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„Don’t Act Like a Teacher” – How Science YouTubers become Experts

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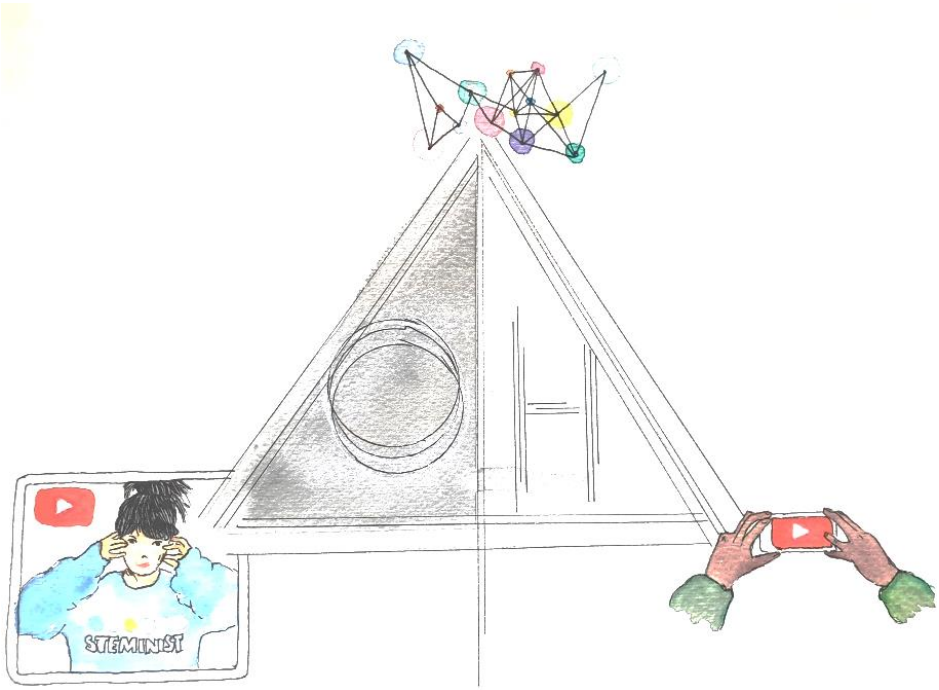
“Don’t Act Like a Teacher”

How Science YouTubers become Experts



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Content

I. INTRO

> *And we just sorta thought: We love science. We love explaining science to people.*
> *(Mitchell Moffit)*[1]

In May 2019, the YouTuber Rezo[2] posted a video called "Die Zerstörung der CDU" (The destruction of the CDU)[3]. The video, in which the YouTuber criticised Germany's governing parties, especially with regard to their climate policy, gained a lot of attention and initiated a discussion concerning the role of YouTubers in public discourses. The video and the consequences it caused are thus exemplary for the subject of this thesis: namely the question of how scientific topics are discussed on YouTube and how expertise is negotiated in this context. To what extent I will explain in the following.

The following description is based on material collected for the paper "Climate Protection Policy in Germany: YouTubers and Scientists united against the Government?" published by Allgaier et al. in 2019. However, the data and interpretations have been extended for this thesis. The CDU (Christlich Demokratische Union Deutschlands) mentioned in the video title is the conservative governing party of Germany's Chancellor Angela Merkel. Up to the release of this video, the YouTuber Rezo was mainly known for entertaining clips with other YouTubers and cover songs. However, in 2019, he joined the public discourse on Article 13 of the "Directive on Copyright in the Digital Single Market" of the European Parliament[4], by uploading a video in YouTube's category "news and politics". In particular video creators of the platform took part in the public discussion, since Article 13 requires internet platforms

[1] From the video "The Science of AsapSCIENCE!": https://www.youtube.com/watch?v=KAbMjI71JqY (accessed: 23.08.2020).
[2] Rezo's (second) channel "Rezo ja lol ey" contains videos with comedy content, funny challenges and a few similar videos dealing with political or societal topics. The videos have between 500,000 and 4 million views. Only the video discussed in this text ("Die Zerstörung der CDU") has received more than 10 million views so far: https://www.youtube.com/channel/UCvU1c8D5n1Rue3NFRu0pJSw (accessed: 14.05.2020). He also runs the channel "Rezo" mainly posting music mash-ups and cover versions but has not posted a video there since autumn 2019.
[3] To date (14.05.2020) the video has 17,229,07 views and 244,736 comments: https://www.youtube.com/watch?v=4Y1lZQsyuSQ (accessed: 14.05.2020).
[4] See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016PC0593 (accessed: 24.08.2020). For more information on public protests regarding article 13, see, for example: https://www.tagesschau.de/wirtschaft/urherberrechtsreform-unterschriften-101.html (accessed: 24.08.2020).

such as YouTube to extract copyright-protected content. In the 60-minute-long video[5] "Die Zerstörung der CDU", Rezo attacks the governing parties and their policies. While he addresses many different topics, the main part criticises the lack of political strategies to fight climate change[6]. He, therefore, quotes various scientific publications, describes scenarios of what might happen if climate emissions are not reduced soon, and underlines his statement with a 13-page document listing all the sources he refers to in the video (Figure 1)[7].

