Communicating “CRISPR Cas-9” through online videos on YouTube

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Abstract

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Pouria Nazemi

The objective of this study is to investigate the communication of gene-editing technology (CRISPR Cas9) through online videos and on YouTube (or “the YouTube video sharing platform”). Despite much research on the communication of new and emerging technologies, CRISPR Cas9 and its representation on YouTube have never been examined in detail. The dynamic ecosystem of YouTube and the novelty of CRISPR Cas9 can help us investigate negotiations between an emerging/controversial technology and a visual media platform. This thesis thereby examined videos on YouTube about CRISPR Cas9 from its emergence in 2014 until the end of 2019. The focus was on what kind of CRISPR Cas9 videos are produced and published on YouTube, how these videos represent this technology, any tendency toward technophobia/technophilic among them, and which models – if any - of science journalism stand out in these videos.

A multi-dimensional search method was used to extract 743 videos to address these issues. After primary analysis, three-time spikes– based on the number of videos published (52 videos)–were chosen to examine in detail. This research used qualitative content analysis (QCA) to focus on the videos’ narratives and graphics and their representation of various issues. This approach generated three significant findings: (1) the number of videos was found to be comparable with other topics related to new technologies; (2) most of the videos had a positive view on the future of CRISPR Cas9 technology, but there were concerns about ethical issues with native content tending to be more opinionated toward the subject than immigrant videos; (3) new models of science journalism were not evident in the sample, but interesting signs of a sub-model of the science literacy model were found. Overall, considering the evolving and increasing role of YouTube in science journalism, this study sheds new light on various paths forward for science journalism studies in digital visual media.

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Table of Contents

List of Tables

List of Figures

CHAPTER 1

INTRODUCTION

This project engages with the debate over the changing landscape surrounding digital video storytelling, journalism, and controversial science and technology. As Stuart Allan argues, digital technologies' communication impacts on science journalism maybe both be salutary and daunting (Allan 2011). This argument is apparent in the popularity of social media and the tendency to produce short format journalism content for the web, which may sacrifice details for brevity and has (re)awoken debates over reliable sources and the spread of pseudoscience online (Thaler and Shiffman 2015; Dunwoody 2014a; Brossard and Scheufele 2013; Allgaier et al. 2013). The trend of producing and consuming online videos on YouTube, Vimeo, IGTV and other such platforms shows exponential growth. Online videos accounted for 70% of all internet traffic in 2015 and were estimated in 2018 to reach 82% in 2020 (León and Bourk 2018b), which means that online video traffic on the internet may increase 100-fold from 2005 to 2020.

According to Limelight Network and “The State of Online Video 2020” report, the average online viewing time continued to grow in 2020 and reached 7.91 hours per week in 2020. This number was 4.28 in 2016 (“State of Online Video 2020 | Limelight Networks” 2020). According to this report, about 27.2 percent of viewers spend more than 10 hours per week watching online videos. The increase of time spent watching online videos has been observed among all age ranges, with the highest jump of weekly average watching among people between age 61 to 99 (“State of Online Video 2020 | Limelight Networks” 2020). “YouTube dominates user-created video viewing with 65 percent spending most of their time on that platform globally, with runner-up Facebook far behind at 16 percent,” according to the report.

A more recent study shows that “[b]y 2022, online videos will make up more than 82% of all consumer internet traffic — 15 times higher than it was in 2017” (“Cisco Annual Internet Report - Cisco Annual Internet Report (2018–2023) White Paper”; “55 Video Marketing Statistics For 2020” 2019). Some estimates say it “would take an individual more than five million years to watch the number of hours that will circulate on the internet each month in 2020” (“Cisco” 2016). The 2019 State of Online Video Report – Part I, published by Tubular, shows that both views and engagements on YouTube kept increasing in 2019, by 26% (views) and 31% (engagement) respectively, and there is no sign of this trend slowing down. This study also shows that Science and Technology videos on YouTube increased by 13.4% in 2019 compared to 2018. (“Report: 2019 State of Online Video” 2020). Online videos are becoming a significant player in shaping our understanding of science and technology.

YouTube continues to be a considerable part of the online video ecosystem. In 2020 it remained the second most accessed platform and website on the internet just after Google.com (“Alexa - Top Sites” 2021.) YouTube has more than 2 billion logged-in monthly users, and “people watch more than a billion hours of video on YouTube every day” (“25 YouTube Statistics That May Surprise You: 2021 Edition” 2021). The pandemic of 2020/2021 was a player ib increasing the interest in online videos as this content became a source for information about Covid-19 (C. E. Basch et al. 2021a; Li et al. 2020). New researches also show how YouTube videos play a role in the perception of trustworthiness of scientists among audiences (Reif et al. 2020).

While some may have concerns about the quality vs quantity in videos on sharing platforms such as YouTube (e.g., Cassidy et al. 2018; Fischer et al. 2013; Sorensen, Pusz, and Brietzke 2014), the 2019 State of Online Video Report indicates that the number of total updates on YouTube decreased by 34% in 2019 while the total engagements and views of these videos increased (“Report: 2019 State of Online Video” 2020). This could be interpreted as more quality videos on YouTube, but regardless, it shows that videos are being increasingly engaged with on this type of platform. Although some studies explore this video content in the context of science and technology (León and Bourk 2018b; Welbourne and Grant 2016; García-Avilés and de Lara 2018), these studies so far only focus on issues such as vaccination, climate change and nanotechnology.

The research on the educational role of science and technology videos on YouTube is ongoing (Koto 2020; Pattier 2021). In 2019 and 2020, when the Covid-19 pandemic hit the world, YouTube became one of the main sources of scientific information. The importance and accuracy of this platform for communicating science about the pandemic have been discussed by various researchers (Li et al. 2020; C. E. Basch et al. 2021a; D'Souza et al. 2020; Marchal, Au, and Howard 2020). The discussion around the pandemic also gave new life to discussions about vaccinations, and YouTube played a prominent role in this debate (C. E. Basch et al. 2021a; C. H. Basch et al. 2020; Puri et al. 2020)

It is important to emphasize that YouTube is a social media based on videos, not a news organization or news media. Still, both news media and journalists use it to reach more audiences. Also, people are using YouTube (specific channels) to get their news. For content creators, YouTube has a particular category to categorize their content as "News."

There is much to be learned from adding new topics to this literature. This thesis takes a closer look at the case of CRISPR Cas-9 technology and its journalism coverage on the platform of YouTube to better understand the use of this platform regarding the communication of CRISPR Cas-9 and the representation of this technology. In particular, this research aims to take a closer look at coverage of CRISPR Cas9 on YouTube in the context of technophobia.

CRISPR Cas-9 is a new and powerful gene-editing tool. With this method, scientists can apply specific changes in any target DNA. This method is changing the landscape of biology

(Doudna and Charpentier 2014). I have been following various trends in science and technology, such as gene editing, which could change human life in future for some time. In the Fall of 2017, at the World Conference of Science Journalism, in San Francisco, I had a chance to meet and chat with Dr. Jennifer Doudna. In 2020, Emmanuelle Charpentier and Jennifer Doudna shared the Nobel Prize in chemistry for developing this precise genome-editing technology (Ledford and Callaway 2020). The meeting showed me the importance of CRISPR Cas-9. Not only because CRISPR Cas-9 brings the promise of change to the world, in ways that were unimaginable (science fiction) years before, but because CRISPR Cas-9 interacts with a wide range of ethical, economic, social and communication issues in science and technology (Doudna and Sternberg 2017; Dayan 2020; Zhang 2015; Gonzalez-Avila et al. 2021; Thompson 2020; Schleidgen et al. 2020; National Academies of Sciences et al. 2020). Considering the fact that the first publication about this discovery was published in 2012 (Ledford and Callaway 2020), awarding the Nobel prize for it just eight years after the publication is an indicator of how fast this field of study is growing, and it is also a testament to the potential power and functions of this technique. It struck me as an essential topic to study.

To explore this topic, this thesis built on efforts to develop models of science journalism (Secko, Amend, and Friday 2013) and presents a qualitative content analysis (QCA) of selected CRISPR Cas-9 videos. Attention was given to the implications of various models of science journalism found on YouTube and their potential for utilising digital tools to empower different model-based stories. The role of technophobia in digital storytelling is seen to emerge as a critical debate for the future.

Research Problematic

Online videos accounted for 70% of all global traffic in 2015 (León and Bourk 2018b). At the same time, the Internet has become Americans' primary source of science and technology (S&T) information, with more than 5 in 10 Americans citing it as their primary source in 2016, compared with about 1 in 10 in 2001 (National Science Board 2018). This trend is not exclusive to the United States. YouTube is a significant source for creating, distributing and viewing online videos. In 2019, YouTube had the 2nd rank in global engagement related to visitors ("Youtube.Com Competitive Analysis, Marketing Mix and Traffic - Alexa" 2019). According to the 'Online video usage in the United States - Statistics & Facts' report, in the 3rd quarter of 2019, 81% of Internet users in the US, aged between 18-25, were users of YouTube (Clement 2019). YouTube was the 2nd most popular social network in 2019 and had 2 billion users worldwide (Clement 2019). About 79% of internet users – in the U.S. – say they have a YouTube account ("Digital 2019: Global Digital Overview" 2019). Therefore, YouTube can be considered as one of the major players in the online video ecosystem.

The focus of this thesis is on communicating CRISPR Cas-9 technology on YouTube. YouTube is essentially a social media platform. Paulussen and Harder (2014) discuss as a solid source for journalists with original content on these platforms sometimes becoming the source of the stories, which appear in 'traditional' media (Paulussen and Harder 2014). The discussion of citizen journalism is also flourishing in this context (e.g., Allan and Thorsen 2009; Goode 2009; Atton 2009). YouTube and other social media platforms are one foundation of citizen journalism and play a significant role in this category (Poell and Borra 2012; Antony and Thomas 2010). Of course, any relationship between a platform such as YouTube and the profession of journalism is a challenging one (Peer and Ksiazek 2011). Still, the fact remains that "journalism has gradually become 'normalized into social media,' and most journalists use social media platforms to publish their work" (Bruns 2018; Djerf-Pierre, Lindgren, and Budinski 2019).

The growth of online videos and YouTube provides a stage for shaping and changing public perception of scientific issues (Welbourne and Grant 2016; Morcillo, Czurda, and Trotha 2015; Busse 2007). This space may also be providing evolving content forms that present different versions of science journalism models (Amend, Capurro, and Secko 2014). As such, YouTube is playing a growing role in the debates about the future of science and technology with the focus on education (Welbourne and Grant 2016; Jaffar 2012; Mayoral et al., n.d.; Everhart 2009; Allchin 2010) and may be influencing concepts of interest to this thesis, such as technophobia and technophilia (Ellahi 2017; Weil and Rosen 1995). Moreover, YouTube may now be a platform to produce and distribute information and misinformation about scientific topics (Madathil et al., 2014; C. H. Basch et al., 2015).

Despite the popularity of digital video, and YouTube in particular, as a source of information on science and technology, these videos' accuracy and fact-based information have not been examined in detail. The few studies that exist are related to health communications (Keelan et al., 2007; Syed-Abdul et al., 2013). And explore topics such as immunization based on whether videos can be categorized as positive, negative or neutral. These studies do not examine the reliability of videos, the themes present, or theorize the models of science journalism present. This gap is important when we realize that competition via social media and between YouTube users (both creators of original content or re-distributers of other's content) to get more engagement, for example, could affect the content itself. This could be due to the metrics for views (engagement) in YouTube being a pathway for financial support and to attract advertisement, thereby gaining various means of financial income.

In the case of the CRISPR Cas-9 gene-editing system, people are dealing with a relativity new technology that emerged during the boom of social media and content sharing platforms (Doudna and Charpentier 2014; Doudna and Sternberg 2017) (for more about the technology of CRISPR Cas-9, see the literature review section below). The ambition to get more audiences by using controversial titles and narrative tactics could be amplified on YouTube, for example, due to the power of this technology to modify genetic material (Dominguez, Lim, and Qi 2016; Redman et al. 2016), its linkage to genetic engineering and controversial social debates (Evans 2002; Ahteensuu 2012; Hoban, Woodrum, and Czaja 1992; Fletcher 1990), and its connection to discussions of technophobia and technophilia (Zhang 2015; Jayaraman and Jia 2012; Doudna and Sternberg 2017). Thus, complex parameters could play a substantial role in the tendency to divert from accurate narratives in the case of CRISPR Cas-9, which provides a fruitful research topic to explore the more significant issue of how science journalism is being presented on YouTube. In doing so, this thesis seeks to add to our understanding of online journalism and new technology (Steensen 2011) and to how journalists (content providers) and audiences interact in an online environment (Secko et al. 2011).

Staging the Stage: A Brief Introductory Literature Review on CRISPR

Doudna and Charpertier (2014) set the stage for this thesis when writing: “The field of biology is now experiencing a transformative phase with the advent of facile genome engineering in animals and plants using RNA-programmable CRISPR Cas-9” (Doudna and Charpentier 2014). CRISPR Cas-9 allows cheap and easy gene editing. Notably, the applications of CRISPR Cas-9 technology will reach human subjects. In 2016, Chinese scientists pioneered the first human CRISPR trial and injected CRISPR-modified white blood cells into a patient with metastatic lung cancer (Cyranoski 2016). In 2018, He Jiankui, of the Southern University of Science and Technology in Shenzhen, China, told the Associated Press that his team had engineered the genomes of twin baby girls (born recently) to modify a gene to confer resistance to HIV infection (Cyranoski 2018; Normile 2018; “AP News” 2018). This announcement created a debate about the future of CRISPR Cas-9 technology (Cyranoski and Ledford 2018; Dickenson and Darnovsky 2019a; Ma, Zhang, and Qin 2019). He Jiankui did not use a traditional science journal to announce his work instead of news outlets and news media. Specifically, the YouTube video sharing platform (Normile 2018).

CRISPR (Clustered Regularity Interspaced Short Palindromic Repeats) and CRISPR associated (Cas) protein are RNA-mediated adaptive defence systems that have evolved in bacteria and archaea. There are three types of CRISPR/Cas systems, of which CRISPR Cas-9 belongs to type II (Jinek et al., 2012). Cas-9 is a DNA endonuclease guided by two RNAs (Jinek et al., 2012). This system provides a potent, relatively cheap, and straightforward tool for targeted gene editing. "CRISPR/Cas9 is a gene-editing technology which involves two essential components: a guide RNA to match the desired target gene, and Cas9 (CRISPR-associated protein 9)—an endonuclease which causes a double-stranded DNA break, allowing modifications to the genome" (Redman et al. 2016). One aspect of this system that makes it powerful is its ability to apply gene editing to the germline and makes those changes inheritable (Baltimore et al., 2015).

This tool and its potential have created interest among general audiences (Weisberg, Badgio, and Chatterjee 2017). However, CRISPR Cas-9 technology has inherited the debate over the appropriate use of genetic technology. While there is extensive literature about public understanding of genetics and genetic engineering (for example see, Evans 2002; Hoban, Woodrum, and Czaja 1992; Sturgis, Cooper, and Fife-Schaw 2005; Van Dijck 1999), for brevity, research into public engagement with genetics can be characterized in terms of three approaches (Haran and O'Riordan 2018): (i) attitude studies (Condit 2010; Sturgis, Cooper, and Fife-Schaw 2005), (ii) media content analysis (Kitzinger 2008; Nerlich, Dingwall, and Clarke 2002), and (iii) focus group work (Roberts and Franklin 2004). Since there are not many in-depth studies about CRISPR Cas-9, media/journalism studies about genetic engineering (which CRISPR Cas-9 is a subset) suggest that, while people focus on the currency of genetics as immediate or emerging technologies, they also view them “longitudinally, not simply at the moment, and use this in relation to their own experience to make knowledge, for example, about genetics” (Haran and O’Riordan 2018). The history of genetic engineering is therefore important background context to this thesis.

In this research, the main focus is on the themes that emerge about CRISPR Cas-9 on YouTube. The discussion about CRISPR Cas-9 extends beyond science, including the economy, policy, ethics and philosophy. There is a booming market for this technology: “According to Coherent Market Insights, the global CRISPR and CAS gene Market was valued at US$1,388.1 million in 2017 and is projected to exhibit a CAGR of 20.8% during the forecast period (2018 – 2026)” (*Bloomberg.Com* 2019). There is also discussion about the ethics of this technology (Lanphier et al., 2015; Cyranoski, 2015) and it's regulation (Dominguez, Lim, and Qi 2016; Waltz 2016). It has also given new life to the idea of genetic determinism and free will (Dennett 2015; Resnik and Vorhaus 2006).

The discussion about the representation of CRISPR Cas-9 in YouTube videos also brings an opportunity to study this technology through the frame of technophobia/technophilia. Most of the work on this issue has focused on the relationship between IT, computer science and AI (Weil and Rosen 1995; Brosnan 1999; Campion 1989). However, the concept of technophobia/technophilia has expanded far beyond computer sciences, and some studies explore this frame via genetics (Jayaraman and Jia 2012; Ma, Zhang, and Qin 2019; Doudna and Sternberg 2017). This suggests that it may be productive to extend this frame to evaluate other disciplines as well (Osiceanu 2015; Eiteljorg II 2014; Brand and Fischer 2013; Marc Grassin 2011).

Lastly, given the primary goal of this research is to study CRISPR Cas-9 representation on YouTube, we should keep in mind that the results of this study will not be open to generalisation, especially considering the concept of the digital divide (J. van Dijk and Hacker

2003). Nevertheless, as one of the leading platforms for creating, sharing and re-distributing video content (León and Bourk 2018b), such new media is creating a new landscape for science information consumers (Brossard and Scheufele 2013) that needs examination. There are some studies about YouTube videos and their accuracy in other fields (León and Bourk 2018b; Keelan et al. 2007; Syed-Abdul et al. 2013; M. A. Shapiro and Park 2015), but none of them focus on CRISPR Cas-9. Yet YouTube content is part of the debate about scientific issues and is becoming a tool for policymakers in different fields of study, including climate change (M. A. Shapiro and Park 2015; Laslo, Baram-Tsabari, and Lewenstein 2011).

Research Questions

Various factors determine the quality and popularity of video content (Diakopoulos, Goldenberg, and Essa 2009; Welbourne and Grant 2016), and by analysing the contents of the selected YouTube videos, this thesis focussed on the following research questions:

RQ1: How many videos about CRISPR Cas-9 are on YouTube between 2012 to 2019?

RQ2: What themes emerge from analyzing the content of selected videos on CRISPR Cas-9?

RQ3: What models of science journalism have been used in the selected videos, and what (if any) new models emerge from analyzing these videos?

The following chapters examine the methods of data gathering used (Chapter 1), provide a quantitative analysis (Chapter 2) and qualitative analysis (Chapter 3) of the data, and asses the models of science journalism in the findings (Chapter 4). The thesis ends with discussing the importance of findings and the future direction of this research (Chapter 5).

CHAPTER 2
DATA GATHERING

Approach to the Problem

To conduct this research on YouTube, a similar path to León and Bourk (2018a), whose work is based on methods presented by Hargreaves et al. (Hargreaves, Lewis, and Speers 2003), was followed.

The origins of research on CRISPR can be traced back to the 1980s, but the main story started in 2012 (Lander 2016) when the following events happened:

- The first commercialisation of CRISPR Cas-9 technology.
- The first patent application was submitted for CRISPR Cas-9 technology.
- The publication of the radically new gene-editing method that harnessed the CRISPR Cas-9 system.

Due to the importance of these events, the project focused on collecting YouTube videos during the period between 2012 and November 2019. Within this timeframe, the thesis approached the overall problematic in three ways:

1. To better understand the volume and general estate of the contents about CRISPR Cas-9 on YouTube, an extraction method was developed to collect raw data from YouTube. As explained in Chapter 3, this method produced a reasonable data set that contained the number of related videos and their related parameters. This data set was used to extract characteristics about the videos: engagement parameters, durations, the origin of the contents (Videos which initially created for YouTube, which I call YouTube native videos and videos which made for other platforms and then shared on YouTube as secondary sharing platform which I call them immigrant videos to YouTube) and possible correlations between the number of uploaded contents and CRISPR Cas-9 trends in the news.

2. After choosing the samples from this data set (Chapter 3), the QCA method of textual and non-textual analysis using the coding (Schreier 2012; Marshall and Rossman 2014; Krippendorff 2004; G. Shapiro and Markoff 1997) was used to evaluate the contents of each selected video. A system of parameters was defined to explore each video based on each video's transcripts and graphical elements. This allowed two main themes of technophobia and the representation of the moral discussions about the CRISPR Cas-9 technology to be examined.
3. Lastly, selected samples were compared with the existing models of science journalism to see which models have been used more often and if these samples hint of new models of science journalism on YouTube.

Theoretical and Practical Considerations

As Kim (2012) mentions, "YouTube has a great impact as a distributor of both user-generated content and professionally generated content" through its own commercial, advertising, and legal system (Kim 2012). While this ecosystem provides a platform that can play a significant role in digital journalism (Poell and Borra 2012), it also represents challenges for researchers. YouTube uses multiple methods and algorithms to promote or hide videos. This means that discovering a video on YouTube is not a direct path (Zhou et al. 2016; Zhou, Khemmarat, and Gao 2010). If you do not have a direct link to a video, finding it could be difficult and subject to parameters decided on by YouTube and its algorithms (e.g., your YouTube activity history, sponsored content, etc.). While this subject is not the focus of this research, it is worth noting that these algorithmic systems could affect the platform's content. Users will tend to generate videos that have a higher chance of being viewed, and they will succeed more if they follow the way that search functions and recommendations work.

For research on YouTube, one obstacle is accessing the raw data and contents on the platform. Any reliable analysis should be based on a reliable and complete set of data, but this is challenging for YouTube content. So far, most researchs have gathered their data based on end-user searches and using search engines such as Google and YouTube (León and Bourk 2018b). But this method – as I show below in this chapter – is highly affected by the algorithm provided by YouTube. YouTube safeguards its databank, even using methods to add errors or hide some results from a search. The level of this error is high enough to make the data set unreliable (addressed below).

While this issue is addressed below via a multi-method approach, several considerations are still important to this thesis:

- Some users will upload their YouTube content as private. This content will not appear in search engines and is also hidden during an API search. This content is primarily available through direct links. Some of the most controversial content, including videos related to bio hacking and 'how to' tutorials, are in this category.
- Some videos reported by other users as impropriate, or those with claims of copyright, could be deleted from the search engine's results.
- Some videos were deleted or edited between the time of data gathering and analyzing data, while users can change the date of publishing their videos.
- Some videos use keywords in their title or description only to be discovered in other searches. In other words, they are using keywords such as 'CRISPR Cas-9' in videos unrelated to the subject to increase their chances of showing up in other searches. This method – like using irrelevant hashtags in other social media – is especially used when some news about the keyword becomes popular and people start searching for the keyword. By using trendy keywords, content generators try to hunt for more viewers.
- Some videos later edited their descriptions and deleted trending keywords. By doing so, while their videos show in primary searches, they no longer show any signs of the keywords during analysis.

These points all show the important consideration that YouTube videos are not static and that instead, specific subjects and specific periods on YouTube are somewhat dynamic. Any research should be aware of this dynamic situation and how time-sensitive the results could be.

Because of these challenges, I can not argue that the data set used here is complete and final. But using the three different methods described next, there is a high degree of confidence that if anyone searches YouTube with publicly accessible search methods, during the chosen time interval and with the selected keywords, their results are included in this data set used in this thesis.

Data Collection

This research is based on the data about videos uploaded on YouTube. The first step was data collection, and there are some challenges to gathering this data and analyzing the contents of the videos. YouTube doesn't provide an advanced and customized search engine, so extracting unbiased data about the subject is problematic (Bärtl 2018). In addition, using methods such as Google advanced search increases the chance of system-bias and does not cover all the available data. Such direct inquiries would therefore not provide detailed characteristics of each video.

To address this issue, a combination of three methods for gathering data from YouTube were used:

1. The coding program, python 3.0, was used to develop a novel and customized search probe to gather data from YouTube. This search probe used the API of YouTube to search and bring back the video data based on specific fields of inquiries such as date, time, producer and publisher, number of interactions, and keywords inside the description field. To be sure that data gathering was not affected by choice of the characters, this series of characters was used: C/c + R/r + I/i + S/s + P/p + R/r + (No space, space, half-space, - , _, / ,\ ) + C/c + A/a + S/s + (No space, space, half-space, - ,

_, / ,\) + 9. This probe is an example of using new digital tools – such as coding – in journalism studies. It also creates a platform for these kinds of customized search probes that can be built upon for future projects, creating a novel outcome of the project. There are a few existing python-based search modules for YouTube, but this probe exclusively addressed the requirements of this thesis. The program was coded with the help of Mrs. Nasrin Ghasemi. The result was published on GitHub as an open-source code for further use (Ghasemi and Nazemi [2020] 2020).

2. YouTube/Google actively safeguards its data bank, and even using the probe and API of YouTube, the result can not be completely reliable. YouTube 'deliberately' adds noise/error to the result. To address this issue, a java script program was created to automatically brows the search results of YouTube. The difference here is that in step #1, the probe searched the source (YouTube) database, but in this second step, the java script searched the results available to the end-user by searching the YouTube website. This improved the data collected in the first step. Because it brings back some results kept hidden from our probe – because of intentional error applied by YouTube, this extra step not only brings back some new results. It is also based on the actual results that a user can see if just want to use the YouTube search engine.
3. To ensure the reliability of step 2 in the data collection, a commercial scraping software, Scrap Storm, was also used to go through the end-user search results. This improved the data collected by ensuring that none of the related results were left uncovered. The results of these three methods were compared, and duplicate videos were removed.

To obtain the list of the videos from January 1st, 2012 to December 2019, the python program used the 'list' option from the API of YouTube ("Search: List | YouTube Data API" n.d.). Using this option, the ID, Title and Upload date were extracted for each video, which matched the string of characters within a search keyword. The extracted ID for each video was then used within the option of ‘videos’ in the API of YouTube (“Videos | YouTube Data API” n.d.) to extract parameters for each video, including the number of views, number of likes, number of dislikes, number of comments, duration of each video, and the description of each video.

Here is how readers can use the developed program to test the results:

- Obtain authorization credentials for API YouTube, also known as a token. You can request this from https://developers.google.com/
- Have Python 3.0 and MySQL installed on your computer. You must create a data bank in MySQL and import the main file into it and then open file ‘config’ to manage the settings.
- To extract the list of videos, you need to run this command in your command window: Python3 get video list.py; This command will return the ID of all videos with the different combinations of the keyword “CRISPR Cas-9”.
- When you create the primary list of all videos, you need to run the 2nd part of this program. By typing ‘python3 get_video_details.py’, this program will use each recorded ID by the previous step and brings back its details parameter and save them.

id	title	video_id	viewCount	publishedAt	likeCount	dislikeCount	createAt
214	CRISPR-Cas9: Safeguarding Gene Drives	4XEvSgaHS1A	649	2015-12-17 16:47:38.000000	11	0	2019-11-22 12:57:44.996581
215	CRISPR/Cas9 Transfection -Mirus Bio	Q6xyz77boFc	73811	2015-12-06 19:38:36.000000	169	114	2019-11-22 12:57:45.003416
216	É possivel editar genes? CRISPR Cas9 | #InstanteBiotec 08	xj6IKSZwSpc	11364	2015-11-19 13:58:32.000000	387	5	2019-11-22 12:57:45.004803
217	How CRISPR lets us edit our DNA | Jennifer Doudna	TdBAHexVYzc	821973	2015-11-12 16:28:30.000000	12073	303	2019-11-22 12:57:45.007011
218	CRISPR-Cas9 gene editing and how it works - with Jennifer Doudna	avM1Yg5oEu0	54160	2015-11-11 00:39:23.000000	295	16	2019-11-22 12:57:45.008401
219	Emmanuelle Charpentier on CRISPR-Cas9, Umeå University, Sweden	cv6UveDO6u0	7502	2015-10-04 15:31:25.000000	39	2	2019-11-22 12:57:45.010683
220	Recent Advances in CRISPR-Cas9 Genome Engineering Technologies	gbTKnB-_wyk	4663	2015-04-13 14:56:54.000000	34	0	2019-11-22 12:57:45.012076
221	Genome editing with the CRISPR-Cas9 system	h18HmFtybnQ	30063	2015-04-06 16:15:46.000000	298	3	2019-11-22 12:57:45.013219
222	Jennifer Doudna (UC Berkeley / HHMI): Genome Engineering with CRISPR-Cas9	SuAxDVBt7kQ	450555	2015-03-23 17:19:22.000000	4078	63	2019-11-22 12:57:45.015441
223	3) CRISPR Cas9 - gRNA Design	dXPDefej0Ps	66534	2015-03-03 02:35:55.000000	347	21	2019-11-22 12:57:45.017563
224	2) CRISPR Cas9 - Methods and Tools	INC_kdr7I34	50075	2015-02-06 03:51:04.000000	318	4	2019-11-22 12:57:45.019579
225	CRISPR Cas9: Gene Therapy	KiuxZxFAsuA	937	2015-01-30 14:11:16.000000	12	0	2019-11-22 12:57:45.020935

Figure 1 Sample from the result page of our search probe

The main challenge in this phase was the lack of accuracy of results. The results were highly different when running this program from different machines or even from the same machine in different times. This difference was not limited to different independent searches. When the program ran to bring me back the parameter of ‘totalResults’ and then was used to bring back the IDs of videos based on that, the total IDs were very different from our primary 'totalResults.'

