternating pattern that incorporates serious and entertaining content was found commonly in

the most popular videos. These videos are usually from authors who apply organized narrative structure and have a good sense of humour and editing skills.

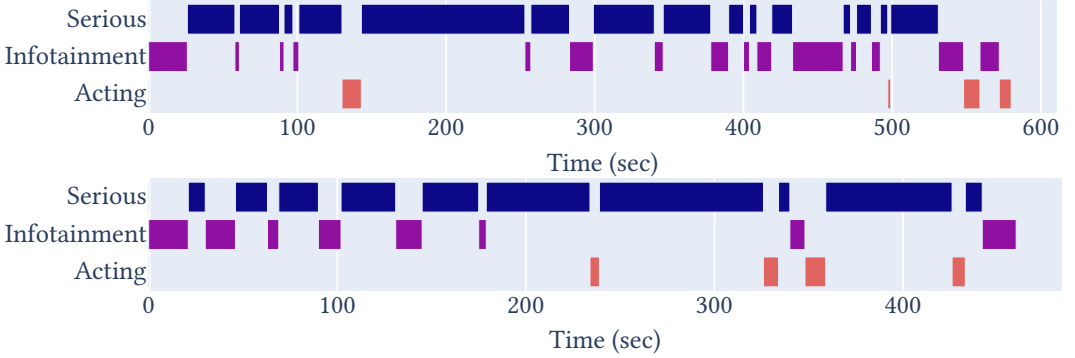


Fig. 6. Video Timeline with Content Partition

4.3.2 Danmaku Response. This subsection presents and elaborates on the key features found in the content analysis for all accessible Danmaku of the chosen videos, emphasizing the relationship between Danmaku behaviour and the storytelling devices. Firstly, The frequency of Danmaku increases when the video narration is transiting from serious content to entertaining content (infotainment and acting), and it is similar to the effect of interaction devices. In some cases, Danmaku can provide unusual observations to other viewers through direct semantic meaning or implication. Danmaku may also use a definitive phrase to summarize pieces of video content. Our investigation for the interaction process between the uploader and the viewers revealed the coexistence of cooperation and in-cooperation. Finally, we found that viewers are sensitive to potential commercial content but engage more in this way.

Danmaku Burst Along With Section Change and Interaction. A dramatic burst of Danmaku can happen along with section changing from serious to entertaining content. The transition begins with an amusing meme, punchline, joke, or acting to boost viewer engagement. Consequently, the frequency of sending Danmaku during the abrupt transition is significantly higher than that of the previous section. Onomatopoeia is extensively posted. Examples like “hhhhh”, “hahahahaha”, and their Chinese expression (“哈哈哈哈哈”) and sub-types (“红红火火恍恍惚惚”) emerge with an enormous amount. The uploader’s verbal encouragement for sending Danmaku also improve viewer engagement. For example, after the uploader says, “Share how many papers you have published and its impact factors. Let me know the average level of research of you guys.”, many Danmaku responds with “Don’t scold me! Don’t scold me!” (“别骂了别骂了”) or simply their answers to the question.

Unusual Observation. Due to the large quantity of viewers, Danmaku can provide unusual observations that are not explicitly presented in the video or ignored by a single observer. For example, an English subtitle saying “drink Bi Tea, and keep Bian Tai away”(Bian Tai means freak, and the English subtitle is deliberately translated to be inconsistent with the Chinese one) receives responses of “Look at the English subtitle! lmao” and later Danmaku like “how funny the English subtitle is”. One another way to inform other viewers is using specific colors for the Danmaku, e.g., an uploader is describing an experiment where the participants should take off clothes, and he says “Hmm, that situation is kind of embarrassing”; abruptly almost all the Danmaku become

“Study new thoughts. Strive to be new youth” (“学习新思想，争做新青年”) that are in the color of yellow (yellow connotes pornography in Chinese).

Summarize. Some prevalent Danmaku repeated many times are summaries of the currently presenting content or situation. They are usually in the form of short, definitive phrases and sometimes with a pair of guillemet (《 》) around. For instance, when an uploader says “growing up a little, it will only be 2 to 4 meters”, many Danmaku responds with “《LITTLE》” or “《ONLY》”. Not only is the phrase extracted from the uploader’s script lines, but it may also come from general notions; e.g., an uploader says “I can fabricate 36,000 this kind of stories overnight”, and the Danmaku responds with “《The Arabian Nights》”.