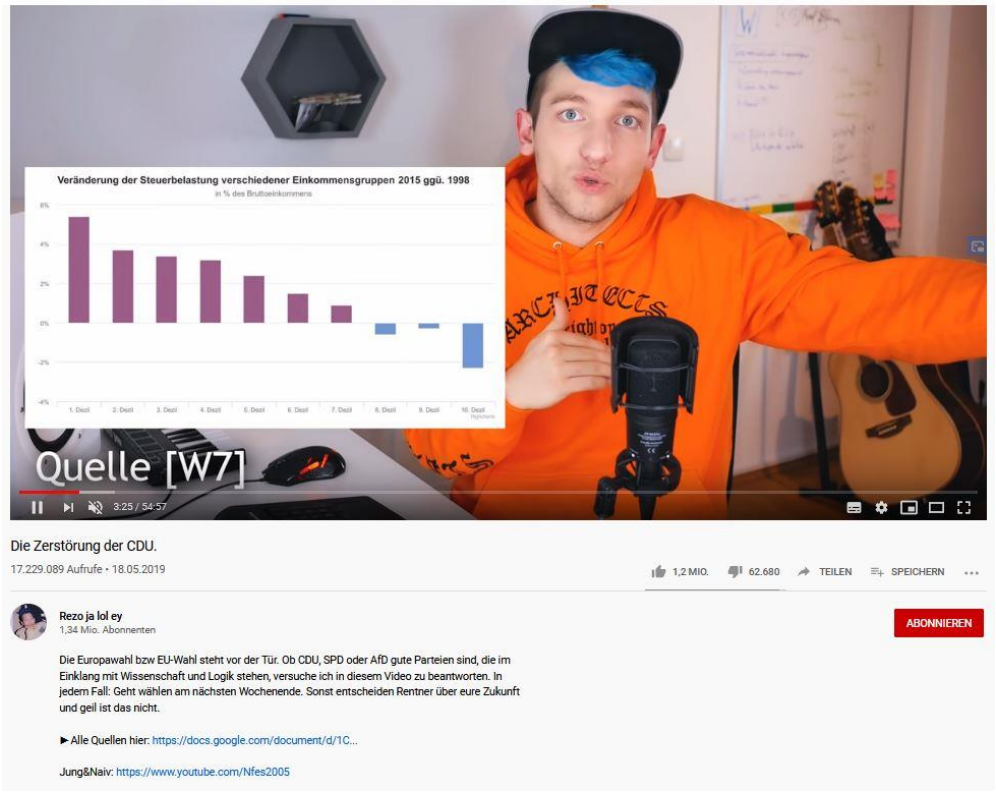


Figure 1: "Die Zerstörung der CDU".
Screenshot of Rezo's video "Die Zerstörung der CDU" where he attacks the governing party of Germany in 2019. In the description he posted a link to a Google document with the scientific references he quoted in the video[8].

[5] The video is unusually long for this channel. Most of Rezo's videos are between 8 and 15 minutes long, which seems to be a common length of videos on YouTube.
[6] In the video, Rezo also criticises other political strategies. However, I only want to focus on climate change here because it is his main topic and subsequent discussions mainly focused on this topic, and especially in this section, he refers to scientific publications (e.g. the Intergovernmental Panel on Climate Change – IPCC).
[7] List of references mentioned in the video: https://docs.google.com/document/d/1C0lRRQtyVAyYfn3hh9SDzTbjrtPhNlewVUPOL_WCBOs/edit (accessed: 14.05.2020).
[8] Screenshot retrieved from: https://www.youtube.com/watch?v=4Y1lZQsyuSQ at 03:35 (accessed: 24.08.2020).

The video was posted shortly before the European parliament elections in Germany and contained a clear statement against voting for governing parties as well as other parties that, according to Rezo, do not support climate protection policies. Therefore, the video can be described as an audio-visual comment on current political affairs and differs clearly from Rezo's usual entertainment videos. Within one day the video reached more than one million views and had been watched more than 11 million times by election day. With the rising number of viewers, national and international news agencies began to review the video’s content. They also discussed the YouTuber himself along with the surprising effect of the video in the public (Connolly, 2019; Schuetze, 2019). Especially Rezo’s expertise as a YouTuber was questioned by journalists and politicians (Deutsche Welle, 2020), referring to his blue hair as well as to the pop-cultural content he normally presents in his videos.

Based on the idea of YouTube as an entertainment platform which can’t be taken seriously regarding societal discourse, the parties addressed in the video didn’t react to the content right away but instead ignored the video and its high numbers of views at first. When the conservative party finally reacted to the video, it posted an 11-page-long pdf document in response to Rezo’s critique, while the SPD (Sozialdemokratische Partei Deutschlands - the other governing party) posted a YouTube video with an offer to discuss the issues at hand. Those different reactions and the time it took for politics to respond display the missing knowledge about YouTube’s culture and how YouTubers shape the communication on the platform. Politicians as well as journalists still seem to underestimate the importance of YouTubers like Rezo and of the platform with regard to political discussions, education and science communication. In a study published shortly before Rezo’s video, researchers found that 93 percent of 18-year-olds in Germany use YouTube for learning, information and entertainment on a regular basis (Rat für Kulturelle Bildung e.V., 2019), which indicates that the platform is no longer simply an entertainment portal but is also gaining importance in other fields of communication.

The scientific facts and publications Rezo quotes in his video were discussed shortly after its release by several scientists, science communicators and science YouTubers. For example, Professor Stefan Rahmstorf, a climate scientist, checked the scientific facts presented by Rezo, stating that it is the job of scientists to help ensure that the discussion about the

climate crisis is based on solid facts (Rahmstorf, 2019). He concluded that Rezo in fact understood the key facts about the climate crisis very well, and that he communicated them clearly in his video. Volker Quaschning, Professor for Regenerative Energy Systems, on the other hand, checked the scientific facts presented by the CDU in response to Rezo's video and concluded that none of the statements presented by the CDU substantially disprove the content of Rezo's video regarding climate change and climate protection (Quaschning, 2019). In addition, Mai Thi Nguyen-Kim, an influential female science YouTuber and science communicator responded to Rezo's video by checking the scientific facts in a video uploaded on her YouTube channel, adding more information on climate change and insights into the research methods and discussions among the scientific community[9]. In the over 20-minute-long video, she, for example, explained that consensus in science does not mean a democratic consensus of scientists' opinions but of scientific evidence, which is a common misconception.