We (Mrs. Ghasemi and I) asked the Google support team to explain this discrepancy. The answer was that "As written in our documentation, totalResult is just an approximation of the actual result." ("Huge Difference Total Result in Sum of Split Date [145687648] - Visible to Public - Issue Tracker" 2019). There are many reasons which could be attributed to this result. Google and YouTube do not share their exact data to safeguard their algorithm. More than that, the algorithm is trying to actively respond to the personal behaviour of users. Also, different settings for each video could affect any search. For example, if someone published her video as private, while it can be shown in the totalResult, their ID won't come back in the search program.

Using this method - and running it from different computers and systems - it was possible to bring back a set of 420 videos. These were videos that had all of the search criteria with high confidence. But as discussed before, due to the intentional errors and algorithmic limitation that YouTube posed against exact searches, this was not a reliable set. After a request to YouTube to provide access to exact data was denied, the two additional steps outlined above were added to make the data set more reliable. Both 2nd and 3rd methods are based on end-user results. These methods did not rely on videos data stored in the YouTube local databank but on the data available via the search engine of YouTube.

To do a complete search on the YouTube search engine, our date interval was selected and keywords (as described in page 23) were used to bring back results. Then, a Java Script command was used to reach the end of the results pages, for example:

```
var scrollInterval = setInterval(function() {
  document.documentElement.scrollTop = document.documentElement.scrollHeight;
  }, 50);
```

The developer console in FireFox web browser was used with a private tab (you can reach this by pressing F12) and the following commands:

```
1- var x = document.getElementsByClassName('title-and-badge');
2- x #This is comment: this returns the number of results and whole htmls and css
codes which we don't need.
3- for (var i = 0; i < x.length; i++) { console.log( x[i].lastElementChild.href ) } #This is comment: this line filter the
result and returns only URLS.
```

All the URLs could then be copied in a text/word file. This method is like going Through all the results that a native YouTube Search engine would provide to gain theID of all available videos. To ensure that the computer's settings and history of previous searches had a minimum effect on the results, all the cookies were deleted, a private search mode was used, and different IPs to search. This method brought back a list of 546 video IDs.

Next, commercial scrapping software was used to scrape and gather the results for the same search and in the same time interval. The use of 'Scrapestorm' software brought back 650 videos IDs.

After gathering video IDs from these three methods, a primary data bank of all video IDs was created. All the duplicated results were deleted to provide the source data for this thesis. The 2nd part of the program was run with the command 'get_video_details.py' to bring back all the details and parameters for all videos in this databank. With this method, I gathered a **total of 743 videos**. Each video contained the main keyword "CRISPR Cas9" in its title or description. For each of these IDs, I extracted the following parameters: Video ID, Published Date, Channel ID, Title, Description, View Count, Like Count, Dislike Count, Comments Count, and Duration.

Data Quality

To examine the quality of the data set, the data quality was checked on a random subset of the databank. For a data bank with a relatively small population size – in this case, N=743 –

reaching a high level of confidence with a small margin of error would only be possible if someone checked a sample size almost equal to the population. To avoid this issue, a two-step quality check was completed. To choose a sample size from our data bank population, I used the following formula:

Formula 1

$$\text{Sample Size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 \times N}\right)}$$

In this formula, **p** is population proportion, which in this case was conservatively set to 50% (which brings me back the largest sample size fit in the requirement); **e** is margin of error, which was set to 10% (any less margin of error will lead to a sample size almost equal to population in this case and would not be usable); **z** is a parameter call z-score that is calculated based on the confidence level. **Z-score** was calculated as follows:

z-score = inverse normal cumulative distribution of $(1 - (\frac{1-Confidence\ level}{2}))$

and for the chosen confidence level of 95%, the z-score is 1.96. Now, with following variables:

N=743

Confidence level is 95%

Z = 1.96

P=50%

e= 10%

Formula 1 will show me that I need a sample size of 86. In other words, if I check 86 videos for the quality of data, it will tell me that the quality of our population is satisfied in the 95% of confidence level and the margin of the error of 10%.

Secondly, to ensure the quality of our final data – Videos around the three chosen dates – I manually check them. I watched all of them and made sure that they were related to our search and that our final data was clear.

This thesis used a python code to select 86 random videos for data quality tests to generate 86 numbers between 1 and 743. This script was designed to avoid duplicate numbers. Because of this, it deleted any random number that was generated twice and/or more. As a result, it is possible that the final number of unique generated numbers would be less than the targeted number of 86. To address this, the code was designed to create 100 random numbers, from which I chose the first 86 numbers – without order - were selected. The script of this command is as follows:

```
import random
list=[]
for i in range(100):
    r=random.randint(1,743)
    if r not in list: list.append(r)

    print(list)
```

This script was run on June 16th, 2020 – 12:52 EST, and brought back the following sequence with 92 numbers (which means eight generated numbers were duplicates):

[162, 666, 155, 653, 168, 116, 94, 733, 538, 660, 55, 561, 664, 119, 700, 108, 285, 172, 652, 134, 683, 79, 47, 590, 374, 89, 730, 353, 68, 262, 378, 153, 124, 459, 634, 490, 597, 253, 40, 310, 715, 251, 342, 118, 593, 537, 30, 148, 137, 394, 123, 114, 457, 171, 225, 1, 160, 237, 425, 629, 248, 617, 147, 517, 409, 78, 80, 236, 22, 522, 539, 740, 170, 584, 208, 437, 24, 141, 347, 642, 23, 600, 243, 704, 11, 581, 256, 293, 725, 606, 712, 72]

The first 86 numbers were selected as follow:

[162, 666, 155, 653, 168, 116, 94, 733, 538, 660, 55, 561, 664, 119, 700, 108, 285, 172, 652, 134, 683, 79, 47, 590, 374, 89, 730, 353, 68, 262, 378, 153, 124, 459, 634, 490, 597, 253, 40, 310, 715, 251, 342, 118, 593, 537, 30, 148, 137, 394, 123, 114, 457, 171, 225, 1, 160, 237, 425, 629, 248, 617, 147, 517, 409, 78, 80, 236, 22, 522, 539, 740, 170, 584, 208, 437, 24, 141, 347, 642, 23, 600, 243, 704, 11, 581]

These numbers correspond with the identification numbers of videos in the data bank.

Upon checking these random videos, it was found that all of them met the qualification criteria of this thesis, which are:

a. CRISPR Cas-9 with any variation has been mentioned in the title or description.
b. Video has been uploaded between years 2012 to 2019; and

c. The related video parameters (such as like, dislike, view, and duration) had been extracted.

This data set was used for the quantitative analysis presented in Chapter 3.

Selection of Videos for Qualitative Analysis

Only selected videos could be analyzed in depth to allow for a robust and detailed qualitative analysis. The purpose of the qualitative study was to answer 2nd and 3rd research questions:

RQ2: What themes emerge from analyzing the content of selected videos on CRISPR Cas-9?

RQ3: What models of science journalism have been used in the selected videos, and what (if any) new models emerge from analyzing these videos?

To decide which videos to analyze, I choose to focus on the three months with the highest uploads. All videos were therefore categorized based on upload date. The following table shows the distribution of uploads per month:

Date	Upload per Month	Date	Upload per Month	Date	Upload per Month
Dec-19	26	Dec-17	13	Dec-15	6
Nov-19	20	Nov-17	14	Nov-15	11
Oct-19	23	Oct-17	15	Oct-15	7
Sep-19	6	Sep-17	9	Sep-15	4
Aug-19	11	Aug-17	20	Aug-15	2
Jul-19	12	Jul-17	13	Jul-15	2
Jun-19	15	Jun-17	21	Jun-15	2
May-19	21	May-17	13	May-15	4
Apr-19	29	Apr-17	8	Apr-15	5
Mar-19	21	Mar-17	11	Mar-15	8
Feb-19	9	Feb-17	19	Feb-15	2
Jan-19	19	Jan-17	8	Jan-15	1
Dec-18	36	Dec-16	12	Dec-14	1
Nov-18	19	Nov-16	12	Nov-14	2
Oct-18	16	Oct-16	13	Oct-14	0
Sep-18	16	Sep-16	11	Sep-14	0
Aug-18	10	Aug-16	9	Aug-14	2
Jul-18	9	Jul-16	5	Jul-14	1
Jun-18	12	Jun-16	12	Jun-14	1
May-18	13	May-16	11	May-14	1
Apr-18	14	Apr-16	12	Apr-14	5

Mar-18	13	Mar-16	12	Mar-14	0
Feb-18	7	Feb-16	11	Feb-14	0
Jan-18	4	Jan-16	8	Jan-14	1

Table 1: Numbers of videos upload/publish per month

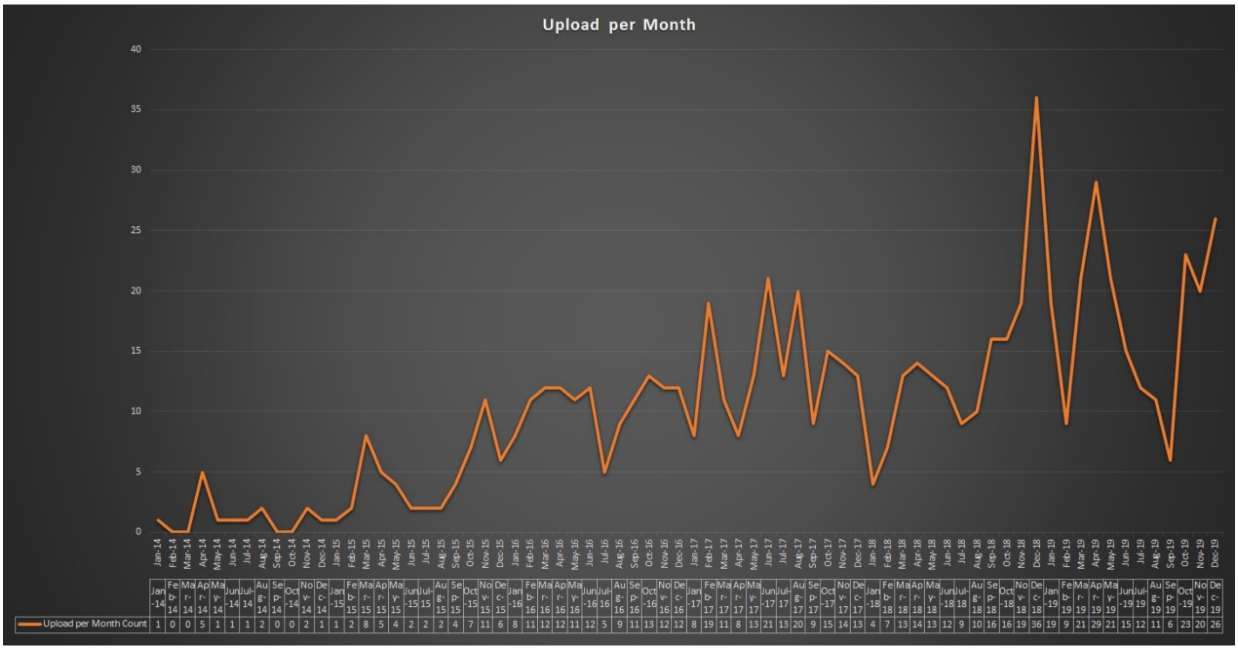

Figure 2: Trend of Upload/Publish per month for CRISPR CAs-9

While our date range for videos was between Jan 2012 to Dec 2019, the first video about the subject only appeared in Jan 2014. Between Jan 2014 to Dec 2019, there were three spikes in the number of Uploads/Publish dates: Dec 2018 with 36 uploads, April 2019 with 29 uploads, and December 2019 with 26 uploads.

These three spikes included an initial set of 91 videos for the detailed analysis. To confirm the quality of these videos, all were verified as conforming to the criteria for inclusion described above. In addition to this, because our analysis was based on both narration/textual and graphical elements of each video, all videos presented in any language other than English or French were excluded (this totalled 29 videos excluded based on language). In addition, seven videos have been deleted by the uploader between the time of data gathering and analysis, one video was duplicated and uploaded by a different user, one video was not completed and interrupted, and one video used the keyword ‘CRISPR Cas-9’ in another context. As such, the final total from the three data spikes was 52 videos. These videos were examined with the methods of the QCA by creating a coding frame and analyzing each video based on the parameters and codes which are described in Chapter 4.

None English-French	Deleted	Duplicated	Other Context	interrupted	Total
29	7	1	1	1	39

Table 2: Reasons for Exclusion (language other than French and English, deleted video, duplicated video)

#	Video ID	Published time
55	E573S0Ezy6g	2019-04-03 15:45:00
165	wnlJ6dRfPFg	2019-04-03 23:37:00
24	7FvWXoRKPlo	2019-04-05 16:55:09
438	2DY6phpUvwI	2019-04-09 14:03:50
648	tx2CiShHgbA	2019-04-14 22:05:35
526	EwO0kCRVNv0	2019-04-15 13:03:48
503	CKJgmwY2qms	2019-04-15 22:13:02
453	4KwfMpLtZxM	2019-04-15 23:15:41
9	3fiS4HK9h0k	2019-04-18 09:58:32
67	g7bkE1krgFM	2019-04-19 18:59:27
473	6P2hYCuccG8	2019-04-19 19:47:57
372	g-uUcqSebbA	2019-04-19 22:22:18
100	KRlJzNj6k3E	2019-04-20 01:57:44
546	gzsnZhPqpyc	2019-04-20 09:23:07
529	fi93KpsV7-U	2019-04-22 03:35:43
232	eCvYT-XvD3M	2019-04-22 17:42:50
435	1TPTclCb5xE	2019-04-24 04:54:36
698	YugJwo2tVHM	2019-04-29 22:57:59
395	nZR6mevfyD4	2019-12-01 12:56:58
450	3rMENVXwHUg	2019-12-02 17:52:03
130	pqm5tg7XQ5A	2019-12-04 22:45:00
521	eHcRxYNIuN4	2019-12-05 05:00:10
672	WbUrkN_tKQE	2019-12-05 08:51:40
567	jSSKk0bM0ZU	2019-12-08 18:46:25
472	6mXB1W_u7es	2019-12-08 20:21:27
539	gCVUVm-hS6o	2019-12-10 05:59:34
514	DlLFhfi55U4	2019-12-11 09:08:08
504	CMpWQqEVqZw	2019-12-14 09:59:07
723	f0M0Y3nytvM	2019-12-20 06:04:52
720	EF45J2K3MLc	2019-12-22 11:41:57
710	5CF0DdAifZI	2019-12-23 16:34:29
727	mOQy2yW6NqY	2019-12-24 09:39:43

Table 3: List of final 52 selected videos

CHAPTER 3
A DATA DRIVEN OVERVIEW OF CRISPR CAS-9 REPRESENTATION ON YOUTUBE

This chapter seeks to examine the number of videos about CRISPR Cas-9 on YouTube between 2012 to 2019 (RQ1). This number was aimed to understand better the volume and weight of videos about CRISPR Cas-9 published on YouTube and to understand measurable reactions to this content, thereby providing a basis for a more detailed analysis of selected videos in Chapter 4. The number of videos also allows a comparison to other scientific topics to better understand the breadth of this topic on YouTube. Using our Python probe and data gathered from this phase, the current state of CRISPR Cas-9 videos is discussed to provide insights about science communication on YouTube.

Total Number of CRISPR videos

Using the methods described in Chapter 2, **743** videos were found. While the exact number of videos that exist on YouTube is not available due to the data noise added by Google, using three different methods, there is a high level of confidence that anybody who searched the keyword 'CRISPR Cas-9' in the same time period and with available search tools (YouTube Search, Google Search and even using API of YouTube; see Chapter 2) would not find any additional, relevant videos beyond our data set of 743 videos.

Comparing CRISPR Cas-9 with other topics in the same period

In the project 'Communicating science and technology through online video' (León and Bourk 2018a), a group of 19 researchers from 9 universities analyzed and discussed the estate of 826 online videos from three categories: Vaccines, Climate Change and Nanotechnology. They based their analysis on videos brought back by a typical YouTube search.

To compare the number of videos on CRISPR Cas-9 with these three subjects, the 2nd method described in Chapter 2 (pages 27; using Java Script on YouTube Search) was used for each of these categories, followed by comparing these results to (a) the number of CRISPR Cas-9 videos brought back by this same method and (b) with the total number of our CRISPR Cas-9 videos. All searches ran on the same time interval (2012 to 2019). These results are presented in Table 4 and Figure 3.

Climate Change	Nano Technology	Vaccines	CRISPR Cas-9 (Only 2nd method)	CRISPR Cas-9 Total
614	536	371	546	743

Table 4:Comparing number of videos in 4 categories based on 2nd search method

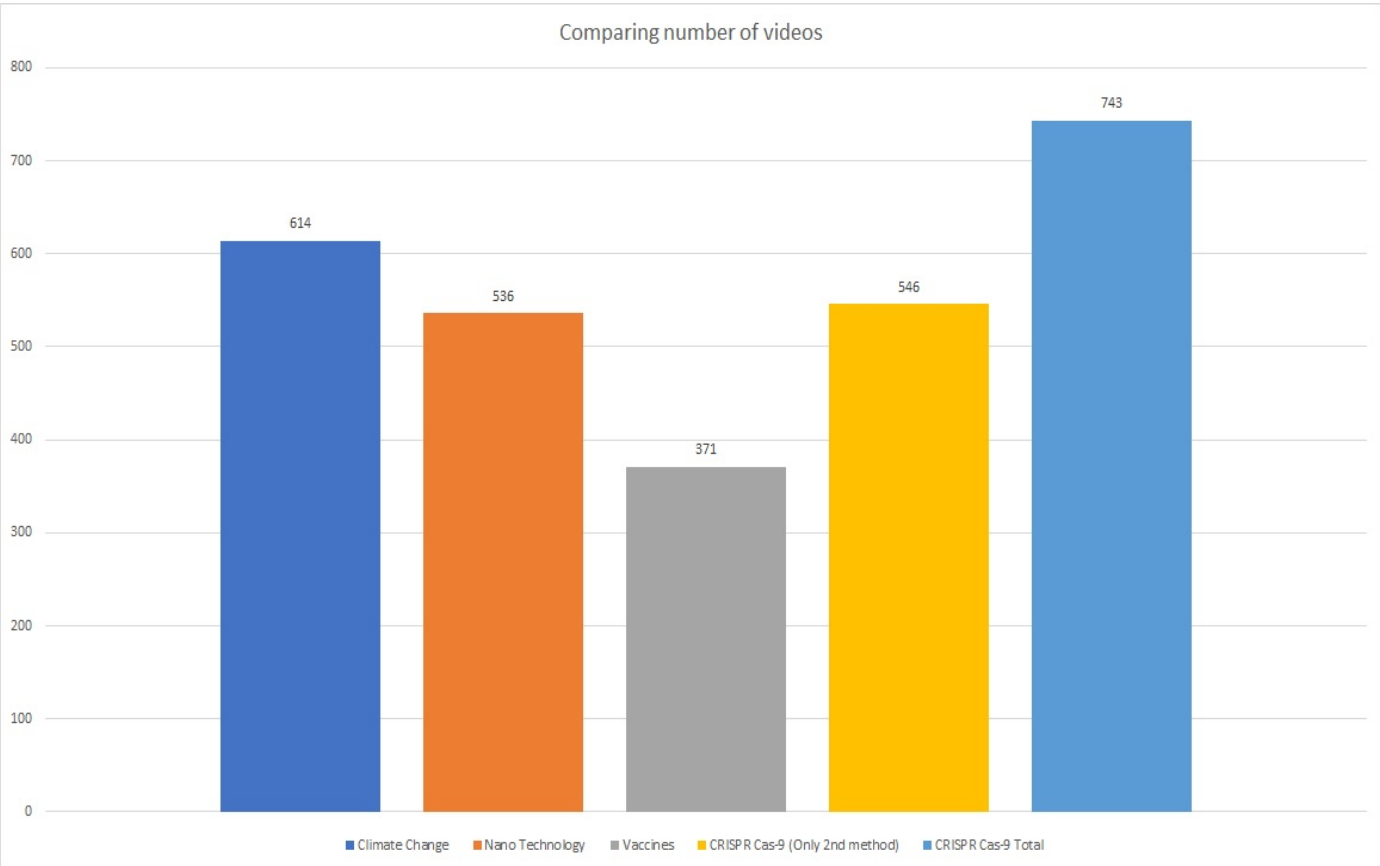

Figure 3: Comparing the number of videos in 4 categories

The results show the relative importance of CRISPR Cas-9, which has comparable numbers to the other well-studied and important scientific topics. Thus, despite being a relatively new technology, the volume of content about CRISPR Cas-9 on YouTube is similar to issues with a much longer history. Only videos about vaccines were much lower (Figure 3), and this may be due to the use of the keyword ‘vaccines,’ as opposed to other terms such as ‘vaccination.’ Regardless, this comparison serves to show that using only one method of data gathering (e.g., using Java Script on YouTube Search) does not provide a comprehensive list of YouTube videos (Figure 3, bar 4 versus 5). This strengthens the argument in Chapter 2 that researchers need to develop a more thorough and complete search strategy for an accurate analysis of videos on YouTube. This also reinforces that our 743 videos, despite limitations, are an improvement and represent a robust data set to base further analysis upon.

Duration vs Views

Does the duration of a CRISPR Cas-9 video on YouTube affect the number of times it is viewed? This is an important question that guides some producers and content generators on YouTube (Richier et al. 2014; Park, Naaman, and Berger 2016; “How Long Should a Youtube Video Be in 2021 (with Examples)” 2021), who can espouse an understanding that using brevity can bring more audience views. To explore this question for CRISPR Cas-9 videos, the number of views of each video was compared to its duration to determine if any statistical correlation existed between these two parameters (for all videos and the three intensity spikes of selected videos). For the data set in the thesis, the views ranged from 2 to 2,130,616, averaging 27,937.66 views per CRISPR Cas-9 video.

For the data set of all videos (743 videos), the correlation between View count and Duration was -0.0514. This number is statistically insignificant and shows non-correlation between these two parameters (Figure 4). The negative correlation indicates that there is an insignificant inclination toward the fact that shorter videos have more views (no meaningful correlation) in this data set.

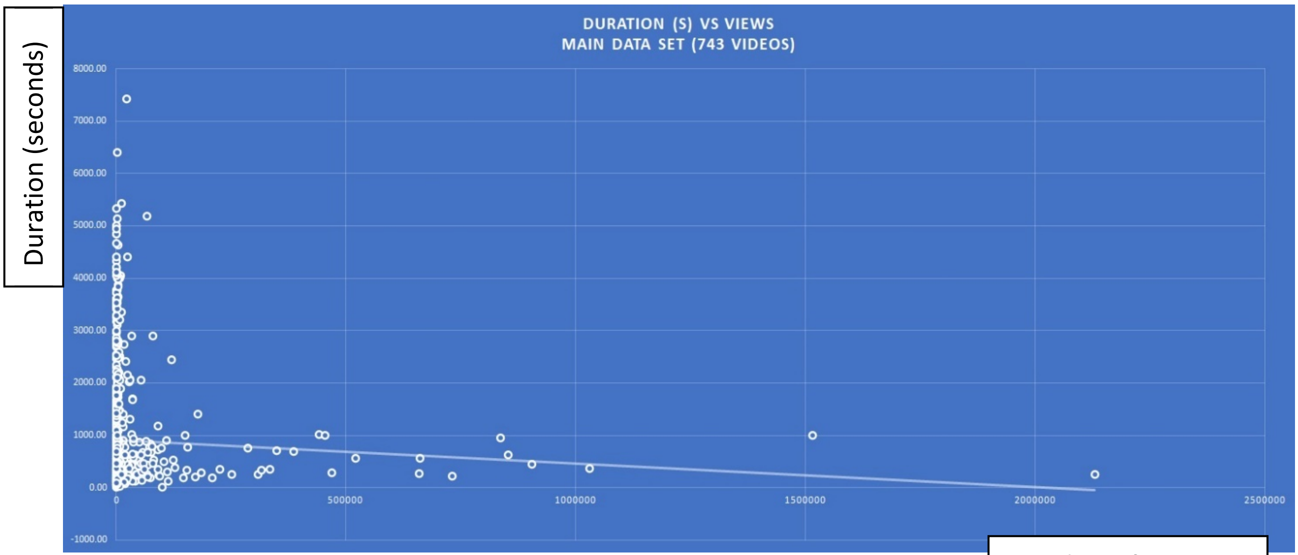

Figure 4: Correlation between Duration and view count on 743 videos

For our sampled videos (91 selected videos for three-period spikes; Chapter 2), the correlation between Views count and Duration was 0.0909. Despite being positive, once again, this correlation is statistically insignificant and shows non-correlation between these two parameters (Figure 5).

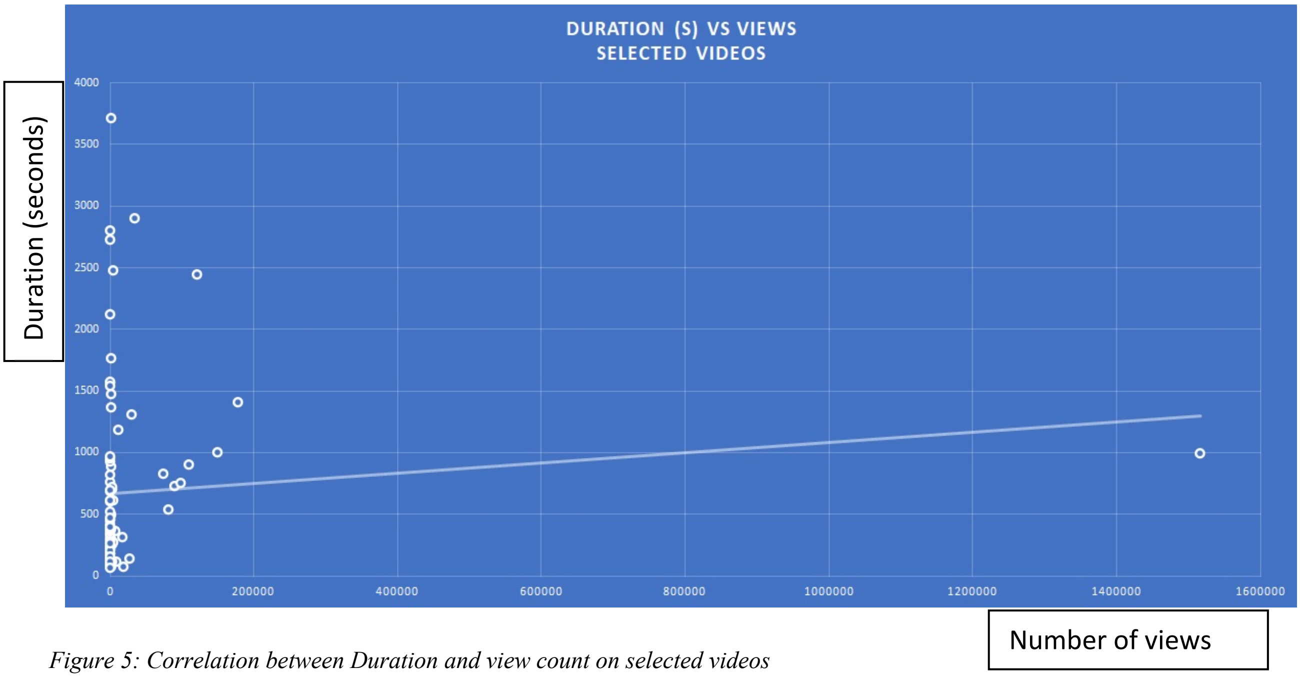

Figure 5: Correlation between Duration and view count on selected videos

There are some considerations about these results. First, only the number of views vs duration of each video was examined. The view count parameter shows us how many times people clicked and started to play a video. It does not correspond with how long they stayed to watch each video. Someone might start a video and leave it a few seconds later without watching it completely. The length of each video that each user watches (the video Watch Time) is not available publicly for all videos. So, this result can't say anything about the correlation between the duration of a video and how long it kept its viewer engaged.

This result only shows no meaningful relationship between the duration of a video and the number of times that people start to watch it. In other words, for this set of data, the duration of a video doesn't play a meaningful role in someone beginning to watch it. The length of the video neither encourages nor discourages a viewer from starting to watch. It is also important to mention that this result cannot be generalized to all videos on YouTube, and it can only speak about the reactions of a viewer to the videos included.

Engagement parameters

YouTube is a platform for sharing videos. The platform provides some tools for audiences to engage with video content. Audiences can share videos on other platforms, subscribe to a YouTube channel to be alerted to new content, and directly react to a video via likes, dislikes and comments. In conjunction with the number of views, these three parameters are important metrics for the creator of content. Many creators invite their audiences to react to their videos and use these metrics to gain financial support.