Cooperate and In-cooperate. The uploader’s narrative devices can trigger cooperation or in-cooperation between him/her and viewers, but both outcomes are entertaining to some extent. The cooperation can appear concurrently with repetition, e.g., “but some audience will say that the part on the lid is the joy of my yogurt” gets responses of “the part on the lid is the joy of my yogurt”. Some Danmaku goes further along with the script lines; e.g., “I hope Mr Deng next time to catch a water monkey up” is followed by “Mr Deng: Thank you” with subtle sarcasm. On the other hand, Danmaku may deliberately in-cooperate; e.g., “Especially the girl, I look at all blushing” gets responses of “I don’t believe you, you old bastard!” (“我信你个鬼，你个糟老头子”). Through cooperation and in-cooperation, the viewers engage like acting together with the uploader.

Commercial Sensitive. Danmaku is found to be sensitive and vigilant to potential commercial ads. The viewers usually have a hunch at an oncoming ad even much prior to its actual appearance. A significant example is a video describing yogurt. At 02:35 of the video, the uploader is talking about the design of the yogurt bottle, but one Danmaku says, “No yogurt ads this time, right?”; at 04:40, the uploader is talking about the chemistry of yogurt, but a prominent amount of Danmaku is saying things like “Receive codeword”(收到暗号), “Something’s wrong”(不对劲), “Are we running?”(要跑了吗?). Danmaku that is similar to them continues until the time of 06:07, at which the ad begins — 87 seconds after massive Danmaku expresses collective hunch about that. Nevertheless, there is also a case where the Danmaku fails to predict the absence of ads, i.e., the Danmaku expresses the hunch about potential ads, but there is not. They are also capable of identifying the shot in popular ads; e.g., an uploader uses a similar special effect to a prevalent ad of Snow Beer; as a result, some Danmaku ask “Did Snow transfer money?”.

5 DISCUSSION

In this study, we illustrated the landscape of popular science videos on Bilibili in order to contribute to the science communication studies under the context of social computing.

In the previous study of r/science [35], a trade-off between entertaining and science rigorousness in terms of the information to be shared in the science communication contexts has been figured out. Our findings about the *Popularizer* also identified the conclusion. Uploaders of *Popularizer* are the most popular than others if counting by the overall number of followers Figure 3. They beat the *Scholar/Researcher* even without fully qualified solid scientific background. Furthermore, they are good at making videos with more infotainment fragments Figure 6 and rich features to enhance the entertaining atmosphere Figure 5.

On the other hand, the findings about Danmaku behavior add new knowledge to the interaction process between the uploader and the viewers. We found that Danmaku behaves differently when the narration is switching from serious to entertaining content, which can be evidence of the effect of storytelling strategy on the viewer behavior and engagement. Furthermore, we provided some new and interesting insights about what the Danmaku is trying to convey and its features. The

findings then revealed that Danmaku, or viewers, are content-receiver and content-amplifier and creators. Rather than as a result of the conventional ‘action-to-reaction’ process that begins from the uploader and ends at the viewers, Danmaku allows content construct by the viewers. Danmaku can provide unusual observations, which is a way to call others’ attention on a particular content and spread the effect to others, i.e., to amplify the content conveyed implicitly by the uploader. Danmaku can also provide summaries that ‘concentrate’ the content and spread to others, which is another way of amplifying the content by the viewers. The cooperation and in-cooperation between the uploader and the viewers through Danmaku is a further expansion of video content, through which a viewer becomes a content-creator rather than only a receiver. Finally, viewers are sensitive to commercial content, which may harm the science communication process.

5.1 Limitations

Our work has some limitations. In the study we only focused on the popular videos and the corresponding uploaders resulting in relatively small sample sets. So that some types of uploaders and their videos are not covered. Also, in terms of the taxonomy, we determine the category based on limited information provided by Bilibili, the insufficient information may lead to incorrect decisions. Another way to understand people’s behaviors and engagements is to directly get in touch with them to know their motivations and perceptions. Thus, interview study of online survey might be a good supplement.

6 CONCLUSION

In this paper, a mixed-method study has been conducted to extend the scope of online video-based science communication to Bilibili. Further we involved a collaborative interaction mechanism (i.e., Danmaku) for video watching to illustrate the correlations between science communicator’s narration strategies and viewer’s engagements in the observed popular science videos. Consequently, a taxonomy of uploader has been created based on observation of 514 samples. The taxonomy categorizes uploaders into 11 classes of which 9 of them do not show any evidence of scientific backgrounds. The result reveals the large population of amateur (in terms of science) content creators on Bilibili suggesting the broad participation of the general public in online science communication. By open coding of 111 sampled videos, we find the uploaders from *Scholar/Researcher* and *Popularizer* categories are good at making videos with skillful video making techniques and rich narration strategies. This result inspired us to explore the viewers’ engagements along with video storytelling narrations. Eventually, we categorize viewers’ behaviors based on the Danmaku content, and illustrate that video fragments with communicator’s acting can foster burst of Danmaku. The phenomenon gives insights to design of interactive mechanism for online video-based science communication.

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