With Mai Thi Nguyen-Kim and others, the community of science YouTubers thus also began to participate in the discourse around Rezo's video, addressing and discussing the scientific statements mentioned by Rezo. Mai Thi Nguyen-Kim has a PhD in chemistry and works as a science communicator and science journalist. While starting her first YouTube channel "The Secret Life of Scientists" in 2015, she has been concentrating since 2016 on what is now her main channel "maiLab" (formerly "schönschlau"). The channel is part of the German public broadcasters (ARD & ZDF) programme "funk" and has up to now more than one million subscribers (24.08.2020). Starting from her career as a science YouTuber, she also became part of television productions in 2018, and host of the science show Quarks (WDR). She is also a part of the YouTube channel "Terra X Lesch & Co", another channel of the German public broadcasters programme "funk"[10].

Following Rezo's video in May 2019 and her own fact checking of it, she produced a video together with Rezo to mobilise people for the climate strike and to influence politicians'

[9] On her channel maiLab, she posted the video "Rezo wissenschaftlich geprüft" (transl.: "Rezo scientifically checked") shortly after Rezo published his video. To date (16.05.2020) the video has more than 2,180,000 views: https://www.youtube.com/watch?v=tNZXy6hfvhM (accessed: 16.05.2020).

[10] Only shortly before the completion of this text, Mai Thi Nguyen-Kim received the Federal Cross of Merit for her work as science YouTubers (see, for example, https://www.deutschlandfunk.de/bundesverdienstkreuz-drosten-levit-und-mai-thi-nguyen-kim.1939.de.html?drn:news_id=1178627 – accessed: 04.10.2020).

decisions on pricing carbon[11]. In the 26-minute-long video, both YouTubers discuss solutions suggested by science on how CO2 emission pricing could help solve one part of the climate crisis. They prominently feature Ottmar Edenhofer, a professor of economics, as well as Klaus Russell-Wells, an engineer, who has a YouTube channel himself, talking about energy transition and sustainability. Mai Thi Nguyen-Kim is thus a good example of how careers of science YouTubers can develop and how collaborations between YouTubers of different genres work. But let us return to Rezo's video and its consequences.

While it was already pretty uncommon that a YouTuber like Rezo produced a highly successful 60-minute video on politics presenting the results of recent scientific publications, it was even more surprising that Rezo subsequently teamed up with other influential German YouTubers from mainly pop-cultural genres to produce another video on politics. In the video "A statement of 90+ YouTubers"[12], more than 90 YouTubers read a statement to highlight the importance of strategies against the climate crisis but also to advise their viewers to vote, as they described it, in line with scientific facts during European elections. The three-minute-long video has so far reached more than 4 million viewers (24.08.2020) and quoted work by the Intergovernmental Panel on Climate Change (IPCC) as well as a statement signed by over 26,000 scientists and scholars from Germany, Austria and Switzerland. The YouTubers taking part were well known in genres such as music, beauty, fashion, gaming or comedy but also in education and science, thus combining a few million subscribers. Therefore, it was no surprise that this video also made nation-wide headlines and that it was viewed almost 3 million times within the first two days. In the end, environmentalism and climate protection became a major topic in the European parliament elections of 2019, and the results displayed a massive loss of votes for the governing parties. However, it is not possible to tell whether Rezo's video had influenced the election results in Germany, since no data was collected regarding this issue.

[11] The video is called "Klimawandel: Das ist jetzt zu tun! (feat. Rezo)" (transl.: Climate change. This needs to be done now.): https://www.youtube.com/watch?v=4K2Pm82lBi8 (accessed: 24.08.2020). In the video, Alison Bernstein talks about scientific consensus and misconceptions (at minute 15:04).

[12] The statement read in the video is also posted in the video's description along with the names of the YouTubers who signed the statement: https://www.youtube.com/watch?v=Xpg84NjCr9c (accessed: 16.05.2020).

After the election, Rezo returned to mainly producing entertaining videos on his YouTube channel. However, he also continued taking part in public discussions. In autumn 2019, he was offered his own column at Zeit Online with the title “Rezo Stört” (Rezo disturbs; which relates to the German word for destruction (Zerstörung)). Every second week he publishes critical comments on current affairs, such as, for example, how cultural institutions and artists went digital during the corona crisis and what they can learn from YouTubers[13]. He was awarded the Nannen Prize in early 2020 for his video “Die Zerstörung der CDU” in the category for best web-project, a prize which honours printed and online journalistic work in six categories. This again led to a discussion on whether a YouTuber can have enough expertise to win a prize aimed at professional journalists. In a comment, Krischke (2020), for example, states that Rezo should not be honoured for his video because he is not a professional journalist and therefore does not follow the specific rules for quality journalism.

In response to the critics, Rezo published a comment on Zeit Online in which he asks the question of how to define good journalism in current times (Rezo, 2020). He recounts the critique his video received already in 2019, e.g. that the video is more entertaining than a journalistic piece because he, as someone who never studied journalism, uses slang and rough language, stating that this critique addresses the form instead of the content of his video. He argues that journalists can learn from YouTubers how important transparency and verifiability is. For him, the combination, not separation, of neutrality and personal comment in what he calls subjective journalism might be something recipients are looking for, as long as both the sources used as well as the personal opinions presented are made transparent.

Starting this text with Rezo’s famous video may at first glance not seem to be the perfect example for science communication on YouTube. Although he is a well-known YouTuber and uses scientific facts in his video "Die Zerstörung der CDU", he is neither a science YouTuber nor a science communicator. However, in my opinion, this case perfectly displays how the concept of expertise on YouTube is negotiated and how this affects general discussions on expertise in public discourse. It also displays how expertise seems to be rather attributed based on numerous characteristics and how aspects such as transparency and verifiability, as

[13] https://www.zeit.de/serie/rezo-stoert (accessed: 16.05.2020).

introduced by Rezo, contribute to this process. It therefore questions normative characteristics of expertise based on scientific and professional degrees and certificates.

In addition, the video displays how scientific facts, research and public discourses are presented and discussed in the YouTube community and influence discussions outside the platform. With this case I also illustrate how long-established institutions in politics and journalism, but also in science, still react with scepticism to communicative processes on social media platforms and how they, as a result, miss the opportunity to understand how social media platforms work and influence social discussion. The case also displays how YouTubers communicate in a different way directly and at eye-level with their communities, which can also be observed in collaborations between science YouTubers and other genres, such as beauty gaming or music, in order to reach a larger number of viewers. This is something professional science communicators outside of YouTube could possibly learn from. Finally, the video demonstrates that users of a platform known primarily for entertainment seem to have a great interest in science and politics. The question is how does science communication react to this demand?