To examine how viewers react to CRISPR Cas-9 videos, engagement parameters were calculated (Table 5) in terms of likes, dislikes and comments. Four additional parameters were also calculated to put these numbers into perspective further:

a) **Comments per view count**: Defined as the percentage of viewers engaged enough to leave a comment and/or start a discussion.

b) **Comments per total like and dislikes**: Defined as the ratio of people engaged in commenting in relation to people who only show their reaction by leaving a like or dislike.

c) **Total likes and dislikes over view count:** Defined as the percentage of viewers engaged enough to react to a video by liking it or disliking it.

d) **The ratio of likes over total likes and dislikes**: Defined as how people react to a video in general. This is an important parameter to study the behaviour of audiences. It shows, among those who responded to the video in terms of a like or dislike, which percentage reacted positively toward the content. If this parameter was around 50%, it could indicate that a video has a highly divided audience. For example, if you have a video and ten people put likes and dislike under it, if this ratio is 50%, it means half of them liked and half of them disliked the video.

Statistics of the complete data set (743 Videos)

	MIN	MAX	AVERAGE
DURATION	8 S	7416 S (2H 3M 36S)	906.017 S (15 M 6 S)
VIEW COUNT	2	2130616	27937.7
LIKE	0	49708	569.12
DISLIKE	0	855	11.75
COMMENTS	0	6008	65.25
COMMENTS / VIEW COUNTS	0	0.35	0.004578 (%0.45)
COMMENTS / (LIKE + DISLIKE)*	0	2.5	0.140647 (%14)
LIKE/(LIKE+DISLIKE)*	0	1	0.95 (%95)
(LIKE+DISLIKE)/VIEW COUNT	0	0.589	0.027 (%2.7)

Table 5: Statistics of the complete data set (743 videos)

* These parameters are calculated for those videos whose denominators are not equal to zero.

Table 5 shows the results of this analysis. According to these results, the average length of a CRISPR Cas-9 video in the data set (743 videos) is 15 minutes and 6 seconds. The average view count is 27,938. While outliers can impact averages, these results suggest CRISPR Cas-9 videos average a healthy audience. A study conducted by analytic company Plex has indicated that a good view count is about 23,389 based on over two billion videos ("Engagement Analysis on YouTube, Instagram, Twitter, and Facebook" 2018). The highest number of views is about 2.13 million, showing the potential for a CRISPR Cas-9 video to reach a high number of viewers on YouTube. The average number of likes (569.12) and dislikes (11.75) per video suggests CRISPR Cas-9 videos generated more positive reactions – in the form of likes – than negative reactions. The Plex study has suggested that the average comments on a video are about 0.1% of average views, which would predict about 23.4 comments per video, with CRISPR Cas-9 videos engaging enough to average 65.25 comments per video. These engagement parameters could vary significantly for different fields, but this comparison suggests potential high engagement (on average) for CRISPR Cas-9 videos on YouTube.

For the additional parameter examined in Table 5, the number of comments per view varied between zero to 0.35, which means about 35% of viewers engaged in commenting in the most extreme case. The average for this parameter was 0.45%, which equates to an average of one viewer commenting about every 222 views. The number of likes and dislikes per view shows that a video generated 59% of viewers liking or disliking the video in the most extreme case. I also observed that 85.33% of CRISPR Cas-9 videos have some likes or dislikes, suggesting that most videos engaged their viewer enough to react in the form of like or dislike. These results show that viewers were more likely to engage in reactions in the form of likes or dislikes rather than comments. The average likes per total like and dislikes ratio was about 95%. This result shows that, on average, the general reaction to a CRISPR Cas-9 video (in terms of distribution of likes/dislikes) is homologous.

Statistics of the Selected data set (91 Videos)

	MIN	MAX	AVERAGE
DURATION	66 S	3718 (1H 1M 58S)	682.48 S (11 M 23S)
VIEW COUNT	2	1516109	28614.9
LIKE	0	19832	605.8462
DISLIKE	0	855	18.06
COMMENTS	0	6008	129.24
COMMENTS / VIEW COUNTS**	0	0.35	0.011 (%1.1)

COMMENTS / (LIKE + DISLIKE)**	0	2.33	0.234 (%23.4)
LIKE/(LIKE+DISLIKE)	0.66*	1	0.97 (%97)
(LIKE+DISLIKE)/VIEW COUNT	0	0.24	0.037 (%3.7)

Table 6: Statistics of the selected data set (91 videos)

- There was not any video with no like and just dislike…all the videos without likes didn't have any dislike either, and because of removing divided on zero, the minimum is above 0

** I didn't include the videos that have 0 in the denominator of this ratio

These parameters were also calculated for the selected data (Table 6) examined more closely in the next chapter. Comparing these parameters for two data sets shows that the selected videos, which have been chosen from three spikes in upload dates (Chapter 2), have a shorter average length (682 seconds vs 906 seconds), but they have higher numbers in all other parameters for engagement (when it could be calculated; Table 6). On the other hand, the percentage of videos without any reactions (Like/Dislike) in this data set is 27.4% (compared to 14.67% for the primary data set in Table 5). This can be interpreted to mean that the reactions for the selected video set (91 videos) were stronger than the average reaction in the primary data set.

Correlation between upload/publish date and search results

As described in Chapter 2, after information was gathered for all 743 videos, the distribution of their publishing/upload date was examined to choose three spikes with the highest published videos. Although the primary intention was not to explore the differences in uploads per month and possible causes, this allows a preliminary assessment for observable correlations between how people may search the keyword 'CRISPR Cas-9'online and the number of uploads CRISPR videos to YouTube during that period.

There are many ways for people to search about a subject on the Internet. Between all of them, I chose three search engines: (a) YouTube's built-in search engine, (b) a Google general search and (c) a Google News search. These three examples were chosen due to the similarity of the general issue (new science and new technology) and because these three areas are examined in detail in previous studies (León and Bourk 2018a). With the help of the Google Trends tool ("Google Trends" n.d.), the distributions of searches for 'CRISPR Cas-9' (and another form of this keywords) in the selected time period (Jan 2014 to Dec 2019) and all three engines was undertaken. The results are presented in Figures 6 to 9 below.

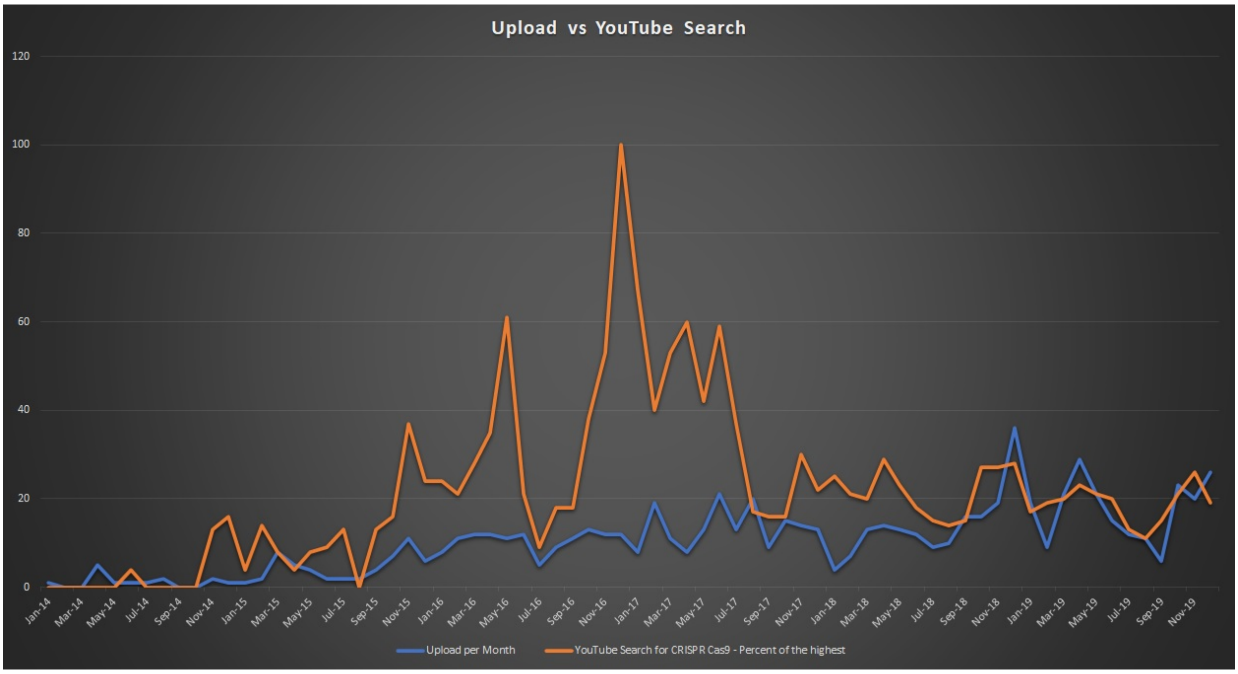

Figure 6: Correlation Between Upload per month and YouTube Search

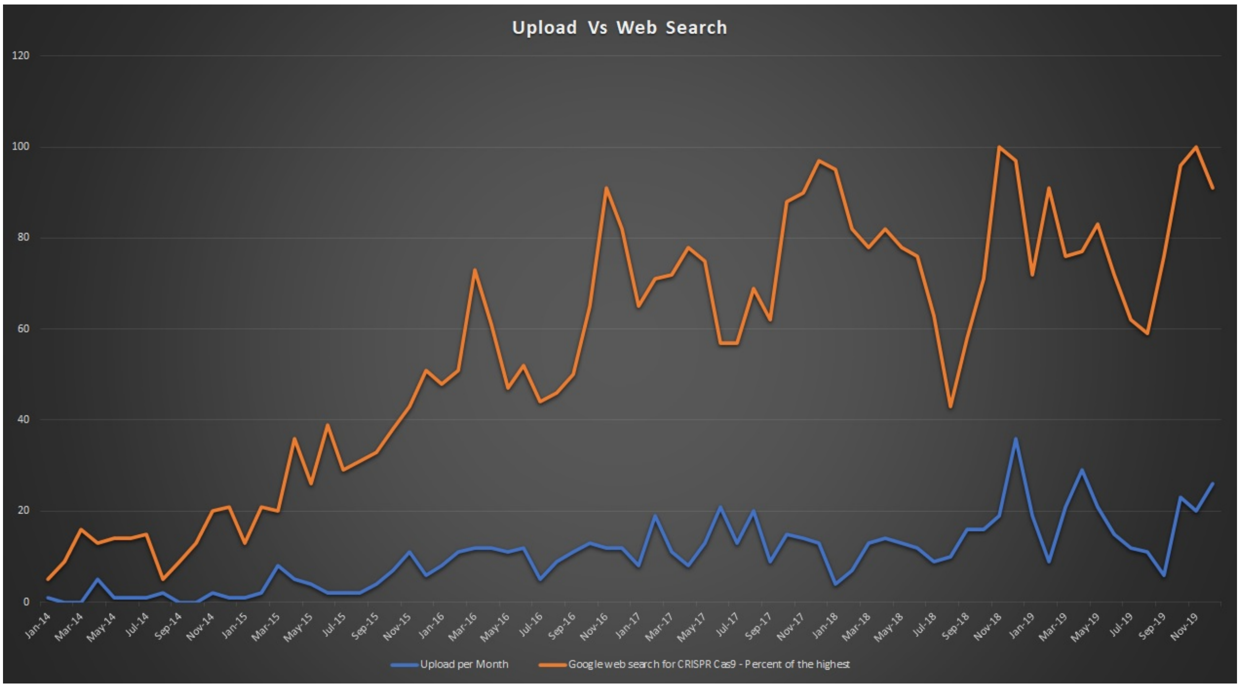

Figure 7: Correlation Between Upload per month and Google Web Search

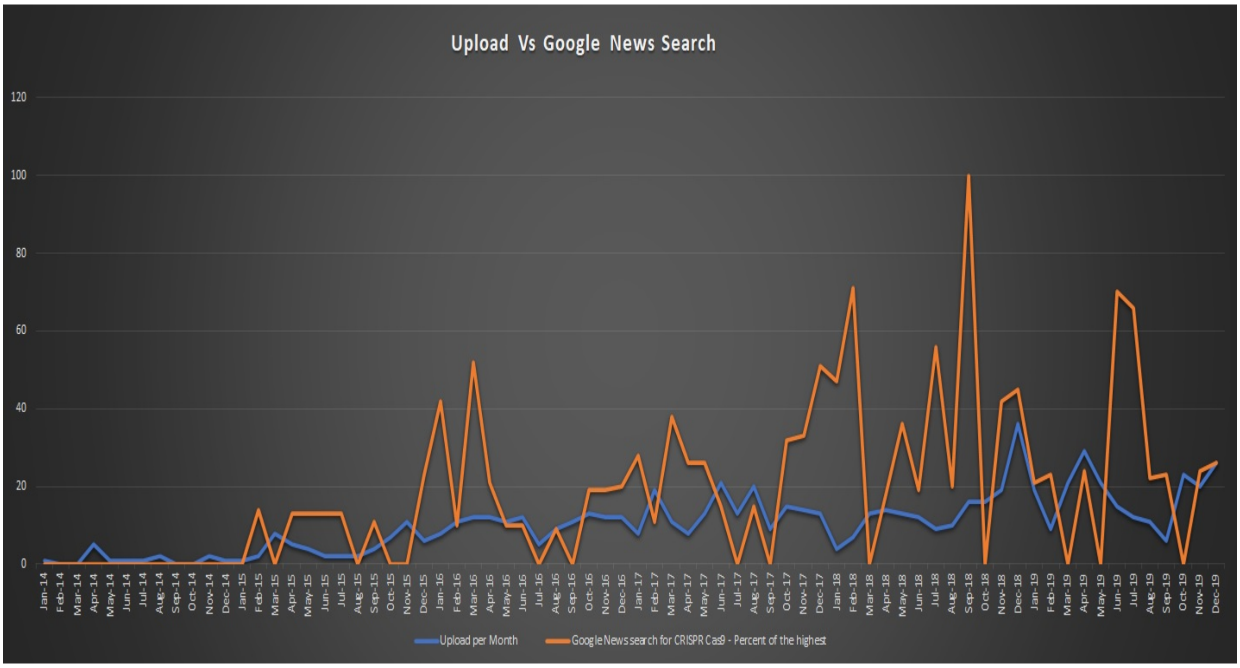

Figure 8: Correlation Between Upload per month and Google News Search

These figures show the number of uploads compared to keyword searches for CRISPR Cas-9 on YouTube, Google Search, and Google News each month. I used the statistical calculation for correlation coefficient for calculating the correlation between these four sets of data, as presented in Table 7.

	Upload per month	*YouTube Search Percentage of the highest*	*Google News Search Percentage of the highest*	*Google Web Search Percentage of the highest*
Upload per month	1			
YouTube Search	0.401097259	1		
Google News Search	0.31867626	0.217166103	1	
Google Web Search	0.758365511	0.538390284	0.517371344	1

Table 7: Correlations between Uploads, YT Search, Google Web search and Google News search

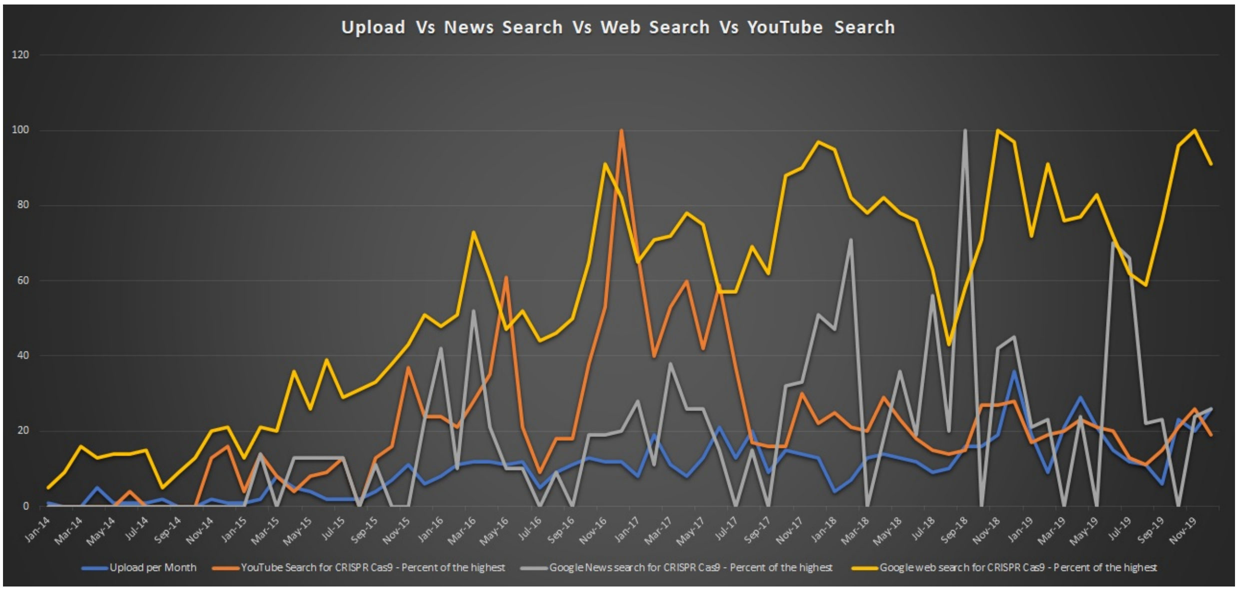

Figure 9: Comparing all 3 searches vs number of uploads per month

The highest positive correlation (0.758365511) existed between the number of uploads per month and a Google Web search for the CRISPR Cas-9. The level of correlation between these two is moderate (when the correlation coefficient is between 0.5 and 0.8), below the range for a positive correlation (correlation above 0.8 is considered a strong correlation.) While this correlation is insufficient for any strong conclusions, as a preliminary assessment, it does suggest there may be value in future exploration of relationships between the number of general web searches about a science subject and the number of videos created/uploaded about that subject (a topic that has yet to be studied). The least correlated parameters are the number of searches for CRISPR Cas-9 in news and uploads. Parameters that have effects in such correlation are (but are not limited to):

- Sharing these contents on other platforms and social media could lead to more searches about the issue.
- Higher searches about an issue on the web reflect trends that content generators use to create or post videos.
- Some news is breaking, and people search it on the web and YouTube, resulting in YouTube users reacting to this news.

Three spikes of Uploads

To see if there is any explanation about why in three chosen spikes (Dec 2018, April 2019 and December 2019) the number of uploaded videos is higher than other times, I searched the Google News Archive in these three time periods to explore if any significant news stories appeared during these time periods. In other words, I did this news search to find out if any significant news had broken before each of these spikes, which could possibly affect the number of videos created and uploaded on YouTube.

- 1 Nov 2019 – 1 Jan 2020; for December 2019
- 1 March 2019 – 1 May 2019; for April 2019
- 1 Nov 2018 – 1 Jan 2019; for December 2018

No specific news items could be identified during the first two upload spikes (December 2019 and April 2019). Most news in this time period was related to general explanations of the technology, review of last year's advances in science, and medical and therapeutic applications of CRISPR technology.

In contrast, there was clear news for December 2018. During this time, the news of the first genetic modification of human embryos was published. Chinese scientists used CRISPR technology to change the DNA of twins to make them immune to AIDS (Le Page 2018). This news created strong reactions in the scientific community and the public (e.g., Cyranoski 2018; Toumey 1992; Sand, Bredenoord, and Jongsma 2019; Dickenson and Darnovsky 2019b). The results in the section above for Google searches/Google News searches/YouTube searches (Figures 6 to 9) show that the number of uploaded YouTube videos increased, as did searches for the keyword CRISPR Cas-9 in all the three search engines. This observation suggests that YouTube does not behave disconnected from broader public events and interests.

Distribution of languages in Selected videos and comparing their parameters

In the 2nd phase of the quality check, videos were excluded that did not fit into the inclusion criteria (see Chapter 2). One of these criteria was the video being presented in English or French to perform a qualitative analysis. In this exclusion process, the distribution of videos by language was extracted. Having this data and the parameters of each video gave the ability to compare the reactions to videos as a function of their language (Table 8). From 91 videos, 11 of them were deleted or without narrations. There are 80 videos in 10 different languages in this data set, as shown in Figure 10.

	#	*Average view*	*Average (like +Dislike)*	*Average comment)*	*Average duration (minutes)*
Chinese	8	252444	2666.75	1032.875	17.5
English	47	2592.596	63.8	13.021	11.8
French	4	30374	7	0.25	13.9
German	6	519.1667	25.3	1.5	10.53
Hindi	4	14272.5	621.5	47.5	7.97
Italian	2	250	37	5	9.34
Portuguese	3	60399.7	6802.67	672	13.4
Russian	1	58	1	0	45.24
Spanish	4	24586.5	2316.5	162.5	8.91
Turkish	1	14	0	0	6.18
N/A	11				
Total	91				

Table 8: Engagements parameters per language

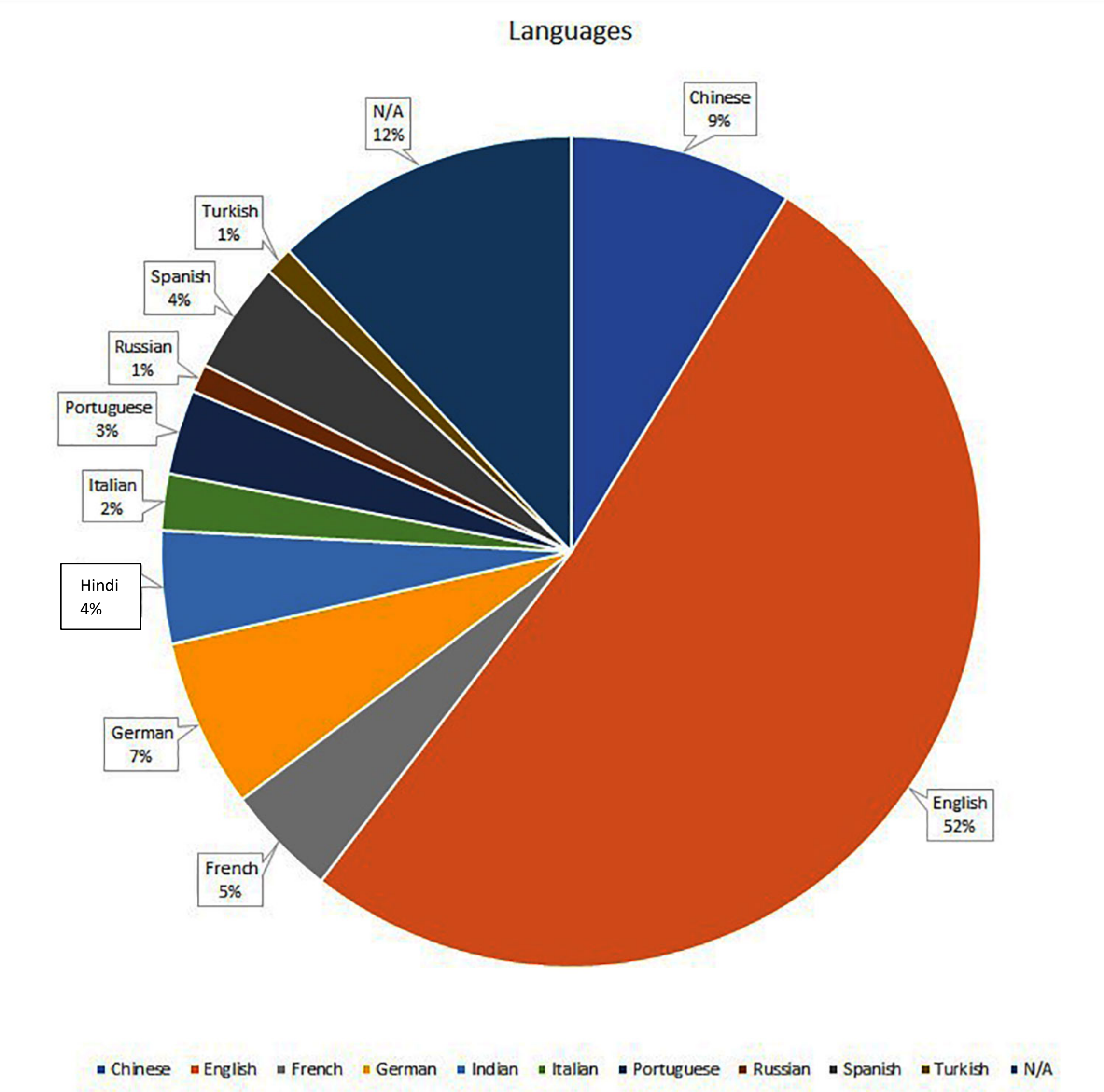

Figure 10: Distribution of videos based on their language

English predominated at 52%, with Chinese (9%) and German (7%) videos being the following highest languages. One question about contents in different languages is how their audiences reacted to the content and whether audiences in different languages have similar reactions to it. To find some primary insights about this issue, extracted parameters of view count, duration, likes and dislikes and comments for each video were compared to the video's language (Figures 11 to 14).

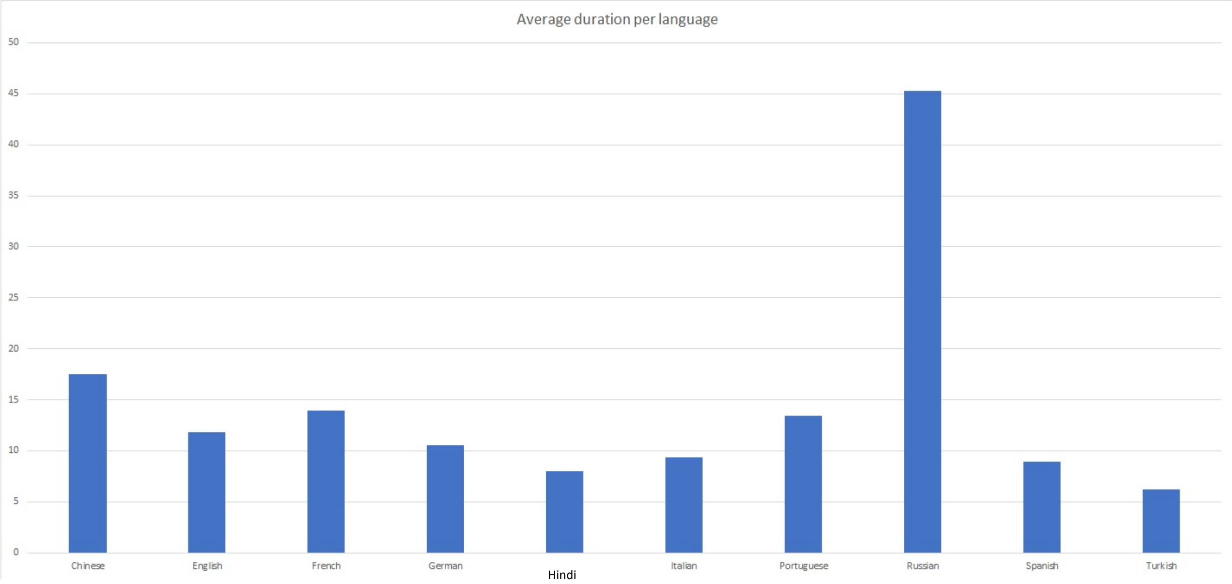

Figure 11: average duration per language

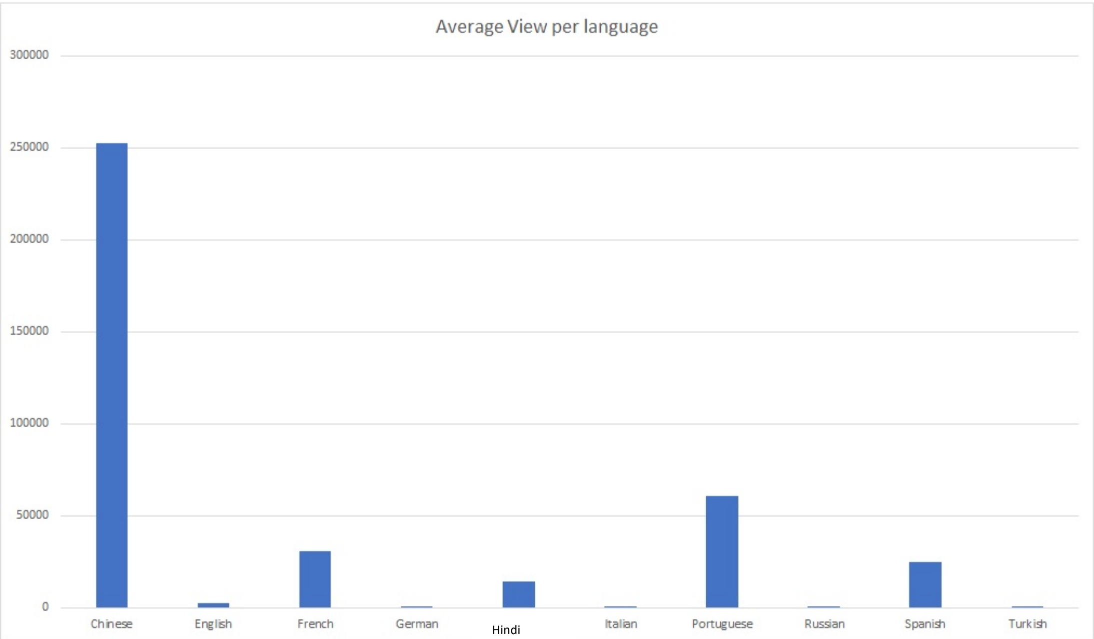

Figure 12: Average view per language

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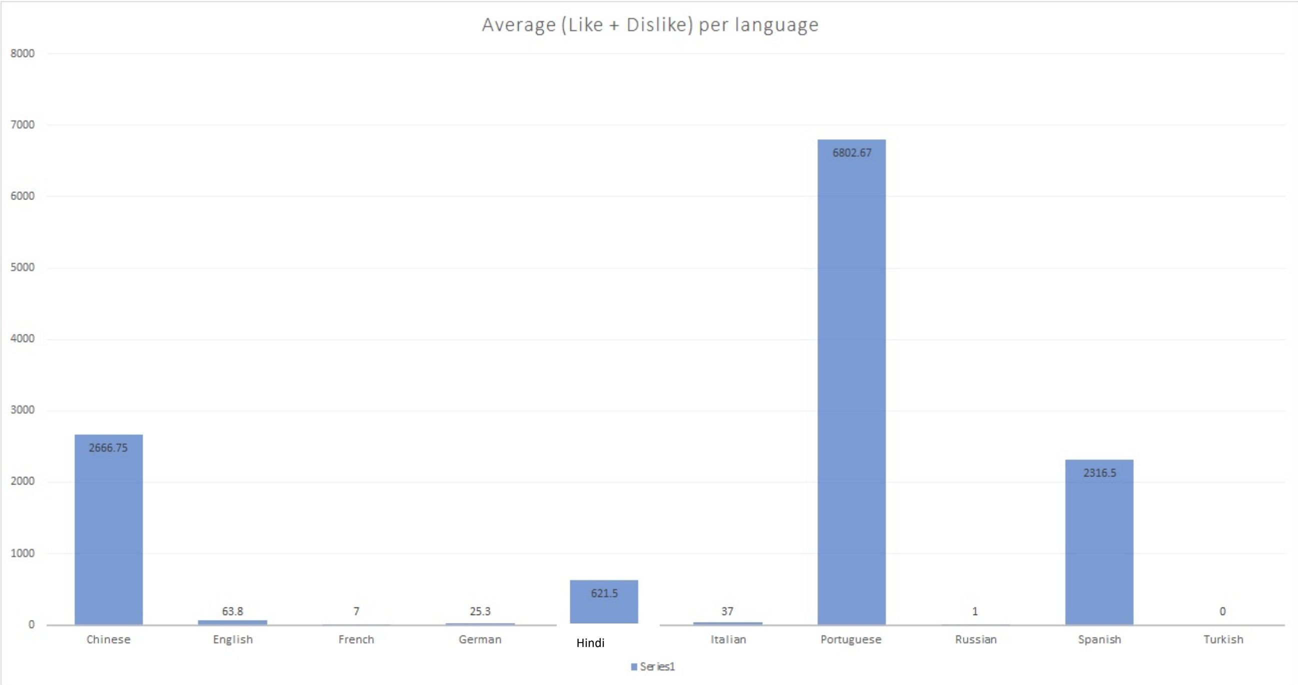


Figure 13: Average Likes + Dislikes per language.