With the presented case of Rezo's video I have accordingly illustrated what influence YouTube videos can have on public discussions and what role scientific findings can play in this context. Thereby, the importance of YouTube as an audio-visual social media platform has generally increased - not only as an entertainment medium but also as an information portal for education and science communication. With around 2 billion users per month the platform is listed as the second most visited website in the world (Alexa, 2020; YouTube, 2020b). Although YouTube cannot be considered a search engine, many users use the platform to get quick answers to everyday questions. So-called "How To videos", which promise to give answers "whenever we need help, whenever we need someone to *show* us how something is done (…)" (Allocca, 2018, p. 153), play a special role in this context. Videos with scientific and educational content are also frequently assigned to this category.

One of those science channels is "AsapSCIENCE", with more than 9 million subscribers[14]. In their videos the two YouTubers introduce scientific knowledge to answer daily and funny questions using a voice-over drawing technique. In an interview, one of the two video

[14] https://www.youtube.com/user/AsapSCIENCE (accessed: 24.08.2020).

creators explains their motivation is based on the idea that "Everyone experiences science. (…) We need to let people know that this is about them" (Allocca, 2018, p. 163). Another example is the German YouTube channel "Kurzgesagt – In a Nutshell", with currently more than 12 million subscribers[15]. The animated videos discuss a broad range of different scientific topics, such as, for example, the Fermi Paradox or the human immune system. In the channel's description, the designer collective behind the channel state that they are "a small team who want to make science look beautiful. Because it is beautiful"[16].

For Allocca, science YouTube channels are successful because the concept of the "Explainer" is driven by the user's curiosity (Allocca, 2018, p. 136), which might explain the rising number of videos related to science and education in recent years. When I started my dissertation in 2015, I did a query with the term "science" which revealed about 1 million channels. While not every channel might factually belong in the category of science and education, the number still illustrates the interest of YouTube's producers and users in scientific topics. Repeating the query in 2017 revealed 15 million distinct channels and about 34 million videos[17], again illustrating that science communication seems to play an increasing role on YouTube. While the constantly changing settings for categorisation, the different definitions of science among the producers and users, as well as the high mobility of content and channels on the platform do make an exact quantification of existing channels dealing with science and education almost impossible, growing numbers of followers on science YouTube channels still indicate the importance of research on this topic.

If, for example, channels, like "Vsauce", "Kurzgesagt – In a Nutshell" and "AsapSCIENCE" reach between 8 and 15 million people, it seems important to ask questions such as who produces the videos, what content is shown and what criteria determine success or failure on the platform. From an academic point of view, surprisingly little is known about science communication on YouTube, how science YouTubers see and legitimise themselves, and how they are received by their communities. In general, there is little research on science communication on social media platforms. This also became apparent in a recently published in-depth empirical analysis of the research field "science communication", in

[15] https://www.youtube.com/user/Kurzgesagt accessed: 24.08.2020).
[16] https://www.youtube.com/user/Kurzgesagt/about (accessed: 17.05.2020).
[17] Because YouTube changed its settings, the number of results found is no longer displayed. Therefore, it is difficult to define the actual number of channels or videos labelled with "science" after 2017.

which Gerber et al. (2020) identified current research gaps. The study triangulated a bibliometric and a content analysis of around 3,000 journal papers and combined the resulting quantitative findings with qualitative interviews with 35 science communication researchers. They identified four main clusters of research gaps, stating that "systematic changes in the digitalised media environments are not yet sufficiently understood" (Gerber et al., 2020, p. 4) and that "new actors in communication" in rapidly changing media systems ask for research on alternative communication models and practices. On social media platforms, new actors communicate science, and the changes in digital media landscapes become visible. They also formulate nine research recommendations, including the need for more research on science communication practitioners, on the communication of the humanities as well as the need for more mixed-methods approaches going beyond one-case-studies combining practical and theoretical approaches (Gerber et al., 2020).

My research has addressed these gaps as well as the recommendations for science communication research in examining the negotiation of expertise in the science YouTube community. When looking at the numbers presented above, it seems obvious that people are driven by curiosity and seek entertaining education and information on a platform like YouTube. At the same time, terms like "post truth" and "fake news" lead to the assumption that dealing with the accessible information and the decision of who to trust is becoming more and more difficult. As Rezo described the importance of transparency and verifiability, YouTube displays the importance of authenticity as a prerequisite for trust. And, while we can observe a loss of trust in institutionalised media companies and journalism, where the mechanisms behind the scenes seem obscure for the people, YouTube becomes more important for the way we produce and receive information. In an interview in the spring of 2020 in The New York Times podcast series "Rabbit hole", Susan Wojcicki, chief executive of YouTube, highlights "That we [YouTube] want to deliver accurate, useful information" when being confronted with the problem of misinformation on the platform, especially during the COVID-19 pandemic (Roose, 2020). After years of cat videos and music clips, YouTube officially seems to shift from an entertainment-driven alternative media space to a media platform following similar rules as those we can observe in mass media.

The question arises how science communication is affected by YouTube's constantly changing platform politics. Who are the producers belonging to the group of science YouTubers? How do they produce their videos along with the platform's rules and the viewer's perceptions and how does this affect science communication in general? With these questions I started my research in 2015. In applying a mixed-methods approach, I dove deep into the community of science YouTubers and YouTube's complex algorithmic cosmos. After collecting first impressions, I decided to "follow the platform" and therefore to follow its definition of science and science communication (see Chapter 1). I conducted semi-structured guideline-based interviews with five different science YouTubers and collected additional data in three ethnographic field studies (see Chapter 2). A first analysis led me to the question of how science YouTubers become experts. In-depth field work, a detailed document analysis as well as a video and commentary analysis allowed me to gradually unbox the platform's concept of "expertise" and how expertise is distributed in socio-technical negotiations.