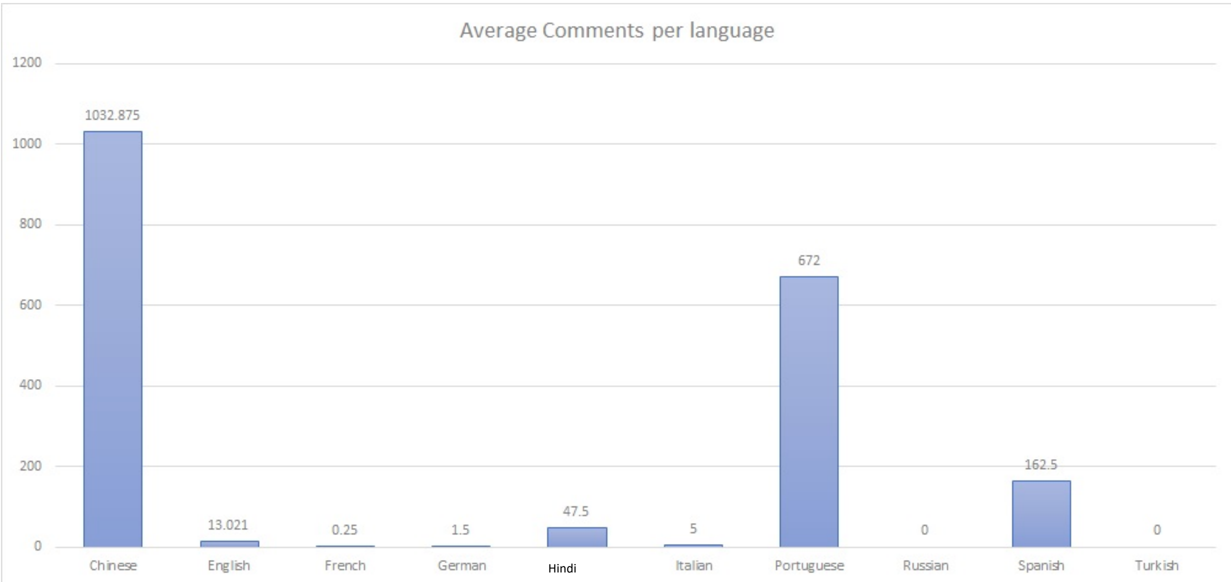


Figure 14: Average Comments per language.

Figures 11 to 14 show the average duration for videos in different languages, with the vertical axis representing the average duration (minutes). The Russian language is an anomaly because it is based on just one data point. Excluding the Russian language, the average durations of videos are comparable, except for videos in Chinese, which was higher than others. The average views for videos in each category showed clear differences for average views per language, with Chinese videos having the highest average view per video, and French, Hindi, Portuguese and Spanish videos having higher average views than English videos. Once again, there is a significant difference between the reactions of likes or dislikes that different languages attract. Videos in Portuguese (Average 6802.67), Chinese (2666.75), Spanish (2316.5), and Hindi (621.5) have the highest interactions, and their averages are far higher than the averages in English videos. Furthermore, the average engagement in the form of comments is higher in Chinese, Portuguese, Spanish and Hindi videos.

Native and Immigrants Videos and their parameters

For the analysis, two main categories were defined for videos: native and immigrant. Some other researchers (León and Bourk 2018a) have used different thermology for videos such as user-generated or institution-created content. These other definitions are based on the producer of videos. In contrast, this thesis focuses on the video content itself rather than who produced it. A video was defined as YouTube native if the video was published primarily on YouTube based on all the available data. For example, PBS is producing a series published on YouTube, and although this is a professional media outlet, it is native content for this thesis. NASA also produces videos to be published primarily on YouTube. These are also considered native content. In contrast, immigrant content is not mainly being published on YouTube. It is published on websites or other venues and then republished or uploaded on YouTube.

The distinction is important here as it eludes to the primary goal for publishing. If videos are created to be published on YouTube and then shared in the media or another website by embedding the code from YouTube, I consider them as YouTube native. But if the same institution of media organization created a digital video to publish on their own website and then upload it to YouTube, I consider it immigrant content. The reason to note this distinction is native content on YouTube has the potential to use the tools and capabilities that this platform provides (e.g., they can embed other videos inside their content, use info cards and end cards, and use tools such as tools 360-degree videos or VR). As Deborah Blum mentions, picturing readers (in this case, viewers) of the content is always helpful for journalists to set their story in a way that better serves them (Blum et al. 2006). Audiences of different platforms have different preferences and behaviours, making this distinction between native and immigrant content important.

After having finalized our data set and excluded unavailable, deleted, and languages other than French and English, the final set of selected videos was 52. From these videos, 23 were

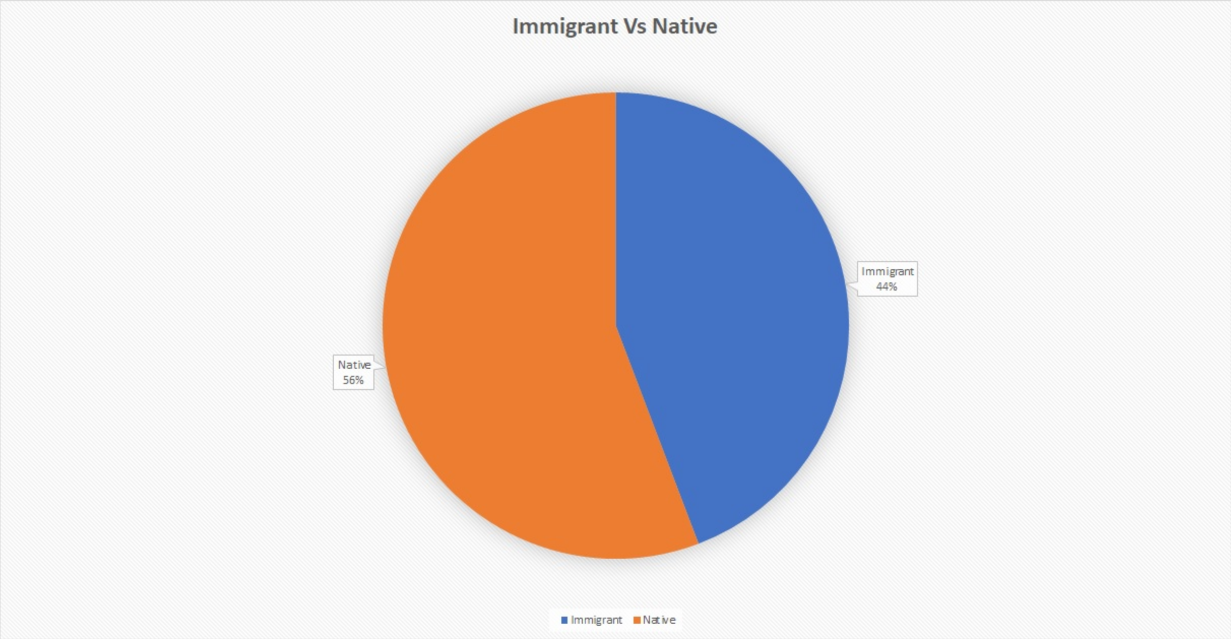


Figure 15: Native Vs Immigrant videos in final data set.

labelled as immigrant videos (44%) and 29 (56%) as native videos. The average parameters of duration, views, likes + dislikes and comments are presented in Table 9.

	Number	*Average View*	*Average (Like + dislike)*	*Average Comments*	*Average Duration (minute)*
Immigrant	23	8432.3	63.34	14.6	17.3
Native	29	1707.414	54.31	9.96	6.96
Total	52	5069.857	58.825	12.28	12.13

Table 9: Engagement parameters based on Native- Immigrant videos.

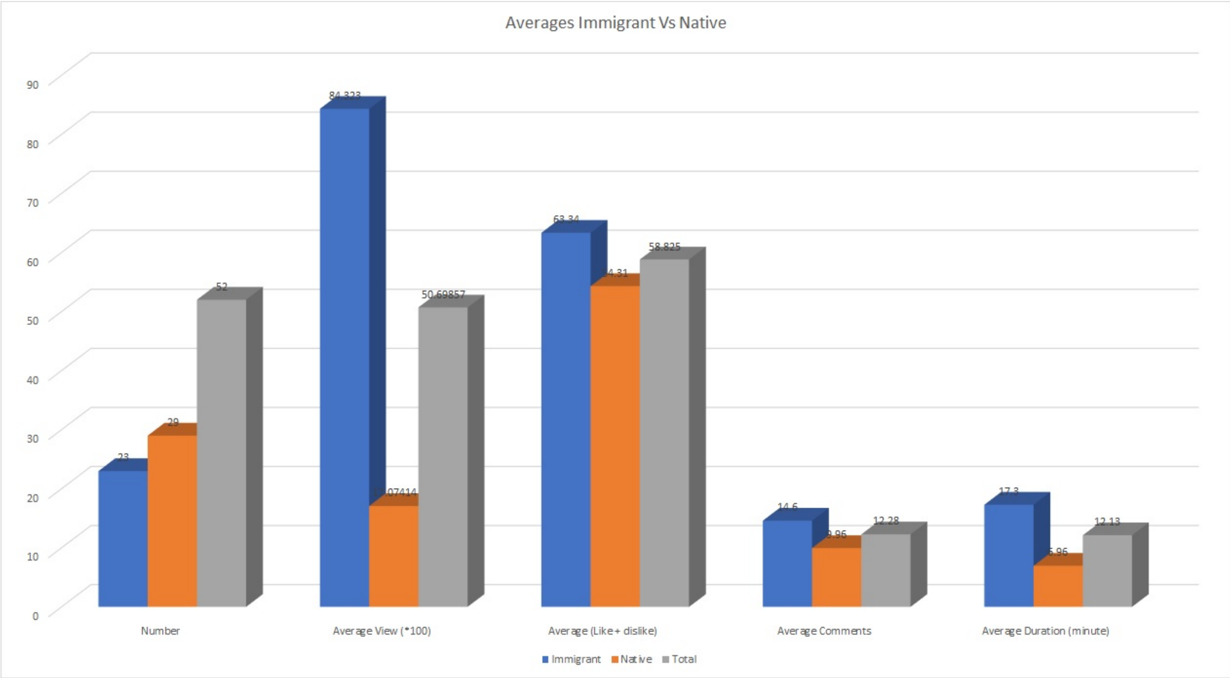


Figure 16: Engagement's parameters based on Native- Immigrant videos.

Summary and discussion

In this chapter, the data set was put into a quantitative perspective. The findings are in line with studies on other scientific topics (León and Bourk 2018a) but do show a high level of engagement with the content about CRISPR CAS-9 on YouTube. A comparison of videos on CRISPR Cas-9 with the total number of videos about "climate change," "nanotechnology," and "vaccines" shows that while CRISPR Cas-9 is a relatively new issue, the number of videos is comparable with other studied topics (Table 4; León and Bourk 2018a). Importantly, this result showed that past methods for gathering available data on YouTube are not currently sufficient but can be improved by combining multiple search strategies (see page 20).

For the video themselves, the quantitative analysis showed no meaningful or significant correlation between video duration and the number of people who started to watch the videos. The study of likes, dislikes, comments, and views showed that these videos' audience is more engaged than average (see, "Engagement Analysis on YouTube, Instagram, Twitter, and

Facebook" 2018). I did not have access to the unique IPs of visitors and did not calculate the unique users who left comments; therefore, this result only focused on the number of views. It is also important to note that the Publisher/Uploader has a choice to close the comment section for viewers. That said, examining the correlation between the number of uploads and web searches (see page 40), while preliminary, points to how a big news story that engaged people on the web may affect the number of videos generated and published on YouTube about that topic. To our knowledge, this result is unique as I could find no current studies exploring this type of relationship. While perhaps not surprising, this result provides a unique quantitative context to why CRISPR videos may focus on explanations of the technology for audiences, suggesting the novelty of CRISPR technology was one of the main drivers for content in this time interval. An analysis of these videos in terms of the nature of their content and models of communications is presented in the following chapters.

In a roundabout fashion, chapter 3 also highlights issues of the 'digital divide' in a unique way related to the diversity in languages in the data. In the process of excluding videos to reach a data set for qualitative analysis, 80 videos of the 91 could be categorized based on their language (see Figure 10). Most of the videos are in the English language. This high density of content in a language gives audiences more choices and therefore diffuses the density of views and interactions with these videos. When you are dealing with a language where scientific content (in general and specifically in new topics in science and technology such as CRISPR Cas-9) are more limited (e.g., comparing the number of scientific videos in English versus Urdu), then the interactions between viewers and the content of a video will be higher (see figures 13 and 14). This provides a hypothesis that in this context, YouTube could play a role in filling the lack of access to scientific content, thereby having a powerful engagement potential for developing societies and as a tool for science journalists who are working in non-English language communities and other minorities.

This hypothesis is based on our collected data set (see figure 12) but needs to be studied on a larger set of videos to enable a more generalized conclusion. However, this issue supports the importance of the concept of 'Digital Divide' in the future of science journalism and science communications. As Van Dijk (J. van Dijk and Hacker 2003) describes, digital divides can be defined as a lack of access to digital platforms due to a lack of infrastructure or a lack of willingness of users to use these platforms. Suppose the role of YouTube in non-English communities can be confirmed and be generalized to other less developed communities. In that case, digital divides become more critical for people who are choosing tools such as YouTube for their journalistic and communication works. In this view, YouTube and encouraging science journalists to use its potential has two consequences: (i) it can provide access to video information for use by content creators without other infrastructure (perhaps reducing digital divides) and/or (ii) it could reduce a desire to improve access and infrastructure in these communities (perhaps even forgetting this lack of access exists in some populations) by suggesting YouTube is already enough and thereby deepening the digital divide (cf. J. van Dijk and Hacker 2003; J. A. G. M. van Dijk 2006; Warschauer 2003; Cullen 2001).

For example, consider the case for a country such as Iran. In Iran, access to YouTube is banned, and it is filtered. People need to use VPN or proxy to access the content on YouTube, which requires a higher level of access and technical skills. At the same time, many Iranian scientists immigrated and worked in other countries with access to YouTube. When these scientists try to increase access to scientific information, in Farsi, by producing videos, also in Farsi, on YouTube, it should, in theory, reduce the gap of available information. But the domestic restrictions on access to YouTube for general audiences mean only those with higher levels of access benefit. This could increase therefore increase digital gaps, not reduce them. This possible dual consequence emphasizes that addressing the digital divide is complex and needs multidimensional solutions.

Lastly, the analysis of native and immigrant content about CRISPR Cas-9 showed that immigrant content has higher numbers of average views, average (likes + dislikes), average comments, and average duration (minute) (see page 35). Two arguments may be capable of explaining this difference: (a) most of the immigrant content is created with more professional methods, and by doing so, they are more compatible with audiences' preferences for CRISPR video content and may be considered more reliable; (b) the other factor could be the diversity of native videos, with these creators experimenting with different techniques, style and voices. This experimental approach to find more creative and engaging videos is an important concept leading into the next chapter, where CRISPR Cas-9 videos are analyzed more deeply.

CHAPTER 4
A QUALITATIVE CONTENT ANALYSIS OF CRISPR CAS-9 VIDEOS ON YOUTUBE

This chapter presents a qualitative content analysis (QCA) of selected videos on CRISPR Cas-9 (RQ2). As Bartlett points out, data never speaks solely for itself (Bartlett and Bartlett 1995). Indeed, Margrit Schreier argues that when we read a text or watch an image, we are constructing meaning for it (Schreier 2012). There are also instances where texts or videos play an active role in constructing these meanings, as explained in the coding-decoding of messages by Stuart Hall (Hall 2001). Here, the goal was to better understand the possible meanings that select videos constructed for viewers via QCA, which has been extensively used to study both textual and non-textual content (Schreier 2012; Marshall and Rossman 2014; Krippendorff 2004; G. Shapiro and Markoff 1997).

Since CRISPR Cas-9 videos are not highly standardized, QCA is useful for organizing emergent themes for analysis. This chapter followed QCA methods as described by Schreier (Schreier 2012), in combination with the categorization approach of León and Bourk's 'video online' project (León and Bourk 2018a) and Hargreaves et al.'s video comparison techniques (Hargreaves, Lewis, and Speers 2003). The approach involved analyzing 52 CRISPR Cas-9 videos (see chapter 2). As will be described after explaining how content was coded, showed the overall presentation of the technology as positive, with views about ethics and future applications remaining neutral. When negative representations appeared, they were in the native videos and tended to engage more people regarding likes/dislikes and comments.

Coding and Categorization

Following Schreier (2012), a hierarchal coding frame was developed based on previous research and a review of the literature (León and Bourk 2018a; Marshall and Rossman 2014; Schreier 2012) to analyze the 52 videos that were in English, French, or didn't have narration.

Each video was reviewed in detail and watched approximately five times during the QCA process. Also, to reduce my personal bias, I coded all the videos twice with one month between them to make sure that my interpretation of videos was the same.

The coding frame was broad to start to allow videos to be organized before detailed open coding was undertaken to examine the content (as such, it is possible for a category not to contain any videos). The top level of the coding frame had three categories that captured the type of video:

A. Native / immigrant Content*

i. Native
ii. Immigrant
iii. Not clear

**The definition of native versus immigrant content is based on the primary intention of the creator to publish the content on YouTube or another platform (see pages 17 and 46).*

B. Content parameters (elements that exist in each video)

i. Narration/voiceover
ii. Presenter
iii. Graphic
iv. Video
v. Photo/slide
vi. Sound bite
vii. Active - embedded - link
viii. Guest

C. Types of videos

i. Video Blog (video cast)
ii. News Report

iii. Analyzing News

iv. Infotainment

v. TV Documentary

vi. Web Documentary

vii. Web interview

viii. Comedy

ix. Web music

x. Recorded conference / event

xi. Tutorials and hands-on, how-to guide

xii. Other

The videos were then organized into four subcategories (Representation of Technology in Narrative, Representation of Technology in Graphics, Representation of ethical issues in Narrative, Representation of the ethical issues in graphics). Once subcategorized, videos were qualitatively coded within four dimensions (positive, neutral, negative, unclear):

i. How does the video view the future of this technology (narration)?

1. Positive
2. Neutral
3. Negative
4. Unclear

ii. How does the choice of graphics portray the technology?

1. Positive
2. Neutral
3. Negative
4. Unclear

iii. How does the video narration portray the ethical considerations of this technology?

1. Positive
2. Neutral
3. Negative
4. Unclear

iv. How does the video graphically portray the ethical consideration of this technology?

1. Positive
2. Neutral
3. Negative
4. Unclear

These categories and dimensions served to provide a qualitative assessment of the content regarding their attitudes toward the technology and its ethical considerations both in graphics and the narration. Videos were coded as positive if the narration, scripts, and graphical elements were encouraging, optimistic and enthusiastic about the subject (Technology or Ethics) and negative if they were alarming, pessimistic and/or represented the subject as dangerous. Videos were coded *neutral* if their overall discussion or use of graphical elements were presented with balance (i.e., without an obvious and/or recognizable tendency toward positivity or negativity, or if they ignored the issue) as interpreted by the author. Of course, even if there is not any obvious tendency toward positive or negative sides in a video, an audience member can still interpret the content this way based on their previous knowledge and biases. This reaction and interpretation of audiences is not the focus of this research.

Videos were coded as unclear if the narration or graphics relayed a complex message that could be interpreted as both positive or negative. Therefore, the subjectivity of interpretation was higher than the capability of our filtering system. For example, in one video, a young person shows how to experiment on *E. Coli* bacteria with a CRISPR Cas-9 gene editing commercial kit in his kitchen. For some people, the capability of doing such an experiment in a home kitchen could be considered positive. Still, at the same time, some could argue that doing such an experiment with a bacterium using kitchen appliances is a negative issue.

Further thematic coding of the videos involved a codebook of keywords gathered during the quality check of the final data set (videos), which was open to revision during the process if new themes arose.

All keywords were evaluated in the context of each video. Coding was challenged by the thesis supervisor to arrive at the reported results.

QCA Findings

A. Qualitative Assessment of Native (Opinionated) vs Immigrant (Explanatory) Videos

As shown in Chapter 3, the 52 CRISPR Cas-9 videos were clearly divided between native (29 videos) and immigrant (23 videos) purposes for content creation (Table 9 on page 47). This assessment shows that, at this level of QCA categorization, CRISPR Cas-9 videos are primarily informative and explanatory. However, native videos were more opinionated and involved discussions of the future and various ethical issues. In contrast, immigrant videos were often explanations of the technology, and any ethical discussion was presented in a more neutral way.

A clear example of this is seen in the native video ‘CRISPR/Cas9 Hitman Sockpuppet’ that portrays the dangerous future of CRISPR technology by representing the technology as a hitman who can be hired and do the deeds of people with wrong intentions. The story narrates, “CRISPR Cas9: Now, I do whatever comes my way, I don’t really care… a job is a job, and a target is a target”. In this example, the story is not about explaining the technology or putting into context any scientific debate about misuse, but rather to emphasize (with a sock puppet) a world where misuse of this technology is common, there is no oversight and ethical concerns, and any use of this technology is just a ‘job’(Jordan Stoddart 2019). Our choice to allow this future is ethically suspect. The graphic portrayal in the video is also dark. The story is shot in black and white, and the CRISPR Cas-9 character is shown smoking, drinking beer, and wearing large sunglasses. Also, no references or sourcing of the scientific literature is employed.

This contrasts with an immigrant video such as ‘CRISPR: Gene editing and beyond,’ which was produced by *Nature* magazine and republished on YouTube. It explained CRISPR Cas9 technology, how it works, and its scientific potential. The video narrates, “CRISPR has already changed the face of research, but these new ideas show that what’s been achieved so far could just be the tip of the iceberg” (nature video 2017). It is graphically uplifting. The graphics and animation of this video used bright colours and focused on the scientific mechanism of the technology. This video also provided additional resources in its description and based its story on scientific data. These differences were seen throughout the data set.

B. Content parameters and the format of CRISPR Cas-9 videos

The QCA provided information on the content parameters (Table 11) and format (Table 12) of the CRISPR Cas-9 videos in the data set. This showed that a wide and even spread (overall) of content parameters were used in the videos, even in native versus immigrant videos (Table 11, column 2 vs 3). Video analysis showed the creators often used narration in the form of voiceovers for explanation and storytelling of CRISPR content (25 of 52 videos). In addition, 22 of 52 videos used a presenter, which is a common practice in producing videocasts and YouTube native videos. In total, 47 of 52 videos (90%) used the main storyteller either as voice-only or as a presenter.

Content parameters (elements that exist in each video)

	Total	Immigrant	Native
Narration/voice over	25	9	16
Presenter	22	13	9
Graphic*	26	7	19
Video	14	3	11
Photo/Slide	26	10	16
Sound bite**	14	3	11
Active – embedded link	3	1	2
Guest	11	9	2

Table 10:Elements of each video

*(*Graphic refers to animation, non-photo/slide graphics; **Sound bite refers to additional sound/music rather than narration)*

FORMATS OF EACH VIDEO	TOTAL	IMMIGRANT	NATIVE
VIDEO BLOG/CAST	13	0	13
NEWS REPORT	3	1	2
ANALYZING NEWS	2	1	1
INFOTAINMENT	3	1	2
TV DOCUMENTARY	4	4	0
WEB DOCUMENTARY	4	1	3
INTERVIEW	6	4	2
COMEDY	3	0	3
WEB MUSIC	2	0	2
RECORDED CONFERENCE / EVENT	15	14	1
TUTORIALS AND HANDS ON, HOW TO GUIDE	1	0	1
OTHERS*	2	2	0

Table 11: Formats of each video.

*(*The two videos which are marked as other include an advertisement for a conference and a B-Roll graphic.)*

These storytellers often spoke about the concept of the technology, its applications and concerns, and took the approach of the science literacy model in science journalism (Secko, Amend, and Friday 2013). They also use this technique as one of the main engines of their storytelling. One example is 'What is CRISPR?'(Bozeman Science 2016), which is presented by the producer but in a way that he would talk in a seminar with a background presentation. This is important due to the hypothesis that the visual storytelling about science on YouTube is still evolving, with some creators only using text or podcast (vocal) based approaches to create videos (i.e., where you can get a complete story without the images in the videos, making the graphical element non-essential). Therefore, the visual storytelling elements in this platform for scientific information can be argued to still be in their infancy.

Indeed, while the use of graphics and imagery was also predominant (26 of 52 videos), its use was secondary in the data set, only being there to either help the narration or just make a story compatible with a visual platform such as YouTube. This is also true of using real photos or slides (26 of 52 videos, including charts, media clips and scientific results) to support their stories or add visual layers. An example of this secondary use is 'Population Engineering | Gene

Drive by CRISPR-CAS9'(SciToons 2018, 9), a native documentary produced with high-quality graphics but only using imagery as a visual aid as part of the main story which the narrator presents.

There were a few videos in the data set that focused on imagery and graphics (visual storytelling) as their primary communication tool (e.g., 'Gene Editing & CRISPR: How Far Should We Go?', 'CRISPR-Cas9 Explained!', (Above The Noise 2019; CRISPy kReme 2019); these videos explored gene-editing technology as a new, consequential technology with wide and sometimes unknown negative potentials). However, this type of visual storytelling was in the minority. Furthermore, visual storytelling was often used to create a negative feeling or tone in a video, such as using elements from popular movies with an ominous and technophobic tone. This can lead audiences to make a mental correlation of the subject with the message of those familiar movies and pop culture references. This process can be explained by methods such as the 'Classical Conditioning' theory in learning. (Klopf 1988; Prokasy and Kumpfer 1973; Bitterman 2006)

Creators did use personal presenters in 22 of the 52 videos, largely for conducting interviews and/or to make the content more personal and powerful for communicating their opinion. The presence of a presenter was used in native videos to emphasize the role of the creator, as this could help a YouTuber with their brand familiarity (Campbell and Keller 2003; Mitchell and Olson 1977). Most of the CRISPR Cas-9 videos were either a video blog (13 of 52) or a recorded conference/event (15 of 52), with a fairly even distribution of the other formats (see Table 12). While there will undoubtedly be some debate about which of these formats can/should be considered science journalism (Djerf-Pierre, Lindgren, and Budinski 2019; Dunwoody 2014b; Hartley 2008), Table 12 is interesting in terms of how the format of videos show significant differences among native and immigrant videos. Interestingly, most of the immigrant videos are in the format of recorded seminars and other events, while most native videos are in the format of a videocast/videoblog (which here are considered as a form of video commentary, mostly using personal voices and tones and almost completely depending on the speech of the creator/narrator).

In most cases, producers of videocasts and videoblogs use some basic elements of journalism, such as putting a story in context, trying to be balanced, and covering different aspects of a story (with an interesting dimension of trying to keep content-neutral). This issue is discussed in detail later in the chapter, related to how these contents can be categorized in terms of the models of science journalism. Briefly, these videos use elements of journalism such as referencing credible sources, using science journalism storytelling techniques (Kovach and Rosenstiel 2014; Angler 2017; Allan 2011; Knight Science Journalism Program at MIT 2020) (REF) and modifying the content for their targeted audiences. Here, it is evident that clear examples of science journalism videos on CRISPR technology (e.g., the native videos 'wnlJ6dRfPFg' and '3fiS4HK9h0k') make use of video cast formats in combination with presenters, narration, video, and graphic content parameters. However, examples such as 'wnlJ6dRfPFg' and '3fiS4HK9h0k'are also include overlay animation, popup graphics, sound effects, playing with the position of presenter on the screen, and other techniques, which are not standard practice in traditional videos produced by established organizations for the purpose of science journalism. For example, the video 'wnlJ6dRfPFg' includes active use of a green screen to put the presenter in the middle of graphics and animations while using movie clips to convey a feeling and play with the positioning of the presenter. Also, the tone and style of the presenter are more informal and personal, which is considered one of the strengths of new media. Indeed, you can compare these videos with traditional, immigrant science journalism videos, such as 'nZR6mevfyD4' and 'EwO0kCRVNv0', which make use of a more formal tone and the formal inclusion of images in videos. These examples also keep their tone formal. Even when they are trying to use graphics to explain a concept, thus, existing experiences on YouTube, and how the creators are producing science stories on this digital platform, could be a guide for future video production of science stories as the preference of people for VOD (Video on demand) services and online platforms continue to overtake classic TV ("Video-on-Demand - Users in the World 2025" n.d.).

Another interesting finding in Table 12 is the unexpectedly low number of 'how-to and tutorials' in the data set (only one video), which one might have expected to be quite high due to biohacking and open access synthetic biology communities (Yetisen 2018; Bennett et al. 2009; Delfanti 2012; Meyer and Vergnaud 2020). An explanation for this may include: (i) the three-time spikes chosen for analysis just happened to have a lower number of this type of upload; (ii) these how-to videos being published as private on YouTube, with self-acclaimed bio-hackers not publicly linking to them directly in their own website or other platforms; (iii) this type of video not mentioning CRISPR Cas-9 in their title or description and, instead, using terms such as biohacking (e.g., you can see videos by or about Josiah Zayner – a well-known biohacker – under titles such as 'A 'Grueling and Grotesque' Biohacking Experiment' or 'DIY Biohacking: Do(n't) Try This at Home' (Freethink.; The Atlantic.)).

C. Positive representations of CRISPR Cas-9 technology and ethical neutrality

The QCA results reveal that 65% of the included videos (34 of 52 videos) positively view the technology in their narrative (see Table 13 and Figure 20). A positive exemplar is the video 'Introduction to Genome Editing Using CRISPR Cas9' (g7bkE1krgFM), which narrated "revolutionary genome-editing technology…[by this method] disease-causing mutations can be corrected by changing the underlying genetic code"(National Institutes of Health (NIH) 2019) about CRISPR Cas9. The content producer clearly sees CRISPR Cas-9 as 'revolutionary' and an important future component for curing diseases.

A second example is the video ‘0400 Outreach Project - CRISPR-Cas9 Technology’ (CKJgmwY2qms), about the future of the CRISPR Cas9, which narrated “…although we can feel intense sadness, profound happiness can be just around the corner. Have you ever imagined a world without disease, no HIV, no acute kidney disease, no cancer, no genetic disease, and no diabetes? Isn’t that wonderful? Well, the good news is we’re almost able to cure all disease through a technology called CRISPR Cas9” (Daniel Zunino 2019). This level of positivity can be interpreted as ‘hype’ for the possibilities that this technology can bring to humanity and links to ideas in the literature about ‘hype’ and ‘techno philia’(Caulfield 2018; Bubela 2006; Caulfield and Condit 2012; Osiceanu 2015).

In contrast, only 11.5% of the videos presented an obvious negative perspective toward technology. For example, the video ‘ CRISPR/Cas9 - Will Genetic Engineering Revolutionize Our World and Us Humans?’ (6wLdwLofMyo) narrated, “…[o]r much worse, we’ll be able to create superhumans with a simple and effective technique… To put it in a nutshell: The scientists have no clue what they did there.” (Clixoom Science & Fiction 2018), which is clearly negative in referring to the concept of Eugenics and creating a ‘superhuman’ (Black 2012; Lombardo 2011). This video also portrays scientists as a group of careless people who are experimenting with something they don’t fully understand, linking to the trope of ‘mad scientists’(Haynes 2016; Flores 2002; Tudor 1989; McAdam 1990). Furthermore, while the literature refers to a few negative aspects of CRISPR Cas-9 technology, such as ‘lack of regulation,’ ‘unsupervised bio hacking’ and ‘role of the market in the future of technology’ (Taning et al. 2017; Plaza Reyes and Lanner 2017; Wolter and Puchta 2017; Meyer and Vergnaud 2020; Ledford 2015; Zettler, Guerrini, and Sherkow 2019), the sampled YouTube data shows little about these issues.

Approximately 21% of the videos stayed neutral about the technology (Figure 20), with their (for example) their narration stating things like “[t]here are some concerns besides the benefits” and “[w]e need more time and more studies to have a clear picture.” Neutrality in this context can be viewed as an attempt to be balanced and objective (Kovach and Rosenstiel 2014; Dunwoody 2014b; Angler 2017).

Visual negativity has been discussed as ‘images that induce anger, fear, and disgust.’ (Newhagen 1998; Keib et al. 2018; Lang, Newhagen, and Reeves 1996). Representations about CRISPR technology based on the choice of graphics and visual elements showed that while 11.5% presented it in a negative way, and 32.6% still portrayed the issue in a positive way, the highest number of videos were presented as neutral (48%; see Figure 19). Examples of neutral graphics include using the explanatory graphics and photos, scientific charts, and data visualizations in videos such as “g7bkE1krgFM” and “6P2hYCuccG8”. As for narration, this neutrality is likely a function of the use of an explanatory approach to the storytelling, or of the creators attempting to show themselves as balanced and objective, covering all sides of the story. Neutrality in visual component can be considered as graphical elements which do not induce generally positive or negative feeling in audiences (or the author in this case), and YouTube videos on CRISPR seem to embody this lack of feeling inducement.

The higher percentage of neutrality in the graphics can also be interpreted as a matter of technicality. Many of the videos in our samples are recorded seminars or scientific presentations, which as a general practice of academic communication, can lack emotion, focusing on process and findings instead. The other parameter is the technical difficulties of producing graphics (either positive or negative). While creators have better and more user-friendly tools to create graphics, producing them requires creative effort, skill, and time. Based on our sample set, most of the video creators – especially in the native group – use available graphics online, most of which are produced by scientific organizations or media studios and therefore more neutral. In addition, most of the immigrant's contents – including seminars, online classes, recorded seminars and presentations – are using YouTube as a repository space and don't re-format their content based on this medium or for additional audience engagement.

In contrast, positive graphics and visual elements involved bright colours, happy characters, and elements that convey positive feelings, as seen in the videos '1viRt8jV-vk' and 'fi93KpsV7-U'. Overall, the role of negativity was again low in the data set (Figure 19 and 20).

	Positive	*Neutral*	*Negative*	*Unclear*	
View on CRISPR Cas9 (Narration)	34	11	6	1	52
View on CRISPR Cas9 (Graphic)	17	25	6	4	52
View on Ethical Considerations (Narration)	5	33	10	4	52
View on Ethical Considerations (Graphic)	2	41	5	4	52
Total	58	110	27	13	

Table 12:Results of QCA on four categories and four dimensions.

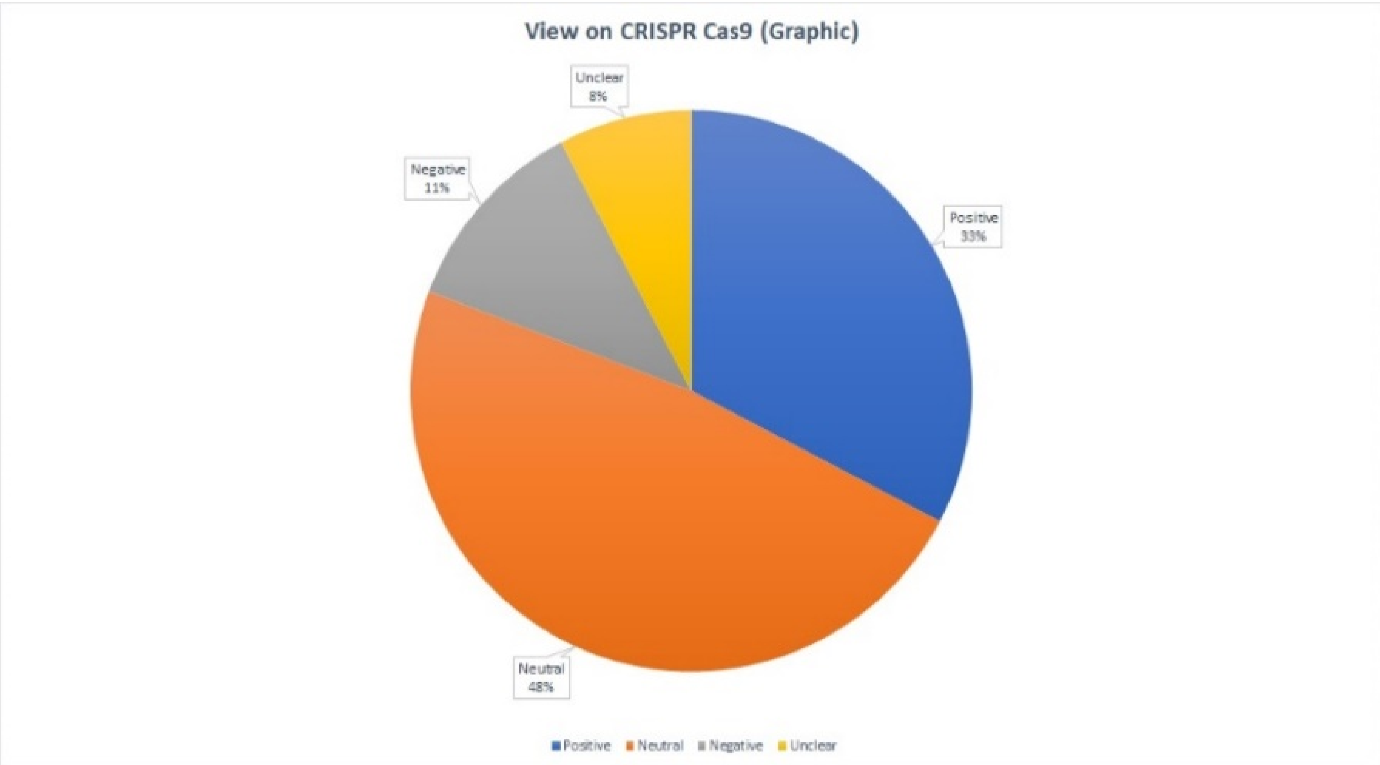


Figure 17: View on Technology - Graphic.

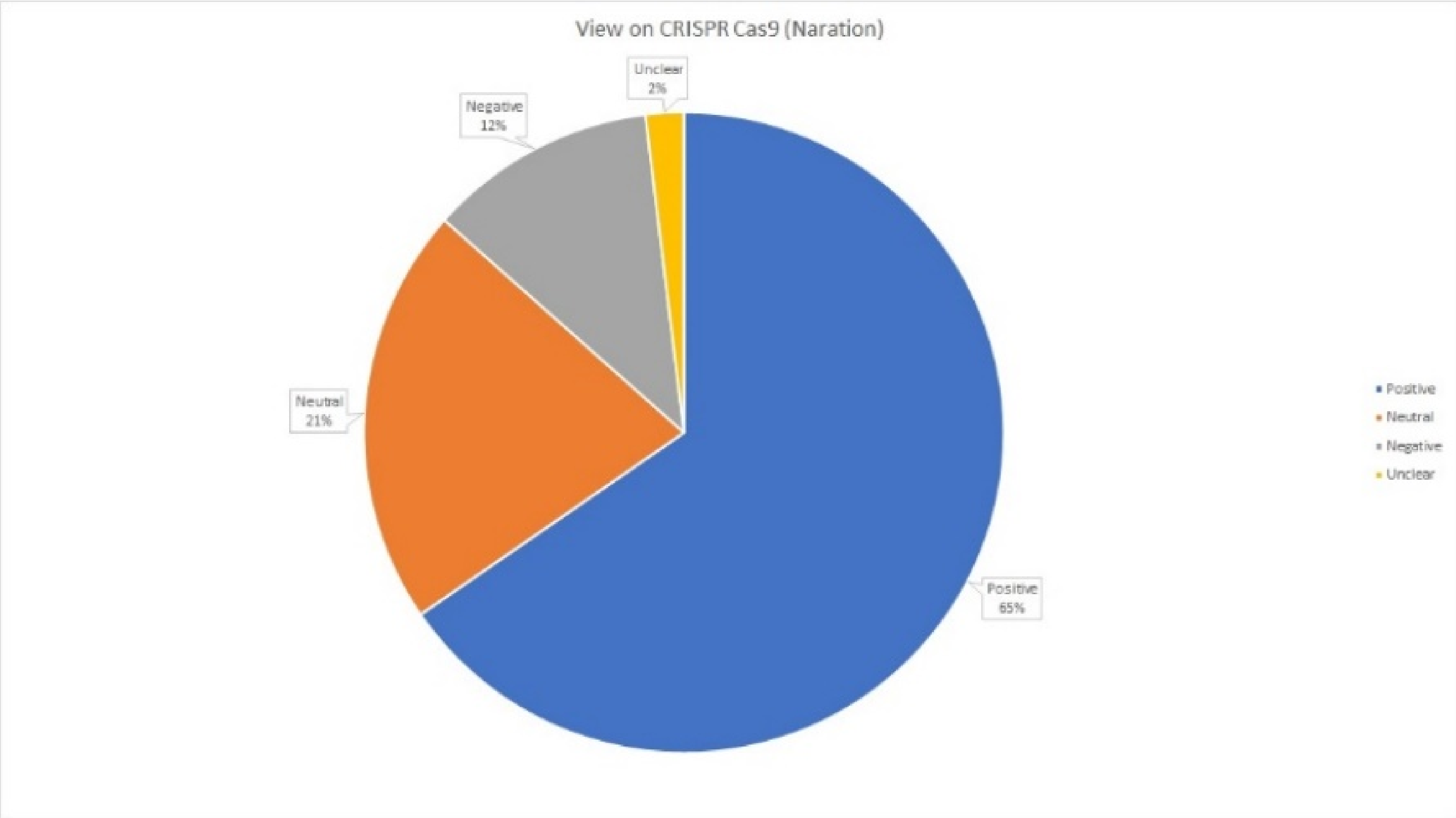


Figure 18: View on Technology – Narration1

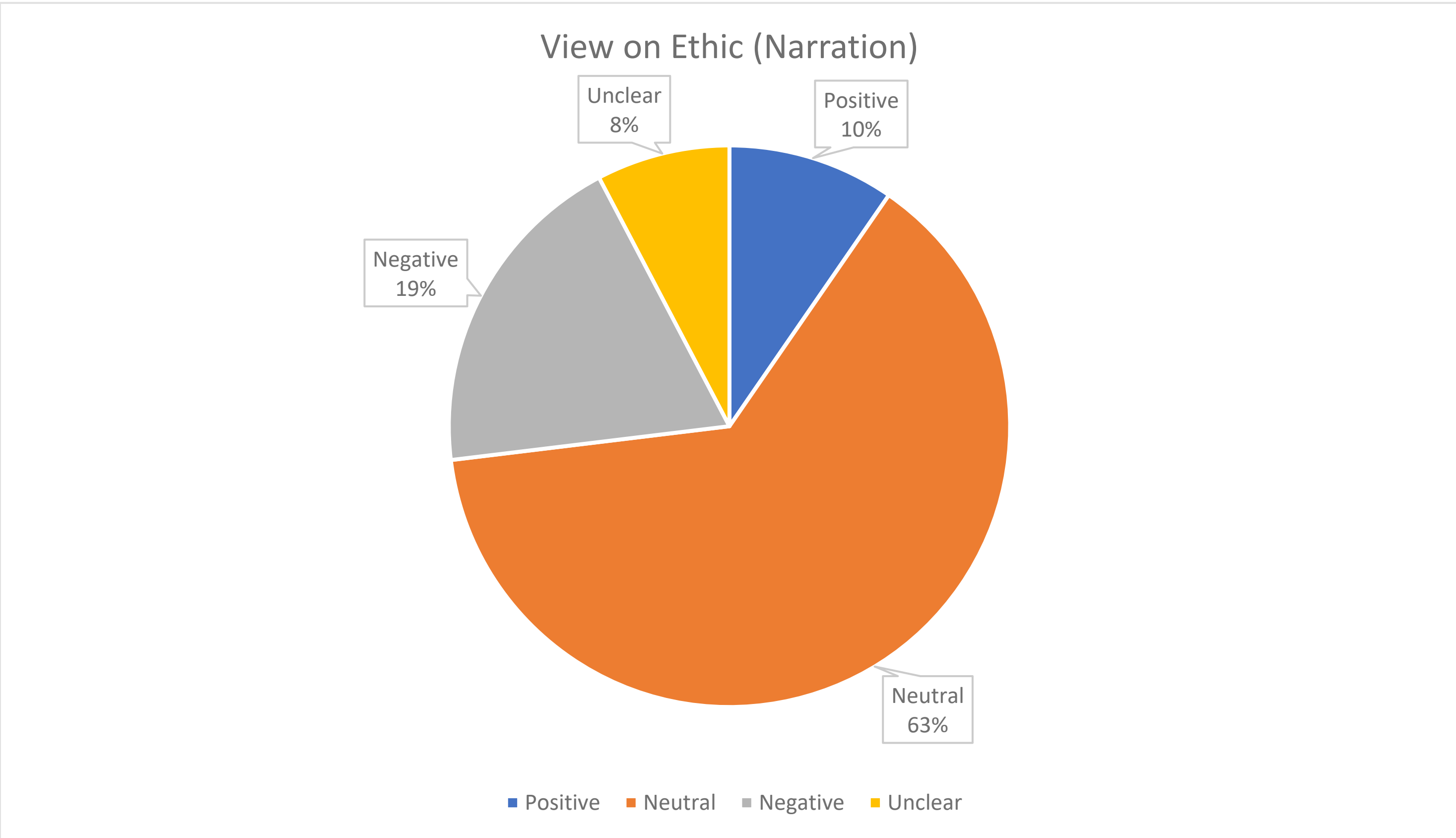


Figure 19: View on Ethics – Narration)

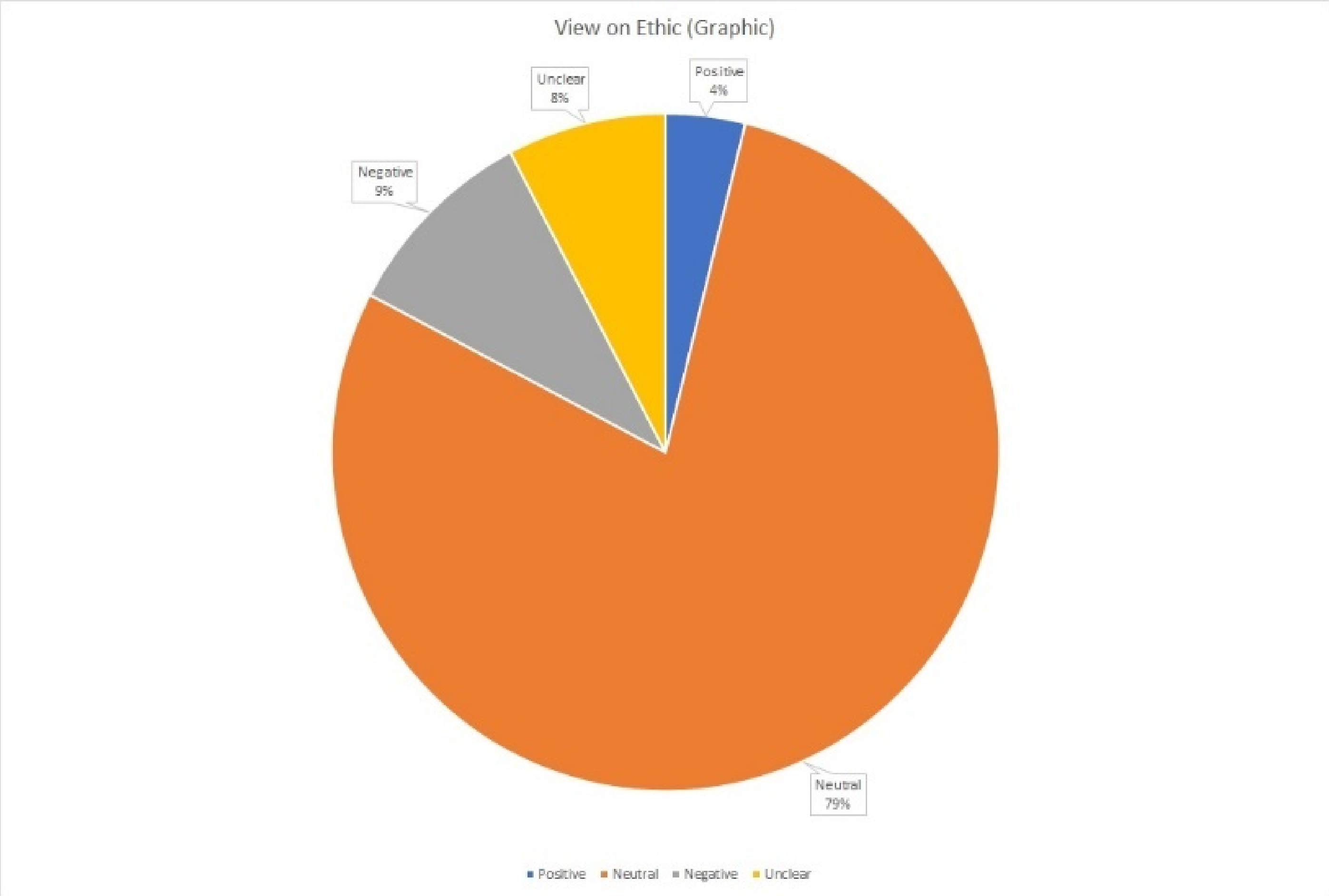


Figure 20: View on Ethics (Graphic)

The 3rd and 4th categories of the QCA (see 'coding and categorization' on pages 52-55) were engaged with the concept of the ethical debate around the issue of CRISPR Cas-9 (Plaza Reyes and Lanner 2017; Cyranoski 2015; Fletcher 1990; Evans 2002; Dayan 2020; Gonzalez-Avila et al. 2021; Plaza Reyes and Lanner 2017; Lombardo 2011). This is one of the research literature's main themes and often discusses CRISPR as a controversial ethical issue. The major ethical concerns are about the misuse of technology, use of human trials, and germline gene editing. It is important to mention that not all the ethical debate CRISPR Cas9 is about possible negative consequences. A school of thought among scientists and bioethics researchers considers employing CRISPR Cas9 on humans and germlines as moral, ethical, and necessary (Cyranoski 2015). They even argue that lack of use this potential is an 'immoral' decision (Cribbs and Perera 2017; Flotte 2015; Baumann 2016; Brokowski and Adli 2019)

Most of the references to ethical issues were presented neutrally or avoided (63% and 78.8% respectively; Figures 21 and 22). An example of a neutral presentation is the video 'CRISPR Cas9 - the "gene scissor"' (h24ljvybXww); in this video, the presenter avoids any mention of ethical and moral issues around the CRISPR Cas9, and the graphical materials are only explanatory. Another example is '0400 Outreach Project - CRISPR-Cas9 Technology' (CKJgmwY2qms). This video has a very positive approach to technology, and when it comes to ethical concerns, the narrator is an attempt at a neutral tone. This video narrated: "most of the ethical discussions related to genome editing center around humans gene editing this is due to changes made in the germline would be passed down to future generations, the debate about genome editing is not a new one but has regained attention following the discovery that CRISPR has the potential to make such editing more accurate, bioethicists and researchers generally believe that human genome editing for reproductive purposes should not be tempted at this time, but the studies that would make gene editing safe and effective should be continued" (Daniel Zunino 2019).

Another graphical example is the video PTtFLuLEdZU, where the narrator talks about ethical and moral issues, choosing explanatory graphics that do not convey any specific feeling. Even in choosing the graphical characters, the creator avoids facial expression using a B-roll of people in the street, which helps to convey that this is a social issue but without any positive/negative bias. This clarifies that there is an effort to keep the visual content free from conveying feelings and (perhaps) thereby more neutral in interpretation. This ethical neutrality could be viewed as unexpected compared to the robust ethical debates seen in the academic literature (Cribbs and Perera 2017; Brokowski and Adli 2019). This neutrality by video creators and not taking sides in debates also may represent that while the debate is tense among academia and scientists, most YouTube creators have yet to reach a conclusion in this matter or are not interested in these debates.

While neutrality dominated the two examined elements of the CRISPR videos, a comparison of the positive vs negative attitudes in both narrative and visual elements showed that a more negative view on ethical issues was a secondary result (Figures 21 and 22 combined totals). For instance, for narration, 9.6% of content was represented positively (e.g., cure of all disease, new age for better food and biosafety) and 19.2% represented it negatively (e.g., dangerous, unknown consequences, creating superhumans). It was 3.8% represented as positive and 9.6% negative for visual elements. This is best exemplified with the contrasting examples of videos j9HO_zow0vI versus wnlJ6dRfPFg.

j9HO_zow0vI narrated "the unlimited opportunity for curing all kinds of disease" and used positive graphical elements such as happy faces. wnlJ6dRfPFg took a negative approach to narration about "unintended consequences." It was visually negative in using colours and using clips from movies with negative views on the future of gene-editing technology. This video also used clips from films such as 'Rampage' and 'Gattaca,' both portraying how we can lose control of gene editing and face unwanted consequences. In addition, when the narrator started to talk about his ethical issues, the background colour turned to yellow, which corresponds t to a warning colour (Above The Noise 2019).

These examples show the striking differences in CRISPR Cas-9 videos, which speaks to different approaches to addressing ethical concerns in the literature (Cribbs and Perera 2017; Brokowski and Adli 2019; Evans 2002; Gonzalez-Avila et al. 2021). This is important due to the role of framing science and new technologies for audiences. Representing and framing an emerging technology in a specific way (pure negative or pure positive) plays a role in creating and expanding technophobia/technophilia.

This echoes the existing concerns and the role of this framing in shaping policies, funding and general public perceptions of emerging technologies in the few studies that explore the role of framing new technologies in media, how it affects the evolution of that technology, and its perception by people and society(M. C. Nisbet and Mooney 2007; Matthew C. Nisbet, Brossard, and Kroepsch 2003; Metag and Marcinkowski 2014).

D. A qualitative cross-section analysis of native and immigrant videos

It was also possible to provide a cross-section analysis of the Native and Immigrants videos due to the hieratical coding system employed in the thesis. Table 15 and Figures 23 to 25 show this cross-section analysis, which revealed the following:

- When combining all four categories, native videos are more likely to consider the subject as positive/negative (6 videos in native vs 0 in immigrant)
- When combining two categories related to the technology itself and two ethical categories (visual and narration), there is a considerable difference among the views toward the technology and ethics (15 positives in the graphic+narration of technology vs two positives in the graphic+narration of ethics). This shows that currently, among these videos, an optimistic and positive view of the technology itself doesn't translate into a favourable view of its morality.