Based on my research, the concept of expertise negotiated by science YouTubers, the users and the platform's algorithms can be described in a two-step process. While the term platform suggests a democratic process of communication, recommendation algorithms and platform-specific rules lead to the necessity of a platform-specific expertise. This expertise may not be the only requirement to start a channel or upload videos, but it is necessary to become visible in the sheer mass of videos. Due to the constantly changing algorithmic and community-based characteristics of the platform, YouTubers need to constantly adapt their production processes by dealing with new trends and an exchange with other (science) YouTubers. Therefore, this platform-specific expertise is partly an experience-based expertise (Collins & Evans, 2002) acquired through ongoing negotiations between networks of users, producers and algorithms and at the same time attributed as described in the concept of ethno-epistemic assemblages by Irwin and Michael (2003). As soon as the video becomes visible, the viewers become more important in attributing success and thus expertise to the science YouTubers.

At this point, the concept of authenticity and its importance on YouTube crossed my path. A supplementary video and commentary analysis revealed that the field term authenticity can be described as negotiations of coherences. Therefore, expertise seems to be attributed

when the science YouTuber succeeds in telling coherent stories. This refers not only to the content of the videos themselves; more importantly, it refers to their own positioning in the genre of science communication and the science YouTube channel's brand. In combining two steps along the dichotomy of invisibility and visibility, I introduce a model for the platform expertise of science YouTubers to answer my research question (see Chapter 3). With the necessity to deal with the constantly changing rules of the platform and to act coherently, the importance of the actual scientific content fades into the background or at least loses importance regarding the perceived expertise. Especially the importance of coherent storytelling regarding the channel's brand and community seems to reveal a growing significance of the relationship between producers and viewers. In this sense it is also understandable that purely normative concepts, such as expertise based on a completed degree or a title, play a lesser role on YouTube. Instead, a mixture of information with personal opinions, emotions and entertaining elements may contribute to the attribution of expertise.

In the following, I will first explain how expertise in science YouTube channels can be described based on the current state of research in science communication as well as the platform's history and the related studies on it. From this, I will derive my research questions and explain them in detail. Subsequently, I will first address the methods used. Based on my research, I describe the challenges of studying platforms like YouTube and why I chose a mixed-methods approach. In addition to the chosen methods, I also describe the selection of my cases and the cases themselves in this chapter. Furthermore, terms relevant for the work are introduced and explained. In the following chapter, I will present my analysis and go into more detail about my understanding of expertise based on the research I have done on YouTube. I will then explain my two elaborated concepts of expertise as an outcome of constant negotiations between producers, users and algorithms; first, an experience-based platform-specific expertise gained in ethno-epistemic assemblages and networks, and second, an attributed expertise based on coherent storytelling regarding the channel's brand and community. At the end of the chapter I bring both concepts together and present them in detail in order to introduce an overall model to describe the platform expertise of science YouTubers. This thesis is rounded off by an outro in which I summarise my findings, explain

their impact on science communication in practice and research, and discuss further research questions deriving from my work.

II. MAIN PART

> *Because I think we live at this time where there's tremendous change, and so yes. We've had years of all this fun and gaming and cat videos, but there are a lot of really important decisions to be made about what this future will hold and what will platforms be and how will they operate in the future. And those rules haven't been written yet, or we're in the process of writing them. (Susan Wojcicki in Roose, 2020)*[18]

Before I start with the Main Part of this thesis, I would like to briefly explain its structure. I decided to organise the text according to the structure of typical YouTube videos: intro, main part, outro (Morcillo et al., 2016). Similar to an introduction of a text, the intro of a YouTube video includes a short outlook or teaser of the video's content. Moreover, the intro introduces the YouTuber's or the channel's brand with a specific logo or a jingle. Only rarely does it also contain an invitation to watch other videos or subscribe to the producer's channel. Those invitations and cross references to other videos or even other channels are more commonly presented in the outro section at the end of the video. Here, the YouTuber tries to catch the viewer's attention to get more subscribers or even to directly ask for financial support, e.g. via the platform Patreon[19]. The producers try to connect to their audience with both the intro as well as the outro. The content the video is about is presented in the main part. For my thesis, this means that the Main Part presents the central elements of my research, including a theoretical introduction to the topic, a presentation of the methods used, a detailed analysis of the data collected, and the conclusions drawn. Intro and outro frame the text, just as they frame a YouTube video. In them I seek to introduce my research topic, ask further questions and put my results into a larger context. Although I will not start this work with a jingle or end it with a call to subscribe to my channel, I hope that the reader will feel connected to the text and enjoy reading it.

In the following chapter, I will introduce YouTube's history as well as fundamentals of platform studies and science communication research. Starting with a detailed description of

[18] https://www.nytimes.com/2020/05/07/podcasts/rabbit-hole-youtube-susan-wojcicki-virus.html (accessed: 24.08.2020).
[19] Patreon (https://www.patreon.com/) is a platform used by YouTubers and other creative people, like e.g. musicians, to earn money for their creative work (accessed: 24.08.2020).

YouTube as a social video platform introduces both a technical and a cultural point of view to better understand the characteristics of this medium (Giglietto et al., 2012). I will outline how YouTube works as a platform and describe its main characteristics, having in mind that those characteristics already might have changed when this text is published. Following this closer look at the platform, I will focus on science communication in general and on YouTube in particular. Looking back at the long history of science communication, I will further describe how science communication is presented and received on social media platforms. This chapter will also contain necessary discussions on how terms like science communication, information and education overlap, especially on social media platforms. Drawn from the presented work on YouTube and on science communication, I will outline my research questions and my research path in detail.

In the second part of the Main Part, I will describe in detail my methodological approach alongside an in depth-analysis of the challenges when studying social media platforms like YouTube. This chapter will display how the decision to apply a mixed-methods approach led to a better understanding of how experts evolve on YouTube. Based on this insight, I will connect my collected data with theoretical assumptions and demonstrate how expertise in the science YouTube community is negotiated.