						Immigrant				***Native***			
		Positive	Neutral	Negative	Unclear	Positive	Neutral	Negative	Unclear	Positive	Neutral	Negative	Unclear
I	View on CRISPR Cas9 (Narration)	34	11	6	1	19	3	1	0	15	8	5	1
II	View on CRISPR Cas9 (Graphic)	17	25	6	4	6	15	1	1	11	10	5	3
III	View on Ethic (Narration)	5	33	10	4	1	16	5	1	4	17	5	3
IV	View on Ethic (Graphic)	2	41	5	4	0	21	0	2	2	20	5	2
	I and II	15	7	5	0	6	3	1	0	9	4	4	0
	I and III	5	10	6	1	1	3	1	0	4	7	5	1
	I and IV	2	9	4	0	0	3	0	0	2	6	4	0
	II and III	4	19	5	3	0	11	1	1	4	8	4	2
	II and IV	2	23	4	3	0	14	0	1	2	9	4	2

III and IV	2	30	4	2	0	15	0	1	2	15	4	1
I and II and III	4	7	5	0	0	3	1	0	4	4	4	0
I and III and IV	2	9	4	0	0	3	0	0	2	6	4	0
II and III and IV	2	17	4	2	0	10	0	1	2	7	4	1
I and II and III and IV	2	6	4	0	0	3	0	0	2	3	4	0

Table 13:Views on videos - Cross References - Immigrant and Native.

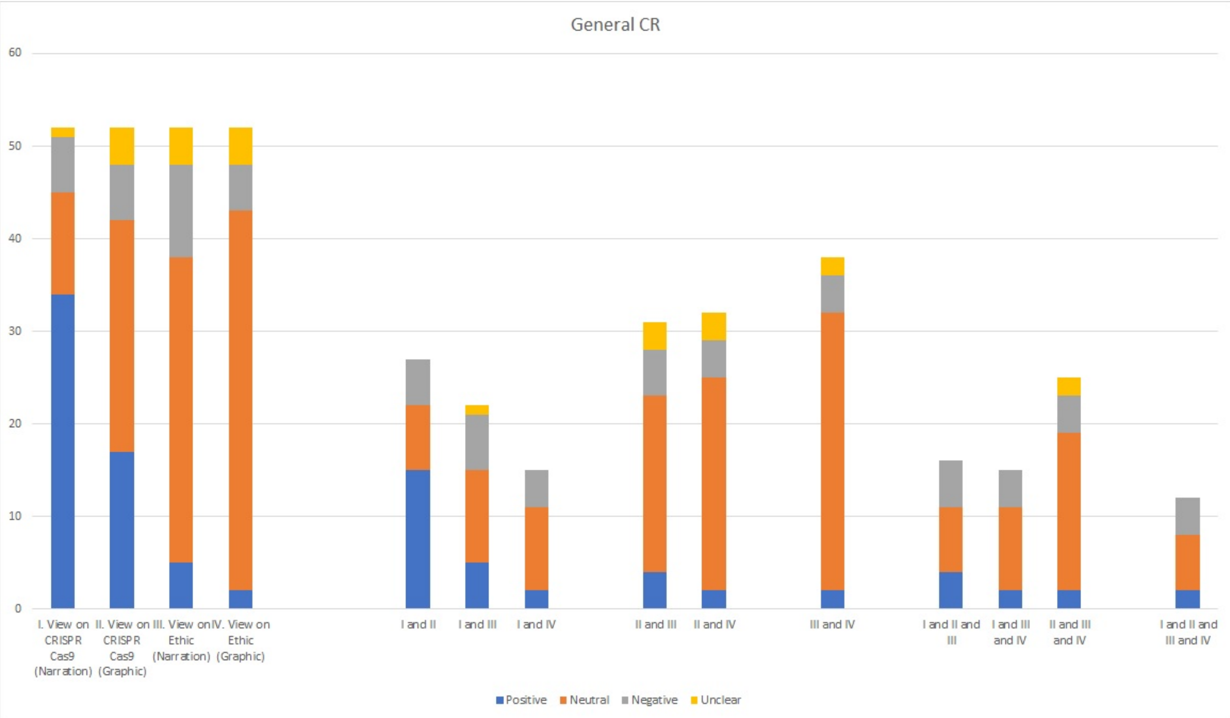


Figure 21: General results on Cross-Categories

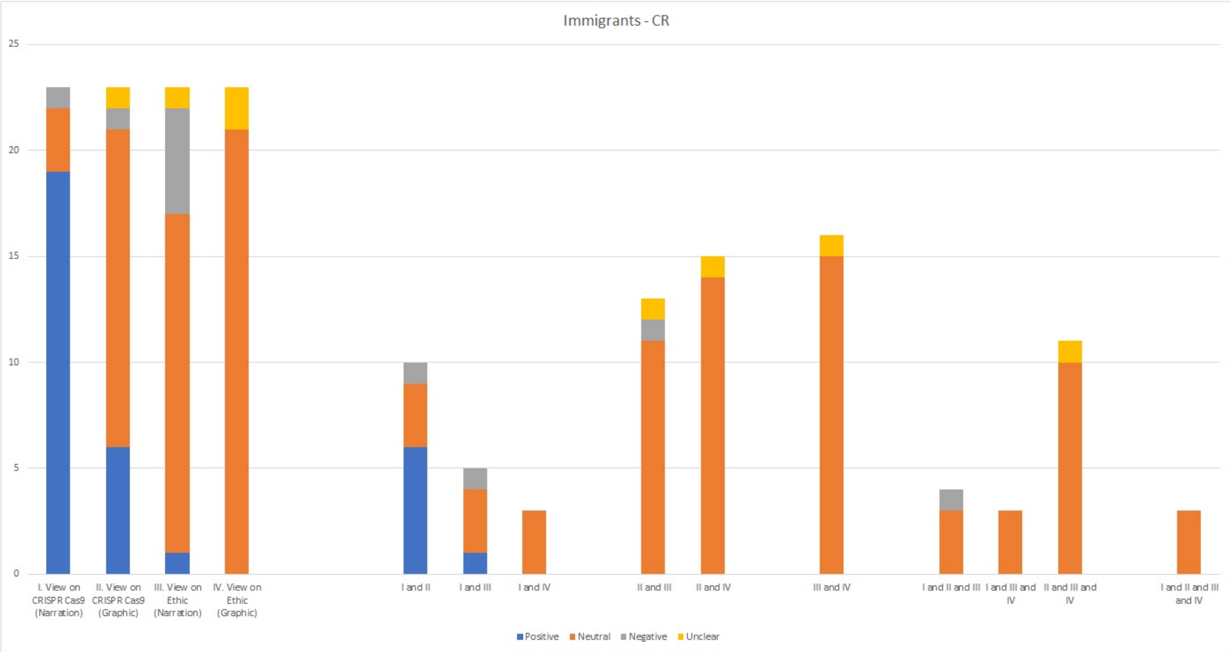


Figure 22: Cross Categories results for immigrant videos.

This cross-section analysis supports a hypothesis (albeit on small sample size) about more opinionated and more negative views in the native contents of the data set. For example, when I combined all four categories in Figure 24, it was impossible to find any video in the immigrant category that had all positive or negative views. In contrast, there were six videos in the native category (see Table 15, columns 10 and 12- the last row) that had all positive or all negative parameters (four of them being all negative), pointing to total negativity in native videos that is twice the total positivity. The comparison of the average of likes, dislikes, comments and view counts for each category (see Figure 26) showed that the average of likes and comments were higher in negative dimensions than positive ones, suggesting that negative contents, both in narrative and graphics, can engage more people in regards of feedback. This also can support the idea that controversy in media - and emphasizing the negative aspects of a story for triggering emotion responses - is one of the most engaging contents. (Blum et al. 2006; McIntyre and Gibson 2016; Nelson-Field, Riebe, and Newstead 2013). It also shows that neutral content could provide high engagement numbers (Table 16, rows 2,5,8 and 10). But, we have to keep in mind that most of these neutral contents are immigrant videos, and their core and main audiences could be different than audiences of native videos.

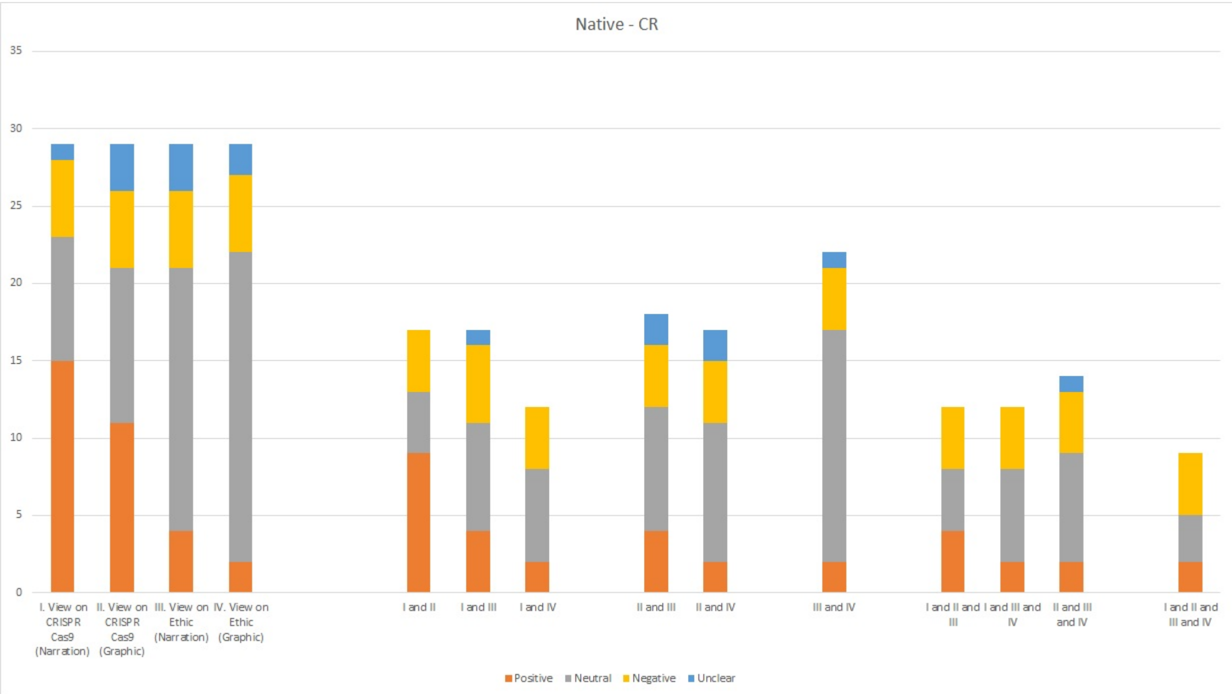


Figure 23: Cross Categories results for native videos.

Finally, the engagement parameters for each dimension in each category could be calculated (Table 16).

It is essential to remind that "audience engagement" in this discussion is based on audiences engagement parameters used as indicators of how people are reacting to a video on YouTube (including like/dislike/comment/view). While helpful to understand how audiences receive a video, these parameters cannot give us a clear picture of how a person engages with a video on a personal level.

This provided a few interesting results, where it became clear that:

(i) The highest number of average likes and comments are related to videos with negative graphics on ethics (Figure 26). A clear example of this is the video wnlJ6dRfPFg. This video has the highest number of likes and views in this category. This is important due to the idea of framing science and how it engages people, and as an example of how negative graphics can engage more viewers.

(ii) With regards to the technology itself (narration), most of the content views were positive, but neutral content had more average likes (Figure 26).

(iii) The highest average of dislikes is related to the negative graphics regarding ethics. (Figure 26). This category has the most average likes as well, an indicator that the negative contents about ethics (in graphics) while engaging more audiences, are also more controversial.

		Views -Av	*Likes-Av*	*Dislikes-Av*	*Comments-Av*
View on CRISPR Cas9 (Narration)	Positive	5603.47	39.94	2.4	7.91
	Neutral	3973	100.63	3.27	19.27
	Negative	1530.8	73.66	0.83	24
View on CRISPR Cas9 (Graphic)	Positive	9791.412	55.35	1.41	4.82
	Neutral	2547.08	58.76	2.84	16.04
	Negative	1378.16	64.83	0.83	23
View on Ethic (Narration)	Positive	181.8	5.6	0	1.2

	Neutral	6941.06	71.27	2.9	14.33
	Negative	945.6	44.7	0.5	14.5
View on Ethic (Graphic)	Positive	31	0.5	0	0
	Neutral	5446.8	53.12	2.31	11
	Negative	3749	137.4	5.4	34

Table14: Engagements per Category per dimension

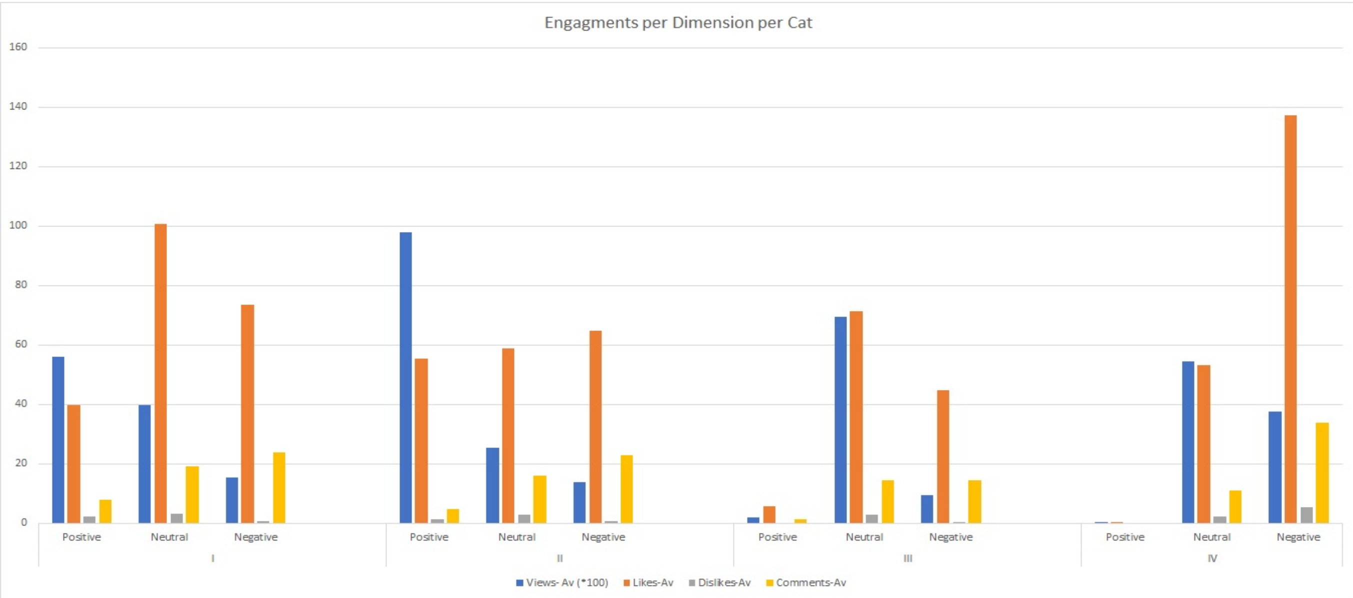


Figure 24: Engagements per Category per dimension

E. Models of science journalism used in selected videos

The 3rd research question in this thesis was about models of science journalism and if the videos about CRISPR Cas-9 on YouTube point towards any specific, existing models or new emerging models. In Secko et al., a general categorization of four existing science journalism models was presented (Secko, Amend, and Friday 2013), including Science Literacy, Contextual, Lay Expertise and Public Participation. These researchers using following criteria to establish these models:

1. Purpose

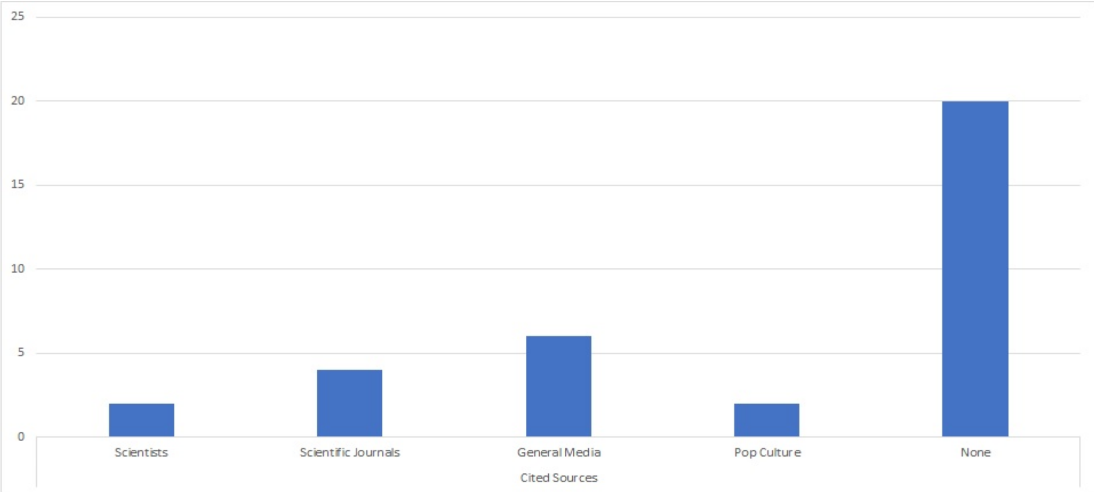
2. Focus
3. Style
4. Sourcing
5. Audience
6. Science

To analyze CRISPR videos in search of models and new ideas, the exploratory QCA analysis was limited to native videos only. The reason to restrict this analysis was that immigrant content mostly just re-published content on YouTube without any changes or modifications. If I could conclude that these immigrant videos have a tendency toward some kind of models, those models reflect the elements of their native platform rather than YouTube. Instead, the goal was to explore if new models were evolving as designed for YouTube specifically. As a result, I limited the review to the 29 native videos, examining 3 of the six criteria from Secko et al. (2013).

For each video, three parameters were examined:

a) Which sources – if any – are cited in the video? (Sourcing)
b) What is the main character and purpose of the story? (Purpose)
c) Who is the focus of the story? (Focus)

The results are presented in Tables 17, 18 and 19 below. Most of the videos (69%) didn’t cite any sources for their content. Among those which cited any sources, traditional news media has the highest citations. Only six videos cited scientific research or journal, or scientists. This is a key finding in this research. The main focus of 79% of the videos was the science of CRISPR Cas-9 and how it works. This suggests that native videos largely employ explanatory models (18 of 29 videos) as outlined for the science literacy model of science journalism (Secko, Amend, and Friday 2013). This model seeks to translate scientific information to general audiences and "seeks to fill audiences perceived knowledge deficit" (Secko, Amend, and Friday 2013a). When



considering audiences for these videos, no proof that any specific group of people was targeted was detected. As such, new models of science journalism were not detected in this sample.

traditional news media

Figure 25: Cited Sources in selected videos

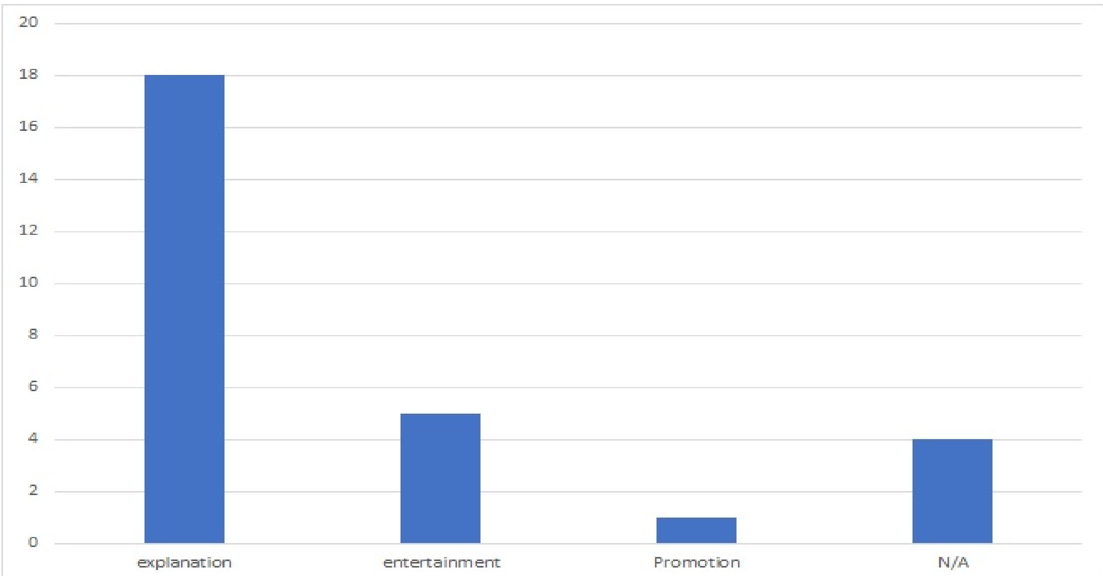


Figure 26: Main goal of producing video.

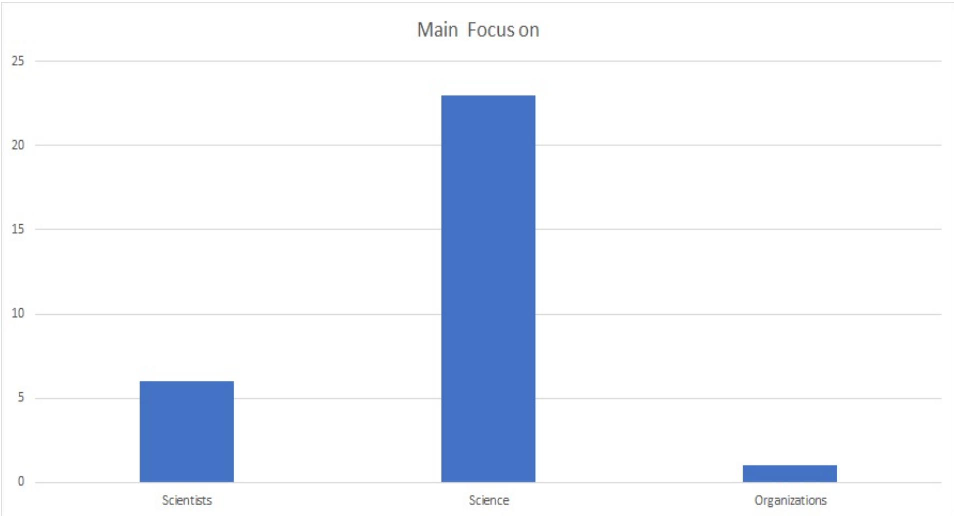


Figure 27: Focus on Characters

Summary and discussion

In this chapter, the content of selected CRISPR Cas-9 videos was analyzed to give a better understanding of the overall message that a YouTube video relayed to audiences. This analysis clarified that YouTube videos prioritized explanatory aspects of storytelling in their content and often dealt with elements of journalism and scientific storytelling.

To summarize, five points are worthy of specific discussion:

A) The elements used in the video varied, but most (47 of 52; Table 11) used some kind of the main storyteller with voice only or with a presenter. This was combined with graphic elements including animation, drawing, stop motion, computer simulation, or other forms of visual storytelling, rather than video footage or real-world photos. This result shows the power of graphics in explaining technical and scientific issues such as CRISPR. Stop motion drawing in native videos stood out as a prime example (Figure 27), where presenters use a whiteboard, or digital board, or even paper and pen, to draw different shapes related to the story. Most of the time, these are not detailed or polished but could help audiences engage and help creators explain ideas without being dependent on high-quality and expensive visual material.

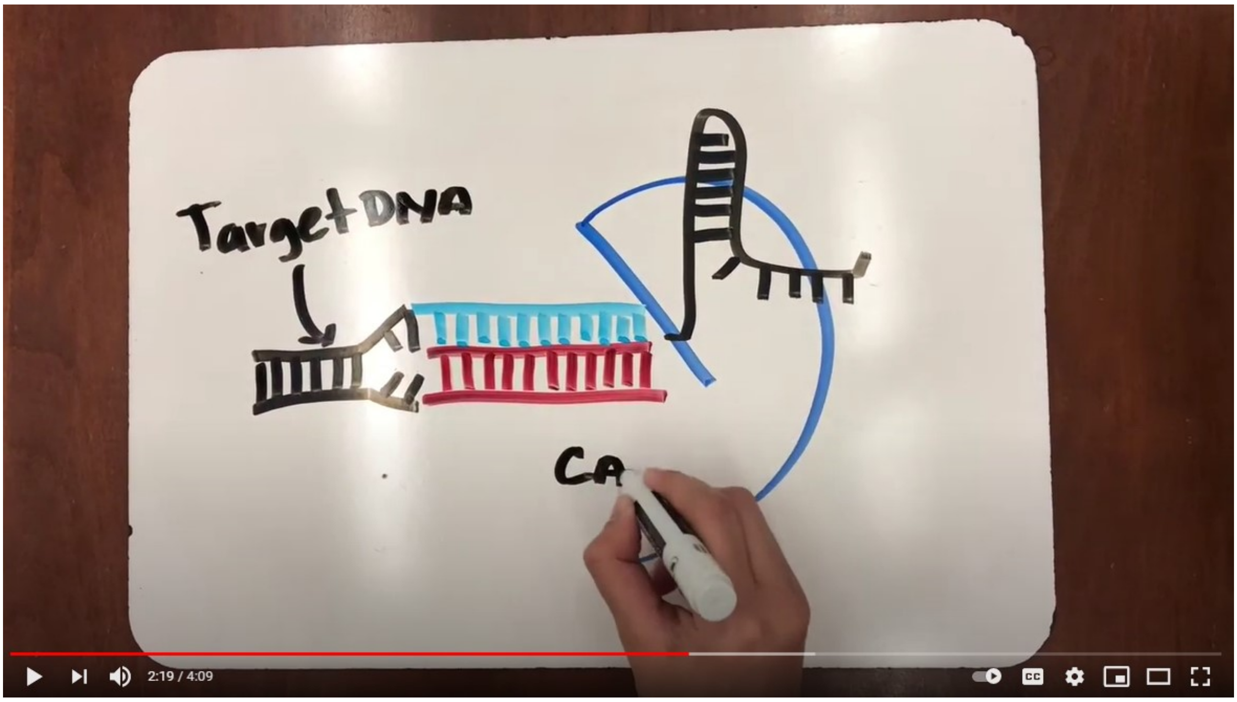


Figure 28: An Example of using stop motion and drawing boards. YouTube 2020. https://youtu.be/CKJgmwY2qms

B) Only three videos in the sample used active-embedded info cards/videos or linked inside their content (Table 11). This is a surprisingly low number since one of the main tools in the YouTube ecosystem is the potential of in-video links and embedded videos and cards. This option works similarly to hyperlinks for the web. By using them, creators can guide viewers to other videos and increase engagement with audiences. The low number suggests CRISPR content creators are not fully aware of the platform's tools or are still just using YouTube as a place to simply share their videos (as point C below further suggests).

C) The QCA coding allowed categorization of the CRISPR videos based on format, which revealed that all the video blogs are native content, and all the recorded events are immigrant content. Video blogs or videocasts are typically a media format that is more personal, subjective, and opinionated. Other forms also stood out, such as using comedy and a puppet show to tell a story about CRISPR Cas-9 (Figure 28).

Figure 29: An example of using puppet shows for comment on CRISPR Cas-9. YouTube 2020. https://youtu.be/4KwfMpLtZxM

This result leads to a hypothesis about the current state of YouTube in communicating about CRISPR Cas-9: ***It seems most of the creators of immigrant content are using YouTube as a repository for their content, and they are not modifying their contents for this medium, while creators of native videos are using YouTube to tell their own stories, express their opinion, and push the limits of visual storytelling.*** From this perspective, creators' current use of YouTube is comparable with the few first years of journalism on the web, were as Carl Zimmer pointed out: "For years, their websites were little more than copy-paste dumping grounds for their print edition" (Zimmer 2016). To unleash the full potential of YouTube for science journalism, the direction could be taken from the evolution of weblogs, podcasts, and other social media (Matthew C. Nisbet and Scheufele 2009). Reviewing these results indicate a few directions that YouTube videos on CRISPR Cas9 and 'emerging technology' can take.

i. Start to think of YouTube as an original medium and not just a place to save recorded events and seminars and republish the original works (as in immigrant contents). YouTube created an ecosystem in which voices and ideas can only grow if they are compatible with this ecosystem. Even the best content could be lost, forgotten, and perish in this wild and dynamic ecosystem if it ignores the climate of this medium. It was clear in the analysis that many creators – especially immigrant videos – are not paying attention to this issue, and even some native content creators are still trying to imitate visual formats from mainstream production.

ii. YouTube is a digital platform. Creators, and users, can and should take advantage of its technical potentials. The analysis shows that very few videos applied such capabilities. Using active links, cards, creating VR and 360-degree videos, live chats and live broadcasts are among these potentials, which are not utilized in the data set. Another lesson that content creators on emerging technology can learn from the history of blogging is creating a diverse community of creators under one channel and co-creating content on the subject. This was a successful experience during the evolution of the blogsphere, which manifests itself in the form of a 'network of weblogs' and/or 'festivals' (Wilcox, Brookshire, and Goldman 2016).

iii. While there are few examples of creating creative graphics in native videos, most still use B-roll and graphics produced for other purposes. Using creative art in the videos and paying more attention to the role of art in science communication could be a way to make more powerful videos (Lesen, Rogan, and Blum 2016).

iv. Diversifying tones and formats are another pathways forward. Adding personal tone, voice and style while keeping the content credible can make the content more relatable.

D) Based on the QCA results, the overall view of CRISPR technology was positive, suggesting that YouTube creators view the technology as a breakthrough in science and technology, with huge potentials in developing cures for diseases, making life better, and as a tool to solve the problem of food shortage with unlimited potential (Carroll 2017; CRISPy kReme 2019; nature video 2017). There was, however, a weak but recognizable negative view about the ethical considerations of CRISPR technology and its future. Negative attitudes–if they continue or grow-could play a role toward a phobia about the future of this technology and its applications (M. C. Nisbet and Mooney 2007; Matthew C. Nisbet, Brossard, and Kroepsch 2003; Metag and Marcinkowski 2014). It is, therefore, interesting to note that in comparing parameters (Table 15), the native videos show higher opinionated views in all four categories (with a higher ratio of negative views to positive ones), while immigrant videos tended to be more neutral on average. This supports a hypothesis that native content on YouTube tends toward negative representations, which can potentially lead to a sense of phobia about CRISPR Cas-9.

E) No new model of science journalism was detected. Instead, a sub-set of the videos followed a science literacy model. As Secko et al. write: " From a journalistic perspective, use of the science literacy model involves employing traditional journalistic norms, such as objectivity, and viewing audiences as lacking knowledge." (Secko, Amend, and Friday 2013; Secko 2007). However, one recognizable difference is that in YouTube, we are witnessing a non-direct and non-linear transmission. Most creators are not citing scientific research but exploring their own understanding of CRISPR. This is where we may be seeing signs of a sub-model of the science literacy model developing, with external sourcing ignored and internal opinions used but still in pursuit of literacy goals. This is an important issue that needs to be explored more in future, especially considering the power of trends and how successful videos – in terms of engagement – could set the style and voice for emerging technology.

CHAPTER 5
OVERALL DISCUSSION

This thesis explored the communication of CRISPR Cas-9 in online videos on YouTube via three research questions. In this final chapter, overall insights on each question are discussed in turn.

How many videos about CRISPR Cas-9 are on YouTube between 2012 to 2019? (RQ1)

Using the combination of three different methods, I extracted **743 videos** with different variations of the keyword CRISPR Cas-9 between Jan 2014 (first video to appear after 2012) to the end of Dec 2019. Comparing these results showed that while CRISPR Cas-9 is a relatively new subject, a comparable number of videos relative to other issues with a long history have been created (Doudna and Charpentier 2014; Doudna and Sternberg 2017; León and Bourk 2018a). It also revealed that using the YouTube in-site search engine alone, which is based on end-user and in-site searches, did not bring all available results. Notably, much of the research on YouTube videos only uses this one method (cf. León and Bourk 2018a; Richier et al. 2014; Park, Naaman, and Berger 2016; "Videos | YouTube Data API" n.d.; Rieder, Matamoros-Fernández, and Coromina 2018; Covington, Adams, and Sargin 2016; Paolillo 2008), and this result showed that if I want to have a better understanding of the status of these videos, we need to improve our search and data gathering approaches. The literature on video analysis (e.g., Lesen, Rogan, and Blum 2016; Keelan et al. 2007; Madathil et al. 2014; Welbourne and Grant 2016) has yet to address this methodological need for future studies.

The three months with the highest video uploads in the sample were December 2018, April 2019, and December 2019. These three spikes included a total of 91 videos in 10 different languages. The presented analysis was based on English and French or nonverbal videos in this dataset, thereby reducing this set of three spikes to 52 videos. I determined that 44% were immigrant videos and 56% were native YouTube videos among these videos. I was interested to determine if any correlation existed between the number of CRISPR Cas-9 videos uploaded each month on YouTube, and any news trends on Google web search and Google News, for example. The only statistically significant correlation observed was between the number of uploads per month and the Google web search for the same keyword at the same time. These two trends correlated by the factor of 0.7586 (see page 42).

What themes emerge from analyzing the content of selected videos on CRISPR Cas-9? (RQ2)

To our knowledge, this thesis presents the first qualitative content analysis (QCA) of CRISPR Cas-9 videos on YouTube. This QCA analysis examined 52 videos related to the themes of narration, graphical elements, and ethical concerns (in both narration and graphics) as related to positive, neutral, negative, and unclear coding dimensions (see Chapter 4). Previous research on CRISPR Cas-9 suggested that this topic was potentially revolutionary in the gene-editing field, controversial, and multi-dimensional with the potential effects on medicine, economy, culture and security (see Doudna and Sternberg 2017; Isaacson 2021; Plaza Reyes and Lanner 2017; Wolter and Puchta 2017; Dickenson and Darnovsky 2019b; Sand, Bredenoord, and Jongsma 2019; *Bloomberg.Com* 2019; Biosciences 2018; Clixoom Science & Fiction 2018). Concerns in the literature are also expressed around this emerging technology's morality and ethical use (Cribbs and Perera 2017; Baumann 2016; Brokowski and Adli 2019; SciToons 2018; Brokowski and Adli 2019). For example, Carolyn Brokowski and Mazhar Adli write about "CRISPR research is progressing at a rapid pace" and "[t]he ethical concerns about CRISPR genome engineering technology are largely due to at least three important reasons. First, there are concerns about CRISPR technology's power and technical limitations. Second, it is unclear whether modified organisms will be affected indefinitely and whether the edited genes will be transferred to future generations, potentially affecting them in unexpected ways. Finally, the skeptical view is that even if the genome is edited as expected and the desired functional output is achieved at the given time, the complex relationship between genetic information and biological phenotypes is not fully understood" (Brokowski and Adli 2019).

Feng Zhang equally argues that the "exciting development of the CRISPR/Cas9 technology for genome editing also raises certain societal challenges and brings a sense of uncertainty and fear of catastrophic misuse" (Zhang 2015). Considering these concerns, the communication of CRISPR Cas-9 was thereby previously thought of as involving elements of technophobia, skepticism, and controversy toward the technology (Metag and Marcinkowski 2014; León and Bourk 2018a; Cribbs and Perera 2017; ZHANG et al. 2006; Zhang 2015; Brokowski and Adli 2019). In contrast, the results presented in this thesis showed that positive perspectives toward CRISPR Cas-9 technology are often presented on YouTube (see pages 66-72). However, as discussed in Chapter 4 (see page 84), a weak but recognizable negative view about the ethical considerations of CRISPR technology was uncovered. This is particularly important as to the role of phobias over CRISPR Cas-9 applications and/or the challenges the field could face if these concerns are not openly addressed (M. C. Nisbet and Mooney 2007; Matthew C. Nisbet, Brossard, and Kroepsch 2003; Metag and Marcinkowski 2014). Additional themes related to (for example) the explanatory aspects of storytelling in the analyzed videos are discussed on pages 79-84.

Finally, for RQ2, I note the insights gained from pushing our analysis one layer further and separating the native and immigrant content in the data set. For example, by comparing these results, it became clear that the number of opinionated (positive or negative) content in native videos is equal or higher to that found in immigrant content, among other results (see pages 48-52, 72). These results again show that even in the native class, views about the technology itself are largely positive, except when ethical considerations are focused on, which tilt the videos toward a negative viewpoint. This finding indicates that during the chosen time interval, and for the keyword CRISPR Cas-9, when native contents are not neutral, they tend to present the most negative portraits of CRISPR Cas-9. This reaffirmed an argument that separating native and immigrant content during analysis is helpful to show that native content is more opinionated. This separation between native and immigrant videos helps a researcher understand the different storytelling approaches to scientific content on YouTube. Native videos are produced to be published on the YouTube platform and for the audiences interested in online video content. They are free from the limitations of other platforms, and subsequently, they can shape their own voices and style and help create a unique culture on YouTube that is worthy of additional study and discussion.

What models of science journalism have been used in the selected videos, and what (if any) new models emerge from analyzing these videos? (RQ3)

The final research question gave the exciting result that despite the video format and the novelty of YouTube as a platform for science journalism (León and Bourk 2018a; Busse 2007; Hartley 2008; Allchin 2010; D'Souza et al. 2020; Djerf-Pierre, Lindgren, and Budinski 2019; Peer and Ksiazek 2011; Welbourne and Grant 2016; C. E. Basch et al. 2021b), no new models of science journalism were detected. Instead, the science literacy model (Secko, Amend, and Friday 2013; Secko 2007), and a potential sub-model, dominated the videos analyzed (see Chapter 4). This was somewhat surprising due to YouTube's focus on entertainment elements (as both method and tool to keep audiences engaged) and the combination of science stories with elements of pop-culture and science fiction, suggesting that these trends have yet to significantly impact the use of the science literacy model. The potential sub-model detected does point to the lack of citation for reliable and scientific sources as modifying approaches to linear transmission in this model (cf. Secko, Amend, and Friday 2013). However, this is noted with caution since the data set was not big enough to let me dive more profound into those kinds of videos. Finally, while the data analyzed did not point to any new model, there are hints towards new roles for infotainment and comedy in science journalism videos. We need more detailed research on a more significant number of videos to explore the possibility.

Strengths and limitations

The main limitation of this project was gathering a complete and accurate data set. As discussed in chapter 2, limitations enforced by YouTube and its algorithm also limit the accuracy of data gathering. To address this issue, two other search methods based on (i) the YouTube API and (ii) a Python program and JavaScript scrapping code were employed. This ultimately can be argued as one of the strengths of the thesis in that a comprehensive data search was completed while showing the simple searches are problematic. Still, the search results are unlikely to contain all existing videos. In addition, creators – especially with native content – are using titles and descriptions as a tool to grab more audiences. Some videos mentioned a keyword in their description, while the video has nothing to do with that keyword or omits a relevant keyword, adding noise to the data searches.

A second limitation for any analysis of videos on YouTube is the possibility of editing by creators. There could be some differences for some videos between the time of data query and when the analysis was started. Creators can go back and edit their title, description or delete the video. They also may change the time of uploading/publishing videos. To avoid this kind of discrepancy, one suggestion for future analysis is that data gathering and data analysis occur in parallel, something not possible here due to only one researcher being involved.

The third limitation of this research is that only a subset of the 743 videos could be analyzed in detail. The use of only three data spikes for analysis means the results of this project cannot be generalized to all CRISPR Cas-9 contents on YouTube or science videos on other topics.

Nevertheless, a significant strength of this thesis is the comprehensive data searches that were undertaken in combination with the first-ever QCA on CRISPR Cas-9 videos from YouTube. This original work sets the stage for more detailed research in the future by revealing qualitative thematic codes and a quantitative baseline for video metrics. Furthermore, distinguishing between native and immigrant content can be considered one strength of this project, as it allowed the comparison of these two sets of data to explore their differences. Overall, these strengths enabled a better understanding of the overall attitudes present in the videos.

Future directions

This project provides some clear directions for future research. One of the most important challenges is finding a way to gather complete and accurate data. Any research that solely uses commercial search engines such as YouTube search can collect only a limited result, possibly under the influence of previous searches and behaviours of that user or IP. More attention is needed towards using multi-method approaches when searching and studying YouTube.

This project also hinted towards different approaches between native and immigrant content on YouTube. These findings generate new questions:

- Are there any similarities between native content for different subjects?
- What is driving these differences on YouTube?
- Are these native contents moving towards new approaches?

I observed some hints towards new approaches to science journalism that blends science fiction as a framework for discussing, framing, and analyzing science. This observation may be worth future studies on creating or fighting against technophobia. This issue is timely in the case of CRISPR Cas-9. In recent years a few Movies and TV series (Rampage 2018, Biohackers-Netflix 2020, designated survivor Season 3 – Netflix, 2019) focused on the issue of CRISPR Cas-9. It is anticipated that more science fiction stories on different platforms may focus on this technology, which could create more space on YouTube for discussions about the CRISPR Cas-9 technology in science fiction.

Final Conclusion

One hypothesis when this project started was that there was a possibility that videos on YouTube about CRISPR Cas-9 would tend to create or empower technophobia. However, this thesis showed that most contents on YouTube tried to be positive or balanced/neutral, with only a weak tendency in native content toward negative representations of CRISPR Cas-9. Indeed, the analyzed videos tended to use a classical science literacy model of science journalism, with only a hint towards emerging sub-models that employ infotainment or comedy (for example). Yet, the number of YouTube videos on CRISPR Cas-9 from 2012-2019 was significant at 743 and comparable to other new technologies topics. It is hoped that this data set will prove useful for additional studies that examine how YouTube is searching to find its voice and place in science journalism. Any future work on how YouTube affects the communication of science should continue to acknowledge the existence of digital divides in society. The potential audiences on YouTube are not representing all members of society. CRISPR Cas-9 is a powerful new technology with a wide range of potential applications and concerns, one that needs to be explained, discussed, and debated widely. YouTube plays a significant role in this discussion, and this analysis gives one glimpse of what YouTube content creators have recorded so far.

BIBLIOGRAPHY

"25 YouTube Statistics That May Surprise You: 2021 Edition." 2021. *Social Media Marketing & Management Dashboard* (blog). February 3, 2021. https://blog.hootsuite.com/youtube-stats-marketers/.

"55 Video Marketing Statistics For 2020." 2019. Biteable. February 12, 2019. https://biteable.com/blog/video-marketing-statistics/.

Above The Noise. 2019. *Gene Editing & CRISPR: How Far Should We Go?* https://www.youtube.com/watch?v=wnlJ6dRfPFg.

Ahteensuu, Marko. 2012. "Assumptions of the Deficit Model Type of Thinking: Ignorance, Attitudes, and Science Communication in the Debate on Genetic Engineering in Agriculture." *Journal of Agricultural and Environmental Ethics* 25 (3): 295–313.

"Alexa - Top Sites." 2020. Alexa. 2020. https://www.alexa.com/topsites.

Allan, Stuart. 2011. "Introduction: Science Journalism in a Digital Age." *Journalism* 12 (7): 771–77.

Allan, Stuart, and Einar Thorsen. 2009. *Citizen Journalism: Global Perspectives*. Vol. 1. Peter Lang.

Allchin, Douglas. 2010. "The Nature of Science: From Test Tubes to Youtube." *The American Biology Teacher* 72 (9): 590+.

Allgaier, Joachim, Sharon Dunwoody, Dominique Brossard, Yin-Yueh Lo, and Hans Peter Peters. 2013. "Journalism and Social Media as Means of Observing the Contexts of Science." *BioScience* 63 (4): 284–87. https://doi.org/10.1525/bio.2013.63.4.8.

Amend, Elyse, Gabriela Capurro, and David M. Secko. 2014. "Grasping Scientific News." 8 (6): 789–808.

Angler, Martin W. 2017. *Science Journalism: An Introduction*. Routledge.

Antony, Mary Grace, and Ryan J. Thomas. 2010. "'This Is Citizen Journalism at Its Finest': YouTube and the Public Sphere in the Oscar Grant Shooting Incident." *New Media & Society* 12 (8): 1280–96.

"AP News." 2018. A Chinese Researcher Claims That He Helped Make the World's First Genetically Edited Babies. November 26, 2018. https://apnews.com/4997bb7aa36c45449b488e19ac83e86d.

Atton, Chris. 2009. "Alternative and Citizen Journalism." *The Handbook of Journalism Studies*, 265–78.

Baltimore, David, Paul Berg, Michael Botchan, Dana Carroll, R. Alta Charo, George Church, Jacob E. Corn, George Q. Daley, Jennifer A. Doudna, and Marsha Fenner. 2015. "A Prudent Path Forward for Genomic Engineering and Germline Gene Modification." *Science* 348 (6230): 36–38.

Bärtl, Mathias. 2018. "YouTube Channels, Uploads and Views: A Statistical Analysis of the Past 10 Years." *Convergence* 24 (1): 16–32. https://doi.org/10.1177/1354856517736979.

Bartlett, Frederic Charles, and Frederic C. Bartlett. 1995. *Remembering: A Study in Experimental and Social Psychology*. Cambridge University Press.

Basch, Charles E., Corey H. Basch, Grace C. Hillyer, Zoe C. Meleo-Erwin, and Emily A. Zagnit. 2021a. "YouTube Videos and Informed Decision-Making about COVID-19 Vaccination: Successive Sampling Study." *JMIR Public Health and Surveillance* 7 (5): e28352.

———. 2021b. "YouTube Videos and Informed Decision-Making about COVID-19 Vaccination: Successive Sampling Study." *JMIR Public Health and Surveillance* 7 (5): e28352.

Basch, Corey H., Charles E. Basch, Kelly V. Ruggles, and Rodney Hammond. 2015. "Coverage of the Ebola Virus Disease Epidemic on YouTube." *Disaster Medicine and Public Health Preparedness* 9 (5): 531–35. https://doi.org/10.1017/dmp.2015.77.

Basch, Corey H., Grace C. Hillyer, Emily A. Zagnit, and Charles E. Basch. 2020. "YouTube Coverage of COVID-19 Vaccine Development: Implications for Awareness and Uptake." *Human Vaccines & Immunotherapeutics*, 1–4.

Baumann, Martina. 2016. "CRISPR/Cas9 Genome Editing–New and Old Ethical Issues Arising from a Revolutionary Technology." *NanoEthics* 10 (2): 139–59.

Bennett, Gaymon, Nils Gilman, Anthony Stavrianakis, and Paul Rabinow. 2009. "From Synthetic Biology to Biohacking: Are We Prepared?" *Nature Biotechnology* 27 (12): 1109–11.

Biosciences, Taconic. 2018. "Deflating the CRISPR/Cas9 Off-Target Controversy." 2018. https://www.taconic.com/taconic-insights/gems-design/off-target-mutations-crispr-animal-models.html.

Bitterman, M. E. 2006. "Classical Conditioning since Pavlov." *Review of General Psychology* 10 (4): 365–76.

Black, Edwin. 2012. *War against the Weak: Eugenics and America's Campaign to Create a Master Race*. Dialog Press.

Bloomberg.Com. 2019. "Global CRISPR and CAS Gene Market to Surpass US$ 7,603.8 Million by 2026," May 6, 2019. https://www.bloomberg.com/press-releases/2019-05-06/global-crispr-and-cas-gene-market-to-surpass-us-7-603-8-million-by-2026.

Blum, Deborah, Mary Knudson, Robin Marantz Henig, and MyiLibrary. 2006. *A Field Guide for Science Writers*. New York: Oxford University Press.

Bozeman Science. 2016. *What Is CRISPR?* https://www.youtube.com/watch?v=MnYppmstxIs.

Brand, Ralf, and Jan Fischer. 2013. "Overcoming the Technophilia/Technophobia Split in Environmental Discourse." *Environmental Politics* 22 (2): 235–54.

Brokowski, Carolyn, and Mazhar Adli. 2019. “CRISPR Ethics: Moral Considerations for Applications of a Powerful Tool.” *Journal of Molecular Biology* 431 (1): 88–101.

Brosnan, M.J. 1999. “Modeling Technophobia: A Case for Word Processing” 15 (2): 105–21.

Brossard, Dominique, and Dietram A. Scheufele. 2013. “Science, New Media, and the Public.” *Science* 339 (6115): 40–41. https://doi.org/10.1126/science.1232329.

Bruns, Axel. 2018. *Gatewatching and News Curation: Journalism, Social Media, and the Public Sphere (Digital Formations, Volume 113)*. Peter Lang Publishing.

Bubela, Tania. 2006. “Science Communication in Transition: Genomics Hype, Public Engagement, Education and Commercialization Pressures.” *Clinical Genetics* 70 (5): 445–50.

Busse, Matthew. 2007. *Online Video Is Transforming and Broadening Perceptions about Science*. Elsevier.

Campbell, Margaret C., and Kevin Lane Keller. 2003. “Brand Familiarity and Advertising Repetition Effects.” *Journal of Consumer Research* 30 (2): 292–304.

Campion, Michael G. 1989. “Technophilia and Technophobia.” *Australasian Journal of Educational Technology* 5 (1).

Carroll, Dana. 2017. “Genome Editing: Past, Present, and Future.” *The Yale Journal of Biology and Medicine* 90 (4): 653–59.

Cassidy, J. T., E. Fitzgerald, E. S. Cassidy, M. Cleary, D. P. Byrne, B. M. Devitt, and J. F. Baker. 2018. “YouTube Provides Poor Information Regarding Anterior Cruciate Ligament Injury and Reconstruction.” *Knee Surgery, Sports Traumatology, Arthroscopy* 26 (3): 840–45. https://doi.org/10.1007/s00167-017-4514-x.

Caulfield, Timothy. 2018. “Spinning the Genome: Why Science Hype Matters.” *Perspectives in Biology and Medicine* 61 (4): 560–71.

Caulfield, Timothy, and Celeste Condit. 2012. “Science and the Sources of Hype.” *Public Health Genomics* 15 (3–4): 209–17.

"Cisco." 2016. Cisco. 2016. https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html.

"Cisco Annual Internet Report - Cisco Annual Internet Report (2018–2023) White Paper." n.d. Cisco. Accessed January 17, 2021. https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html.

Clement, J. 2019. "Online Video Usage in the United States - Statistics & Facts." www.statista.com. https://www.statista.com/topics/1137/online-video/.

Clixoom Science & Fiction. 2018. *CRISPR/Cas9 - Will Genetic Engineering Revolutionize Our World and Us Humans?* https://www.youtube.com/watch?v=6wLdwLofMyo.

Condit, Celeste M. 2010. "Public Attitudes and Beliefs about Genetics." *Annual Review of Genomics and Human Genetics* 11: 339–59.

Covington, Paul, Jay Adams, and Emre Sargin. 2016. "Deep Neural Networks for Youtube Recommendations." In *Proceedings of the 10th ACM Conference on Recommender Systems*, 191–98.

Cribbs, Adam P., and Sumeth MW Perera. 2017. "Focus: Genome Editing: Science and Bioethics of CRISPR-Cas9 Gene Editing: An Analysis towards Separating Facts and Fiction." *The Yale Journal of Biology and Medicine* 90 (4): 625.

CRISPy kReme. 2019. *CRISPR-Cas9 Explained!* https://www.youtube.com/watch?v=WbUrkN_tKQE.

Cullen, Rowena. 2001. "Addressing the Digital Divide." *Online Information Review*.

Cyranoski, David. 2015. "Ethics of Embryo Editing Divides Scientists." *Nature News* 519 (7543): 272.

———. 2016. "Chinese Scientists to Pioneer First Human CRISPR Trial." *Nature News* 535 (7613): 476.

———. 2018. "CRISPR-Baby Scientist Fails to Satisfy Critics." *Nature* 564 (7734): 13–15.

Cyranoski, David, and Heidi Ledford. 2018. “Genome-Edited Baby Claim Provokes International Outcry.” *Nature* 563 (7733): 607–8.

Daniel Zunino. 2019. *0400 Outreach Project - CRISPR-Cas9 Technology*. https://www.youtube.com/watch?v=CKJgmwY2qms.

Dayan, Fazli. 2020. “Ethico-Legal Aspects of CRISPR Cas-9 Genome Editing: A Balanced Approach.” *Bangladesh Journal of Medical Science* 19 (1): 11–16.

Delfanti, Alessandro. 2012. *Tweaking Genes in Your Garage: Biohacking between Activism and Entrepreneurship*. Innsbruck University Press.

Dennett, Daniel C. 2015. *Elbow Room: The Varieties of Free Will Worth Wanting.* MIT Press.

Diakopoulos, Nicholas, Sergio Goldenberg, and Irfan Essa. 2009. “Videolyzer: Quality Analysis of Online Informational Video for Bloggers and Journalists.” In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 799–808. ACM.

Dickenson, Donna, and Marcy Darnovsky. 2019a. “Did a Permissive Scientific Culture Encourage the ‘CRISPR Babies’ Experiment?” *Nature Biotechnology* 37 (4): 355.

———. 2019b. “Did a Permissive Scientific Culture Encourage the ‘CRISPR Babies’ Experiment?” *Nature Biotechnology* 37 (4): 355–57.

“Digital 2019: Global Digital Overview.” 2019. DataReportal – Global Digital Insights. 2019. https://datareportal.com/reports/digital-2019-global-digital-overview.

Dijk, Jan A.G.M. van. 2006. “Digital Divide Research, Achievements and Shortcomings.” *Poetics* 34 (4–5): 221–35. https://doi.org/10.1016/j.poetic.2006.05.004.

Dijk, Jan van, and Kenneth Hacker. 2003. “The Digital Divide as a Complex and Dynamic Phenomenon.” *The Information Society* 19 (4): 315–26. https://doi.org/10.1080/01972240309487.

Djerf-Pierre, Monika, Mia Lindgren, and Mikayla Alexis Budinski. 2019. “The Role of Journalism on YouTube: Audience Engagement with ‘Superbug’ Reporting.” *Media and Communication* 7 (1): 235–47. https://doi.org/10.17645/mac.v7i1.1758.

Dominguez, Antonia A., Wendell A. Lim, and Lei S. Qi. 2016. “Beyond Editing: Repurposing CRISPR–Cas9 for Precision Genome Regulation and Interrogation.” *Nature Reviews Molecular Cell Biology* 17 (1): 5.

Doudna, Jennifer A., and Emmanuelle Charpentier. 2014. “The New Frontier of Genome Engineering with CRISPR-Cas9.” *Science* 346 (6213): 1258096.

Doudna, Jennifer A., and Samuel H. Sternberg. 2017. *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution*. Houghton Mifflin Harcourt.

D’Souza, Ryan S., Shawn D’Souza, Natalie Strand, Alexandra Anderson, Matthew NP Vogt, and Oludare Olatoye. 2020. “YouTube as a Source of Medical Information on the Novel Coronavirus 2019 Disease (COVID-19) Pandemic.” *Global Public Health* 15 (7): 935–42.

Dunwoody, Sharon. 2014a. *Science Journalism*. Routledge New York.

———. 2014b. “Science Journalism: Prospects in the Digital Age.” In *Routledge Handbook of Public Communication of Science and Technology*, 43–55. Routledge.

Eiteljorg II, Harrison. 2014. “Technophobia and Technophilia.” *CSA Newsletter* 26 (3): 1–3.

Ellahi, Abida. 2017. “Fear of Using Technology: Investigating Impact of Using Social Networking Sites in Business Education.” In *2017 IEEE 15th Student Conference on Research and Development (SCOReD)*, 234–37. IEEE.

“Engagement Analysis on YouTube, Instagram, Twitter, and Facebook.” 2018. Pex. February 21, 2018. https://pex.com/blog/analysis-of-user-engagement-videos-worlds-biggest-social-sites/.

Evans, John H. 2002. *Playing God?: Human Genetic Engineering and the Rationalization of Public Bioethical Debate*. University of Chicago Press.

Everhart, Jerry. 2009. “YouTube in the Science Classroom.” *Science and Children* 46 (9): 32–35.

Fischer, Jonas, Jeroen Geurts, Victor Valderrabano, and Thomas Hügle. 2013. "Educational Quality of YouTube Videos on Knee Arthrocentesis:" *Journal of Clinical Rheumatology* 19 (7): 373–76. https://doi.org/10.1097/RHU.0b013e3182a69fb2.

Fletcher, John C. 1990. "Evolution of Ethical Debate about Human Gene Therapy." *Human Gene Therapy* 1 (1): 55–68.

Flores, Glenn. 2002. "Mad Scientists, Compassionate Healers, and Greedy Egotists: The Portrayal of Physicians in the Movies." *Journal of the National Medical Association* 94 (7): 635.

Flotte, Terence R. 2015. "Therapeutic Germ Line Alteration: Has CRISPR/Cas9 Technology Forced the Question?" *Human Gene Therapy* 26 (5): 245–46. https://doi.org/10.1089/hum.2015.28999.tfl.

Freethink. n.d. *DIY Biohacking: Do(n't) Try This at Home*. Accessed August 8, 2021. https://www.youtube.com/watch?v=fV-Edkh1iqE.

García-Avilés, José Alberto, and Alicia de Lara. 2018. "An Overview of Science Online Video: Designing a Classification of Formats." In *Communicating Science and Technology Through Online Video*, 15–27. Routledge.

Ghasemi, Nasrin, and Pouria Nazemi. (2020) 2020. *GhassemiN/YouTube-VIdeo-Data*. Python. https://github.com/ghassemiN/YouTube-VIdeo-Data.

Gonzalez-Avila, Luis Uriel, Juan Manuel Vega-López, Leda Ivonne Pelcastre-Rodriguez, Omar Alejandro Cabrero-Martínez, Cecilia Hernández-Cortez, and Graciela Castro-Escarpulli. 2021. "The Challenge of CRISPR-Cas Toward Bioethics." *Frontiers in Microbiology* 12: 1344.

Goode, Luke. 2009. "Social News, Citizen Journalism and Democracy." *New Media & Society* 11 (8): 1287–1305.

"Google Trends." n.d. Google Trends. Accessed February 23, 2021. https://trends.google.com/trends/?geo=US.

Hall, Stuart. 2001. “Encoding/Decoding.” *Media and Cultural Studies: Keyworks*, 166–76.

Haran, Joan, and Kate O’Riordan. 2018. “Public Knowledge-Making and the Media: Genes, Genetics, Cloning and Mass Observation.” *European Journal of Cultural Studies* 21 (6): 687–706.

Hargreaves, Ian, Justin Lewis, and Tammy Speers. 2003. “Towards a Better Map: Science, the Public and the Media.” Swindon: Economic and Social Research Council.

Hartley, John. 2008. “YouTube, Digital Literacy and the Growth of Knowledge.” In *Proceedings of the Media, Communication and Humanity 2008 Conference: Media@ Lse Fifth Anniversary Conference*, 1–17. LSE Department of Media and Communications.