1. HOW TO ENGAGE WITH SCIENCE COMMUNICATION ON YOUTUBE?

How YouTube's platform politics influence expertise

A wiggly camera image portrays a young man in front of an elephant paddock in a zoo. The weather seems bleak, the video colourless. Voices can be heard in the background; the noise of wind illustrates the rather poor recording quality. In only 18 seconds the young man tells us the following: "All right, so here we are, in front of the elephants. And the cool thing about these guys is that they have really, really, really long trunks and that's, that's cool. And that's pretty much all there is to say"[20]. This is the very first video uploaded on YouTube in 2005 by Jawed Karim, one of the founders of the social video platform. The video called "Me at the zoo" is still available and has so far gained more than 97 million views. While the initial idea of Chad Hurley, Steve Chen and Jawed Karim was to create a video dating site, they

[20] https://www.youtube.com/watch?v=jNQXAC9IVRw (accessed: 01.06.2020).

soon realised that people were more often using it to share funny videos of their friends (Burgess & Green, 2018). With the well-known slogan "Broadcast Yourself" YouTube introduced a concept of the centred user, emphasising the idea of a platform for democratic public discourse or as Allocca (2018) describes it: to create a "(…) culture shaped by all of us" (p. xi). Ever since, the platform further emphasised the idea of everybody having the opportunity to upload, watch and share videos. In doing so, video creators as well as viewers become part of the platform's community, where producers and users share their experiences and knowledge.

As the term community is an important one when it comes to social media platforms, I will start with a short excursus on how I will use it in the context of online communities[21]. Especially in view of the emergence of the internet and, not least, social media, the concept of proximity in its meaning for community has been increasingly discussed in recent years (for example Wellman, 1996). Virtual or online communities differentiate from personal communities in a face-to-face setting as well as from imaginary communities, such as nations or social movements (Thiedeke, 2008). While van Dijck (2013) describes the formation of communities on social media platforms as a "product of human collectivity and technical connectivity" (p. 147), community as observed on platforms, like YouTube, seem to display precisely this human collectivity. Virtual communities can be described as socio-technical systems (Thiedeke, 2000, 2008) between users and algorithms with characteristics such as interactivity, fluidity or pseudonymity. Regarding the users of the platform, the term community describes several things.

The founders of YouTube use the narrative of community to describe the belonging to the platform itself. Video creators and users with their own accounts, interacting with other users and producers, become part of this community and may even benefit from it. With this narrative, YouTube implies that members of the community not only share interests and values but also a specific knowledge about the platform. Shared interests and the proposal of specific reasons as to why one should become a member of this community are typical characteristics for online communities (Preece & Maloney-Krichmar, 2003), like video

[21] I am well aware that the term "community" in general has been discussed widely. For a closer look in this discussion, see e.g. Tönnies and Lichtblau (2012) or Gertenbach et al. (2018).

producers who become part of the YouTube Creator community and get access to knowledge and other services to create high-quality video content. Therefore, members of the community have access to shared resources (e.g. YouTube Creator Academy) and support each other (e.g. in formal and informal networks). However, a community on YouTube can also describe a group of producers and viewers who share common interests in video content or in a particular genre and actively participate in social interactions with each other and with the videos. They also often have a shared context of social interactions and language (Preece & Maloney-Krichmar, 2003). One example is the gaming community around "Let's play" videos, where video creators comment games while they play them live. But also the science YouTubers can be described as a community.

Finally, on YouTube, the term community can also describe the group of subscribers of a specific channel. Here, the social interactions are between the video producers and their subscribers. Those interactions are based on a virtual proximity and can be very intense, creating strong emotional ties (Preece & Maloney-Krichmar, 2003). Channel communities are therefore very important for the success of the channel's creator. Intense interactions between creators and their subscribers also foster interactions with published videos, which lead to more recommendations and in the end a higher advertisement revenue. Especially for science YouTubers, a community with strong emotional ties is important to gain money because their income is mostly based on crowdfunding and donations. In the following, I will describe the overall community of the platform as "YouTube community", the content-related community as "genre community" and the channel-related community as "channel community".

When Allocca (2018) had the opportunity to ask Jawed Karim whether he regrets that "Me at the zoo" was the first video on the platform, he answered: "I don't mind it being the first video. It does get the point across that on YouTube anyone can broadcast what they want and the community decides what its values is" (Allocca, 2018, p. 4), thus emphasising the very idea of a community-driven culture of democratic video broadcasting on YouTube. Jenkins (2013) describes YouTube's participatory culture as a result of the garage cinemas and do-it-yourself newsrooms of the 1970s and 1980s. The platform has also been influenced by agents, content and institutions from traditional broadcasting and can therefore be described as a convergence medium between the internet and TV (Kim, 2012).

With the rising number of uploaded video content in the first couple of years, the platform became attractive for Google. In late 2006, Steve Chen and Chad Hurley celebrated Google's takeover in a video sharing their emotions in directly addressing the YouTube community[22]. While the equal participation and community-building remain central narratives of the platform, YouTube can no longer be described as a pure service for video-sharing. Instead, it has become a mainstream media platform "with its complex relationship to broadcast and cable television and the music business, and with homegrown YouTube stars boasting billions of subscribers" (Burgess & Green, 2018, p. 2). As the second most visited website (Alexa, 2020), YouTube has become an integral part of most people's everyday life. People might use the platform to check how to clean the drain, watch new music videos, re-experience old TV series and discover new formats for entertainment or education. For institutions it is hard to avoid using YouTube if they want to publish videos, especially when they want to reach a broad audience. Being available in 75 countries and in 61 languages (YouTube, 2020b), the platform has an undeniable influence on the way audio-visual information is conveyed, recorded and distributed.