Haynes, Roslynn D. 2016. “Whatever Happened to the ‘Mad, Bad’Scientist? Overturning the Stereotype.” *Public Understanding of Science* 25 (1): 31–44.

Hoban, Thomas, Eric Woodrum, and Ronald Czaja. 1992. “Public Opposition to Genetic Engineering 1.” *Rural Sociology* 57 (4): 476–93.

“How Long Should a Youtube Video Be in 2021 (with Examples).” n.d. Accessed July 26, 2021. https://www.youtube.com/watch?v=4z-T1i76yac.

“Huge Difference Total Result in Sum of Split Date [145687648] - Visible to Public - Issue Tracker.” 2019. December 5, 2019. https://issuetracker.google.com/issues/145687648.

Isaacson, Walter. 2021. *The Code Breaker: Jennifer Doudna, Gene Editing, and the Future of the Human Race*. New York: Simon & Schuster.

Jaffar, Akram Abood. 2012. “YouTube: An Emerging Tool in Anatomy Education.” *Anatomical Sciences Education* 5 (3): 158–64. https://doi.org/10.1002/ase.1268.

Jayaraman, Killugudi, and Hepeng Jia. 2012. *GM Phobia Spreads in South Asia*. Nature Publishing Group.

Jinek, Martin, Krzysztof Chylinski, Ines Fonfara, Michael Hauer, Jennifer A. Doudna, and Emmanuelle Charpentier. 2012. “A Programmable Dual-RNA–Guided DNA

Endonuclease in Adaptive Bacterial Immunity.” *Science* 337 (6096): 816. https://doi.org/10.1126/science.1225829.

Jordan Stoddart. 2019. *CRISPR/Cas9 Hitman Sockpuppet*. https://www.youtube.com/watch?v=4KwfMpLtZxM.

Keelan, Jennifer, Vera Pavri-Garcia, George Tomlinson, and Kumanan Wilson. 2007. “YouTube as a Source of Information on Immunization: A Content Analysis.” *Jama* 298 (21): 2482–84.

Keib, Kate, Camila Espina, Yen-I. Lee, Bartosz W. Wojdynski, Dongwon Choi, and Hyejin Bang. 2018. “Picture This: The Influence of Emotionally Valenced Images, on Attention, Selection, and Sharing of Social Media News.” *Media Psychology* 21 (2): 202–21.

Kitzinger, Jenny. 2008. “Questioning Hype, Rescuing Hope? The Hwang Stem Cell Scandal and the Reassertion of Hopeful Horizons.” *Science as Culture* 17 (4): 417–34.

Klopf, A. Harry. 1988. “A Neuronal Model of Classical Conditioning.” *Psychobiology* 16 (2): 85–125.

Knight Science Journalism Program at MIT. 2020. *KSJ Science Editting Handbook*. Cambridge, Mass: Massachusetts Institute of Technology. https://ksjhandbook.org.

Koto, Irwan. 2020. “Teaching and Learning Science Using YouTube Videos and Discovery Learning in Primary School.” In *Elementary School Forum (Mimbar Sekolah Dasar)*, 7:106–18. ERIC.

Kovach, Bill, and Tom Rosenstiel. 2014. *The Elements of Journalism: What Newspeople Should Know and the Public Should Expect*. Three Rivers Press (CA).

Krippendorff, Klaus. 2004. “Reliability in Content Analysis: Some Common Misconceptions and Recommendations.” *Human Communication Research* 30 (3): 411–33.

Lander, Eric S. 2016. “The Heroes of CRISPR.” *Cell* 164 (1–2): 18–28. https://doi.org/10.1016/j.cell.2015.12.041.

Lang, Annie, John Newhagen, and Byron Reeves. 1996. “Negative Video as Structure: Emotion, Attention, Capacity, and Memory.” *Journal of Broadcasting & Electronic Media* 40 (4): 460–77.

Lanphier, Edward, Fyodor Urnov, Sarah Ehlen Haecker, Michael Werner, and Joanna Smolenski. 2015. “Don’t Edit the Human Germ Line.” *Nature News* 519 (7544): 410.

Laslo, Esther, Ayelet Baram-Tsabari, and Bruce V. Lewenstein. 2011. “A Growth Medium for the Message: Online Science Journalism Affordances for Exploring Public Discourse of Science and Ethics.” *Journalism* 12 (7): 847–70.

Le Page, M. 2018. “CRISPR Babies: More Details on the Experiment That Shocked the World.” *New Scientist* 28.

Ledford, Heidi. 2015. “Biohackers Gear up for Genome Editing.” *Nature News* 524 (7566): 398.

Ledford, Heidi, and Ewen Callaway. 2020. “Pioneers of Revolutionary CRISPR Gene Editing Win Chemistry Nobel.” *Nature* 586 (7829): 346–47. https://doi.org/10.1038/d41586-020-02765-9.

León, Bienvenido, and Michael Bourk. 2018a. *Communicating Science and Technology through Online Video: Researching a New Media Phenomenon*. Routledge.

———. 2018b. “Investigating Science-Related Online Video.” In *Communicating Science and Technology Through Online Video*, 1–14. Routledge.

Lesen, Amy E., Ama Rogan, and Michael J. Blum. 2016. “Science Communication Through Art: Objectives, Challenges, and Outcomes.” *Trends in Ecology & Evolution* 31 (9): 657–60. https://doi.org/10.1016/j.tree.2016.06.004.

Li, Heidi Oi-Yee, Adrian Bailey, David Huynh, and James Chan. 2020. “YouTube as a Source of Information on COVID-19: A Pandemic of Misinformation?” *BMJ Global Health* 5 (5): e002604.

Lombardo, Paul A. 2011. *A Century of Eugenics in America: From the Indiana Experiment to the Human Genome Era*. Indiana University Press.

Ma, Yuanwu, Lianfeng Zhang, and Chuan Qin. 2019. "The First Genetically Gene-edited Babies: It's 'Irresponsible and Too Early.'" *Animal Models and Experimental Medicine* 2 (1): 1–4.

Madathil, Kapil Chalil, A Joy Rivera-Rodriguez, Joel S Greenstein, and Anand K Gramopadhye. 2014. "Healthcare Information on YouTube: A Systematic Review." *Health Informatics Journal* 21 (3): 173–94. https://doi.org/10.1177/1460458213512220.

Marc Grassin. 2011. "Technophilia and Technophobia: Is a Critique Possible?" *Revue d'éthique et de Théologie Morale*, Varia, , no. 3: 75. https://doi.org/10.3917/retm.265.0075.

Marchal, Nahema, Hubert Au, and Philip N. Howard. 2020. "Coronavirus News and Information on YouTube." *Health* 1 (1): 0–3.

Marshall, Catherine, and Gretchen B. Rossman. 2014. *Designing Qualitative Research*. Sage publications.

Mayoral, Pedro, Ro Tello, José Gonzalez, Pedro Mayoral, Ro Tello, and José Gonzalez. n.d. *YouTube Based Learning*.

McAdam, Janice Emens. 1990. "The Persistent Stereotype: Children's Images of Scientists." *Physics Education* 25 (2): 102.

McIntyre, Karen Elizabeth, and Rhonda Gibson. 2016. "Positive News Makes Readers Feel Good: A 'Silver-Lining' Approach to Negative News Can Attract Audiences." *Southern Communication Journal* 81 (5): 304–15.

Metag, Julia, and Frank Marcinkowski. 2014. "Technophobia towards Emerging Technologies? A Comparative Analysis of the Media Coverage of Nanotechnology in Austria, Switzerland and Germany." *Journalism* 15 (4): 463–81. https://doi.org/10.1177/1464884913491045.

Meyer, Morgan, and Frédéric Vergnaud. 2020. "The Rise of Biohacking: Tracing the Emergence and Evolution of DIY Biology through Online Discussions." *Technological Forecasting and Social Change* 160: 120206.

Mitchell, Andrew A., and Jerry C. Olson. 1977. "Cognitive Effects of Advertising Repetition." *ACR North American Advances*.

Morcillo, Jesús Muñoz, Klemens Czurda, and Caroline Y. Trotha. 2015. "Typologies of the Popular Science Web Video." *ArXiv Preprint ArXiv:1506.06149*.

National Academies of Sciences, Engineering, Division on Engineering and Physical Sciences, Health and Medicine Division, Policy and Global Affairs, Division on Earth and Life Studies, Forum on Cyber Resilience, Board on Health Sciences Policy, et al. 2020. *AREAS OF LEADERSHIP IN THE GLOBAL ECONOMY*. *Safeguarding the Bioeconomy*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK556430/.

National Institutes of Health (NIH). 2019. *Introduction to Genome Editing Using CRISPR Cas9 HD*. https://www.youtube.com/watch?v=g7bkE1krgFM.

National Science Board. 2018. "Science and Engineering Indicators 2018." Alexandria, VA: National Science Foundation. https://www.nsf.gov/statistics/indicators/.

nature video. 2017. *CRISPR: Gene Editing and Beyond*. https://www.youtube.com/watch?v=4YKFw2KZA5o.

Nelson-Field, Karen, Erica Riebe, and Kellie Newstead. 2013. "The Emotions That Drive Viral Video." *Australasian Marketing Journal* 21 (4): 205–11.

Nerlich, Brigitte, Robert Dingwall, and David D. Clarke. 2002. "The Book of Life: How the Completion of the Human Genome Project Was Revealed to the Public." *Health:* 6 (4): 445–69.

Newhagen, John E. 1998. “TV News Images That Induce Anger, Fear, and Disgust: Effects on Approach-avoidance and Memory.” *Journal of Broadcasting & Electronic Media* 42 (2): 265–76.

Nisbet, M. C., and C. Mooney. 2007. “SCIENCE AND SOCIETY: Framing Science.” *Science* 316 (5821): 56–56. https://doi.org/10.1126/science.1142030.

Nisbet, Matthew C., Dominique Brossard, and Adrianne Kroepsch. 2003. “Framing Science: The Stem Cell Controversy in an Age of Press/Politics.” *Harvard International Journal of Press/Politics* 8 (2): 36–70. https://doi.org/10.1177/1081180X02251047.

Nisbet, Matthew C., and Dietram A. Scheufele. 2009. “What’s next for Science Communication? Promising Directions and Lingering Distractions.” *American Journal of Botany* 96 (10): 1767–78. https://doi.org/10.3732/ajb.0900041.

Normile, Dennis. 2018. *Shock Greets Claim of CRISPR-Edited Babies*. American Association for the Advancement of Science.

Osiceanu, Maria-Elena. 2015. “Psychological Implications of Modern Technologies: ‘Technofobia’ versus ‘Technophilia.’” *Procedia - Social and Behavioral Sciences* 180 (May): 1137–44.

Paolillo, John C. 2008. “Structure and Network in the YouTube Core.” In *Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008)*, 156–156. IEEE.

Park, Minsu, Mor Naaman, and Jonah Berger. 2016. “A Data-Driven Study of View Duration on Youtube.” In *Proceedings of the International AAAI Conference on Web and Social Media*. Vol. 10.

Pattier, Daniel. 2021. “Science on Youtube: Successful Edutubers.” *TECHNO REVIEW. International Technology, Science and Society Review* 10 (1): 1–15.

Paulussen, Steve, and Raymond A. Harder. 2014. “Social Media References in Newspapers: Facebook, Twitter and YouTube as Sources in Newspaper Journalism.” *Journalism Practice* 8 (5): 542–51. https://doi.org/10.1080/17512786.2014.894327.

Peer, Limor, and Thomas B. Ksiazek. 2011. “YouTube and the Challenge to Journalism: New Standards for News Videos Online.” *Journalism Studies* 12 (1): 45–63.

Plaza Reyes, Alvaro, and Fredrik Lanner. 2017. “Towards a CRISPR View of Early Human Development: Applications, Limitations and Ethical Concerns of Genome Editing in Human Embryos.” *Development* 144 (1): 3–7.

Poell, Thomas, and Erik Borra. 2012. “Twitter, YouTube, and Flickr as Platforms of Alternative Journalism: The Social Media Account of the 2010 Toronto G20 Protests.” *Journalism: Theory, Practice & Criticism* 13 (6): 695–713. https://doi.org/10.1177/1464884911431533.

Prokasy, WILLIAM F., and KAROL L. Kumpfer. 1973. “Classical Conditioning.” *Electrodermal Activity in Psychological Research*, 157–202.

Puri, Neha, Eric A. Coomes, Hourmazd Haghbayan, and Keith Gunaratne. 2020. “Social Media and Vaccine Hesitancy: New Updates for the Era of COVID-19 and Globalized Infectious Diseases.” *Human Vaccines & Immunotherapeutics*, 1–8.

Redman, Melody, Andrew King, Caroline Watson, and David King. 2016. “What Is CRISPR/Cas9?” *Archives of Disease in Childhood-Education and Practice* 101 (4): 213–15.

Reif, Anne, Tim Kneisel, Markus Schäfer, and Monika Taddicken. 2020. “Why Are Scientific Experts Perceived as Trustworthy? Emotional Assessment within TV and YouTube Videos.” *Media and Communication* 8 (1): 191–205.

“Report: 2019 State of Online Video.” 2020. *Tubular Labs* (blog). 2020. https://tubularlabs.com/research-guides/report-2019-state-of-online-video-part-1/.

Resnik, David B., and Daniel B. Vorhaus. 2006. “Genetic Modification and Genetic Determinism.” 1 (January): 9–19.

Richier, Cédric, Eitan Altman, Rachid Elazouzi, Tania Altman, Georges Linares, and Yonathan Portilla. 2014. “Modelling View-Count Dynamics in Youtube.” *ArXiv Preprint ArXiv:1404.2570*.

Rieder, Bernhard, Ariadna Matamoros-Fernández, and Òscar Coromina. 2018. “From Ranking Algorithms to ‘Ranking Cultures’ Investigating the Modulation of Visibility in YouTube Search Results.” *Convergence* 24 (1): 50–68.

Roberts, Celia, and Sarah Franklin. 2004. “Experiencing New Forms of Genetic Choice: Findings from an Ethnographic Study of Preimplantation Genetic Diagnosis.” *Human Fertility* 7 (4): 285–93.

Sand, Martin, Annelien L. Bredenoord, and Karin R. Jongsma. 2019. “After the Fact—the Case of CRISPR Babies.” *European Journal of Human Genetics* 27 (11): 1621–24.

Schleidgen, Sebastian, Hans-Georg Dederer, Susan Sgodda, Stefan Cravcisin, Luca Lüneburg, Tobias Cantz, and Thomas Heinemann. 2020. “Human Germline Editing in the Era of CRISPR-Cas: Risk and Uncertainty, Inter-Generational Responsibility, Therapeutic Legitimacy.” *BMC Medical Ethics* 21 (1): 1–12.

Schreier, Margrit. 2012. *Qualitative Content Analysis in Practice*. Sage publications.

SciToons. 2018. *Population Engineering | Gene Drive by CRISPR-CAS9*. https://www.youtube.com/watch?v=u2kBt9eiXtA.

“Search: List | YouTube Data API.” n.d. Google Developers. Accessed February 21, 2021. https://developers.google.com/youtube/v3/docs/search/list.

Secko, David M. 2007. “Learning to Swim with Salmon: Pilot Evaluation of Journalism as a Method to Create Information for Public Engagement.” *Health Law Review* 15 (3): 32.

Secko, David M., Elyse Amend, and Terrine Friday. 2013. “FOUR MODELS OF SCIENCE JOURNALISM.” *Journalism Practice* 7 (1): 62–80.

Secko, David M., Stephany Tlalka, Morgan Dunlop, Ami Kingdon, and Elyse Amend. 2011. “The Unfinished Science Story: Journalistâ€“audience Interactions from the Globe and Mailâ€™s Online Health and Science Sections.” *Journalism* 12 (7): 814–31.

Shapiro, Gilbert, and John Markoff. 1997. “A Matter of Definition.” *Text Analysis for the Social Sciences: Methods for Drawing Statistical Inferences from Texts and Transcripts* 1: 9–34.

Shapiro, Matthew A., and Han Woo Park. 2015. “More than Entertainment: YouTube and Public Responses to the Science of Global Warming and Climate Change.” *Social Science Information* 54 (1): 115–45. https://doi.org/10.1177/0539018414554730.

Sorensen, Jeffrey A., Max D. Pusz, and Scott E. Brietzke. 2014. “YouTube as an Information Source for Pediatric Adenotonsillectomy and Ear Tube Surgery.” *International Journal of Pediatric Otorhinolaryngology* 78 (1): 65–70. https://doi.org/10.1016/j.ijporl.2013.10.045.

“State of Online Video 2020 | Limelight Networks.” n.d. Accessed June 14, 2021. https://www.limelight.com/resources/market-research/state-of-online-video-2020/.

Steensen, Steen. 2011. “Online Journalism and the Promises of New Technology: A Critical Review and Look Ahead.” *Journalism Studies* 12 (3): 311–27.

Sturgis, Patrick, Helen Cooper, and Chris Fife-Schaw. 2005. “Attitudes to Biotechnology: Estimating the Opinions of a Better-Informed Public.” *New Genetics and Society* 24 (1): 31–56.

Syed-Abdul, Shabbir, Luis Fernandez-Luque, Wen-Shan Jian, Yu-Chuan Li, Steven Crain, Min-Huei Hsu, Yao-Chin Wang, Dorjsuren Khandregzen, Enkhzaya Chuluunbaatar, and Phung Anh Nguyen. 2013. “Misleading Health-Related Information Promoted through Video-Based Social Media: Anorexia on YouTube.” *Journal of Medical Internet Research* 15 (2): e30.

Taning, Clauvis Nji Tizi, Benigna Van Eynde, Na Yu, Sanyuan Ma, and Guy Smagghe. 2017. "CRISPR/Cas9 in Insects: Applications, Best Practices and Biosafety Concerns." *Journal of Insect Physiology* 98: 245–57.

Thaler, Andrew David, and David Shiffman. 2015. "Fish Tales: Combating Fake Science in Popular Media." *Ocean & Coastal Management* 115 (October): 88–91. https://doi.org/10.1016/j.ocecoaman.2015.04.005.

The Atlantic. n.d. *A "Grueling and Grotesque" Biohacking Experiment*. Accessed August 8, 2021. https://www.youtube.com/watch?v=uO6l6Bgo3-A.

Thompson, Paul B. 2020. "Gene Editing, Synthetic Biology and the Next Generation of Agrifood Biotechnology: Some Ethical Issues." In *Food and Agricultural Biotechnology in Ethical Perspective*, 343–74. Springer.

Toumey, Christopher P. 1992. "The Moral Character of Mad Scientists: A Cultural Critique of Science." *Science, Technology, & Human Values* 17 (4): 411–37.

Tudor, Andrew. 1989. "Monsters and Mad Scientists." *Genre* 1: 1931–60.

Van Dijck, José. 1999. "Cloning Humans, Cloning Literature: Genetics and the Imagination Deficit." *New Genetics and Society* 18 (1): 9–22.

"Video-on-Demand - Users in the World 2025." n.d. Statista. Accessed August 8, 2021. https://www.statista.com/forecasts/456771/video-on-demand-users-in-the-world-forecast.

"Videos | YouTube Data API." n.d. Google Developers. Accessed February 21, 2021. https://developers.google.com/youtube/v3/docs/videos.

Waltz, Emily. 2016. *CRISPR-Edited Crops Free to Enter Market, Skip Regulation*. Nature Publishing Group.

Warschauer, Mark. 2003. "Demystifying the Digital Divide." *Scientific American* 289 (2): 42–47.

Weil, M.M. (1), and L.D. (2) Rosen. 1995. “The Psychological Impact of Technology from a Global Perspective: A Study of Technological Sophistication and Technophobia in University Students from Twenty-Three Countries.” *Computers in Human Behavior* 11 (1): 95–133. https://doi.org/10.1016/0747-5632(94)00026-E.

Weisberg, Steven M., Daniel Badgio, and Anjan Chatterjee. 2017. “A CRISPR New World: Attitudes in the Public toward Innovations in Human Genetic Modification.” *Frontiers in Public Health* 5 (May): 117. https://doi.org/10.3389/fpubh.2017.00117.

Welbourne, Dustin J., and Will J. Grant. 2016. “Science Communication on YouTube: Factors That Affect Channel and Video Popularity.” *Public Understanding of Science* 25 (6): 706–18.

Wilcox, Christie, Bethany Brookshire, and Jason G. Goldman. 2016. *Science Blogging: The Essential Guide*. Yale University Press.

Wolter, Felix, and Holger Puchta. 2017. “Knocking out Consumer Concerns and Regulator’s Rules: Efficient Use of CRISPR/Cas Ribonucleoprotein Complexes for Genome Editing in Cereals.” *Genome Biology* 18 (1): 1–3.

Yetisen, Ali K. 2018. “Biohacking.” *Trends in Biotechnology* 36 (8): 744–47.

“Youtube.Com Competitive Analysis, Marketing Mix and Traffic - Alexa.” 2019. 2019. https://www.alexa.com/siteinfo/youtube.com.

Zettler, Patricia J., Christi J. Guerrini, and Jacob S. Sherkow. 2019. “Regulating Genetic Biohacking.” *Science* 365 (6448): 34–36.

Zhang, Feng. 2015. “CRISPR/Cas9: Prospects and Challenges.” *Human Gene Therapy* 26 (7): 409–10. https://doi.org/10.1089/hum.2015.29002.fzh.

ZHANG, Ling, Jie WANG, Ji-nan ZHANG, Jian-hua LU, and Jian-guo WU. 2006. “Technophobia about Genetically Modified Foods and Strategy [J].” *Journal of Dialectics of Nature* 6.

Zimmer, Carl. 2016. "2. From Page to Pixel: A Personal History of Science Blogging." In *Science Blogging*, 13–20. Yale University Press.

APPENDICES

Appendix I
General information about the final 52 selected videos

This table represents the general information for the final 52 videos. For the list of complete videos and more details on raw data, don't hesitate to get in touch with the author (pnazemi@gmail.com)

	video_id	Published At	view	like	dislike	comment	Time (New)	Language	Native / immigrant
1	PTtFLuLEdZU	2018-12-03 12:19:53	8590	134	5	75	0:01:55	English	Immigrant
2	2maTH4a_Oc0	2018-12-05 09:34:55	2874	0	0	20	0:11:46	English	Native
3	4AV6bYOAyyo	2018-12-06 07:58:17	10518	302	22	33	0:19:47	English	Native
4	6wLdwLofMyo	2018-12-07 17:00:01	944	57	0	7	0:08:17	English	Native
5	n2TP_8ntk-0	2018-12-07 21:24:17	127	1	0	1	0:25:44	English	Immigrant
6	w7FyOg9Fr7Y	2018-12-07 21:24:18	102	4	0	0	0:15:52	English	Immigrant
7	u2kBt9eiXtA	2018-12-10 16:51:03	2744	54	1	3	0:04:21	English	Native
8	Om-5zqB64Tw	2018-12-11 01:21:13	31	0	0	0	0:02:17	English	Immigrant
9	1viRt8jV-vk	2018-12-11 15:00:31	16814	513	7	46	0:05:14	English	native
10	CHwpFJNOE-Q	2018-12-12 12:44:18	523	18	0	2	0:05:40	English	Immigrant
11	iCrBkZgFaKc	2018-12-12 15:32:42	155	5	0	0	0:26:16	English	Immigrant
12	fN4cIztQRWA	2018-12-13 10:44:50	984	50	0	20	0:04:58	English	native
13	za12mBDR24Y	2018-12-14 03:56:37	3866	74	22	0	0:04:34	English	Native
14	NUbVrvvpNRk	2018-12-14 16:38:08	447	27	1	12	0:06:26	French	Native
15	wWxXYujAirc	2018-12-14 20:27:54	1374	20	0	0	0:01:13	English	Immigrant
16	R2nK2h8DeX0	2018-12-16 04:25:45	1072	30	1	3	0:04:15	English	Native
17	j9HO_zow0vI	2018-12-18 18:16:29	116	0	0	0	0:04:00	French	Immigrant
18	UMupGQfWFfo	2018-12-19 16:08:49	598	8	0	2	1:01:58	English	Immigrant
19	h24ljvybXww	2018-12-30 16:07:54	124	7	0	0	0:04:19	English	Immigrant
20	tWhB96GIxFs	2019-04-01 14:33:59	52	2	0	0	0:01:44	None	Native
21	E573S0Ezy6g	2019-04-03 15:45:00	3892	90	7	4	0:41:15	English	Immigrant
22	wnlJ6dRfPFg	2019-04-03 23:37:00	6825	318	5	91	0:06:08	English	native
23	7FvWXoRKPlo	2019-04-05 16:55:09	513	6	3	4	0:02:16	English	Native
24	2DY6phpUvwI	2019-04-09 14:03:50	80	12	0	28	0:35:22	English	Native
25	tx2CiShHgbA	2019-04-14 22:05:35	19	3	0	1	0:16:09	English	Immigrant
26	EwO0kCRVNv0	2019-04-15 13:03:48	2712	86	3	18	0:01:55	English	Immigrant
27	CKJgmwY2qms	2019-04-15 22:13:02	42	1	0	0	0:04:10	English	Native
28	4KwfMpLtZxM	2019-04-15 23:15:41	36	2	0	0	0:01:26	English	Native
29	3fiS4HK9h0k	2019-04-18 09:58:32	42	0	0	0	0:03:42	English	Native
30	g7bkE1krgFM	2019-04-19 18:59:27	18879	189	6	8	0:01:19	English	immigrant
31	6P2hYCuccG8	2019-04-19 19:47:57	174	5	0	1	0:26:07	English	immigrant

32	g-uUcqSebbA	2019-04-19 22:22:18	938	19	0	3	0:29:25	English	immigrant
33	KRlJzNj6k3E	2019-04-20 01:57:44	33738	774	40	215	0:48:20	English	Immigrant
34	gzsnZhPqpyc	2019-04-20 09:23:07	94	6	0	1	0:06:08	English	immigrant
35	fi93KpsV7-U	2019-04-22 03:35:43	47	0	0	0	0:05:37	English	Native
36	eCvYT-XvD3M	2019-04-22 17:42:50	799	26	0	5	0:24:36	English	immigrant
37	1TPTclCb5xE	2019-04-24 04:54:36	26	0	0	0	0:02:22	English	Native
38	YugJwo2tVHM	2019-04-29 22:57:59	59	1	0	0	0:02:21	English	Native
39	nZR6mevfyD4	2019-12-01 12:56:58	120921	0	0	0	0:40:47	French	immigrant
40	3rMENVXwHUg	2019-12-02 17:52:03	26	1	0	1	0:08:45	English	native
41	pqm5tg7XQ5A	2019-12-04 22:45:00	1290	53	0	18	0:14:46	English	Native
42	eHcRxYNIuN4	2019-12-05 05:00:10	11	0	0	0	0:05:01	English	Immigrant
43	WbUrkN_tKQE	2019-12-05 08:51:40	28	4	0	1	0:02:20	English	Native
44	jSSKk0bM0ZU	2019-12-08 18:46:25	10	0	0	0	0:13:44	English	Native
45	6mXB1W_u7es	2019-12-08 20:21:27	88	4	0	1	0:03:32	none	Native
46	gCVUVm-hS6o	2019-12-10 05:59:34	7	0	0	0	0:03:01	English	Native
47	DlLFhfi55U4	2019-12-11 09:08:08	5	0	0	0	0:07:40	English	Native
48	CMpWQqEVqZw	2019-12-14 09:59:07	16	1	0	0	0:07:40	English	Immigrant
49	f0M0Y3nytvM	2019-12-20 06:04:52	15	0	0	0	0:07:52	English	Native
50	EF45J2K3MLc	2019-12-22 11:41:57	10	0	0	0	0:04:29	French	Native
51	5CF0DdAifZI	2019-12-23 16:34:29	10	0	0	0	0:01:57	English	Immigrant
52	mOQy2yW6NqY	2019-12-24 09:39:43	51	2	0	1	0:01:06	English	Native

Appendix II
Code Book

The keywords and graphics which considered Negative or Positive include but are not limited to the following:

Keywords		Graphic	
Positive	Negative	Positive	Negative
Potential	Scare	Using bright colours	Poster of the movie with the technophobic theme
Future application	Weakness	Graphic of people with happy faces	Sad and dying animals
Powerful tools	No Clue	Happy and positive graphic of cells	Aggressive use of tools in graphic
Game-changing	Unplanned mutation		Using clips of technological disaster in movies
Revolutionary	Too much can go wrong		Showing humans as customized goods
Fast	Too Risky		Exaggerated image and caricature
Cheap	Not global census		Using genes or edited genes as aggression
Easy to use	Un predictable		Portraying tech as a murderer
Precise	Unintentional consequences		Using black and white and dark setting
Breakthrough	Rushed		Mad scientist
	Not there yet		
	Confused		
	Hybrid creatures		
	Eugenicist revival		
	Add diseases		
	Swearing		
	Mentioning sci-fi movies as a sample for future		
	Factory of clones		
	Evil work		
	Against God		
	Against nature		
	Compared with atomic technology and atomic disasters		