For Soukup (2016, p. 25), the combinations of "mass audience appeal with niche audience applicability" as well as of professional and amateur content are characteristics of the platform's success. With the increasing spread of smartphones and the constant availability of the internet in recent years, the importance of audio and video continues to grow. Reception independent of time and place thus also leads to an own form of audio-visual production of content. In 2016, the group of 14-19-year-olds consumed the most online videos with 30 minutes per day (Koch & Frees, 2016) in Germany. In 2019, already 42 minutes per day of video content was consumed online, across all age groups. On a weekly basis, 40 % of those online videos were watched on YouTube, 82 % among people older than 30 (Beisch et al., 2019). Subsequently, the YouTube video is described to be the dominant form of videography in the early 21st century (Lister et al., 2010). This form of videography was, especially in the first years of the platform, shaped by the video creators. So-called user-generated content (UGC) was characterised by amateurish technology, such as shaky camera images or poor sound quality. With the possibility to upload, share and comment on

[22] https://www.youtube.com/watch?v=QCVxQ_3Ejkg (accessed: 01.06.2020).

video content, the platform clearly differs from curated media offerings such as media libraries. The easy access to the platform, the wide distribution and the diverse range of offers are reasons for its market dominance. Although YouTube cultivates the narrative of the amateur, a convergence between the dual logics of community and commerce can be observed from the beginning (Burgess & Green, 2018). This convergence became even more apparent since Google took over in 2006. The introduction of advertisement resulted in an increase of professionally generated content (PGC) produced by major media groups (Kim, 2012).

Kim (2012) introduces the term institutionalisation of YouTube to describe this transformation from a UGC to a more PGC dominated platform. PGC does not follow the same production philosophy as UGC, which is why YouTube created an advertising-friendly environment and tightened copyright rules[23] to become more interesting for advertisers and media companies. Companies as well as media broadcasters discovered the platform as a tool to enhance marketing strategies and reach a wider and potentially younger audience. Due to the increase of uploaded video content in general and the growth of PGC in particular, it has become more difficult for amateurs uploading UGC to become visible and therefore successful. As a consequence, UGC producers became more professional themselves, especially regarding their video production techniques and their strategies in following the rules of the recommendation algorithm (Morcillo et al., 2016; Rieder et al., 2020). These recommendation algorithms play a central role in measuring the success of videos. In addition, successful videos increase the advertising revenue of the platform and are promoted accordingly by being presented in the recommendation bar or on the landing page.

Especially since the introduction of advertising in 2007, the professionalisation of user generated content has become explicit, and professional YouTubers aiming to earn money with their videos needed to professionalise their strategies to increase the number of subscriptions and video views. The more successful, the more relevant a video is, the greater is the advertising revenue. However, the revenue of advertising content in, under or next to the video promises rather low returns because commercials inserted before or during

[23] Copyright is one central topic within the platform, which has been discussed widely regarding its influence on participatory culture and professionally produced content in Burgess and Green (2018).

playback must be played in full by the users, unless they have already been deactivated by advertising-preventing software. Greater profits are promised by product placements in the video itself. Therefore, an increase in product placement can be observed in the last couple of years (Schwemmer & Ziewiecki, 2018). For this purpose, YouTubers cooperate with companies and receive money for naming or recommending a company's products. However, the non-labelling of such contractual agreements due to a lack of regulations continues to be a major problem of the platform (Döring, 2014).

To help video creators deal with those algorithms, YouTube enables access to services such as Multi-Channel Networks (MCN) to foster "audience development, content programming, creator collaborations, digital rights management, monetization, and/or sales" (Google, 2020). MCNs are therefore middlemen between YouTube and advertisers, which Cunningham et al. (2016) describe as "Google/YouTube-approved intermediary aggregating, affiliated with, and/or managing YouTube channels" (p. 377). MCNs may help video creators with copyright-claims, getting access to other YouTubers or in simplifying contracts for product placement (Davidson, 2013b; Ladwig, 2018). In return, YouTubers assign a portion of their revenues to the MCNs. Burgess and Green (2018) describe MCNs as similar to talent agencies in aggregating "similar channels within clearly defined market niches (like games, lifestyle and beauty, or how-to)" (p. 56). The idea originated in the USA, but there are also MCNs in Germany, such as TubeOne Networks or Mediakraft Networks. With funk, the German public broadcasting organisations founded a content-network similar to an MCN in 2016, managing YouTube channels but also creating their own content. Funk offers online content for young people between 14 and 29 years and also aggregates German science YouTube channels[24]. In recent years, MCNs have been criticised for being too large to take care of managed channels sufficiently and for not being able to adapt to the rapid developments of the platform (Flynn, 2019; Ludwig, 2014). As a result, informal networks have been established. Here YouTubers join forces to support each other in sharing knowledge and implementing collaborations. An example for an informal network of YouTubers in Germany is 301+[25]. Besides intermediaries like MCNs, YouTube offers services

[24] https://www.funk.net/funk (accessed: 14.06.2020).
[25] http://301plus.berlin/ (accessed: 14.06.2020).

such as the YouTube Creator Academy[26], the YouTube Creators programme[27] or the use of production facilities, like the YouTube Creator Spaces[28], to support video producers in becoming more successful. For example, with the YouTube Creator Academy, the platform offers a free-of-charge learning programme to help video creators increase subscriber numbers and improve advertising revenue. The website is created as an online course programme, where users can compile their individual syllabus and learn from successful YouTubers how to set up a channel, how to produce a video or how to foster marketing strategies.

Due to the many interactions between YouTube and its users, producers, advertisers, MCNs, media partners and others, the platform falls under the concept of multi-sided media markets, as described, for example, by Wikström in 2013 (cited in Burgess & Green, 2018). With the shift from two-sided media markets to multi-sided media markets in the mid to late 2000s up to the mid-2010s, a platform paradigm emerged (Burgess, 2015), conceptualising how social media landscapes function as businesses. Helmond (2015) introduces the term "platformization" of the internet to describe a similar shift from social network sites (SNS) to social media platforms as a dominant economic model of the social web. YouTube is often described as the second most used search engine because people often use the landing page to find instructional videos. However, the platform does not meet the criteria of a search engine. On the other hand, YouTube functions as a kind of media library or an archive where users can consume music videos, comedy, series or news.

Therefore, from the users' point of view – especially those without a YouTube account, it sometimes is surprising that YouTube can also be defined as a SNS, although it is different from other SNS such as Facebook or Instagram. boyd and Ellison (2007) define SNS as "web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded systems, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system" (p. 211). On YouTube, video producers establish this public or semi-public profile when creating an account. A YouTube account is, for example, necessary to comment on videos

[26] https://creatoracademy.youtube.com/page/home (accessed: 14.06.2020).
[27] https://www.youtube.com/creators/ (accessed: 14.06.2020).
[28] https://www.youtube.com/intl/de/space/ (accessed: 14.06.2020).

but most importantly to upload videos. In doing so, the users become part of the YouTube community, share connections to and interact with other video creators and viewers. For Helmond (2015), "platformization entails the extension of social media platforms into the rest of the web and their drive to make external web data 'platform ready'" (p. 1). She proposes a material-technical perspective on platforms, placing the offer of Application Programming Interfaces (APIs) at the centre of the transformation from SNS into social media platforms (Helmond, 2015). While her description is based on a computational sense (see also Bogost and Montfort, 2009), Gillespie (2010) approaches the concept of platform from a rhetorical perspective. He describes a conceptual use of the term's connotations as:

> (…) computational, something to build upon and innovate from; political, a place from which to speak and be heard; figurative, in that the opportunity is an abstract promise as much as a practical one; and architectural, in that YouTube is designed as an open-armed egalitarian facilitation of expression, not an elitist gatekeeper with normative and technical restrictions. (Gillespie, 2010, p. 352).

Especially the presentation of YouTube as an "open-armed egalitarian facilitation of expression", describing the platform as an open and democratic space where everybody can upload content, is something Gillespie (2010, 2017) questions in his work. Although it is implied that anyone can upload anything, certain criteria must be met to publish videos on the platform. The YouTube guidelines summarise these criteria as community guidelines, terms of use, copyright regulations, age rating, monetisation, and guidelines for creating promo-friendly content (YouTube Creator Academy, 2020). With the narrative of accessibility for everyone, YouTube differentiates itself from mainstream broadcasters and publishers, presenting itself rather as a facilitator or host and not as gatekeeper or curator (Gillespie, 2010). At the same time, the platform pursues clear commercial goals in order to secure income through contracts with advertising customers.

Guidelines, such as those described in the YouTube Creator Academy, serve to regulate and thus increase precisely those advertising revenues. Therefore, YouTube's specific business model may not force the platform to act like a traditional gatekeeper but does have consequences for how video upload and dissemination are regulated (Gillespie, 2010). Gillespie (2017) describes this discrepancy between the suggested neutrality and the platform guidelines as the "myth of the impartial platform" (p. 4). In the last couple of years

governance by platforms has gained significance. Social media platforms, like YouTube, have increasingly begun to curate content to protect their corporate image alongside their policy and institutional ethics, avoid harassment and legal actions (Gillespie, 2017) as well as foster fact-based information (Roose, 2020). With this form of increasing curation, it is becoming more important for video producers to engage with the policies of the platform by consulting the statistics and services provided by YouTube and exchanging information in MCNs or informal networks. The self-uploaded videos must first be found before they can be classified as successful according to YouTube's evaluation criteria. Thereby, the access to videos takes place via different ways. For example, users can access the YouTube video page via search engine results, players integrated into websites or content shared on other social media platforms or via messengers. It is also possible for users to search for videos directly from the platform's starting page or to be redirected via the recommendation bar. As soon as the users land on the video page (Figure 2), they may not only watch the video but also interact with it, which means to rate (like or dislike), share or comment on it. In addition, other videos are presented next to the video in the recommendation bar.

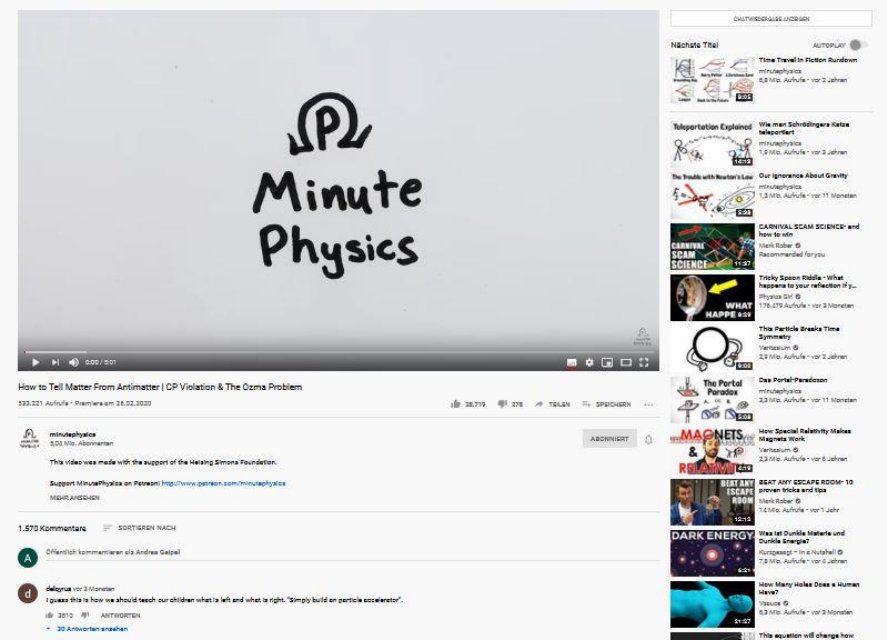


Figure 2: Example of a video page.[29]

[29] Screenshot retrieved from the channel "minutephysics": https://www.youtube.com/user/minutephysics (accessed: 07.06.2020).

How and to what extent viewers interact with the video in turn influences the recommendation algorithm. In addition to the number of views, shares, likes and dislikes, the number of comments and the watch time are among the characteristics that seem to influence the success of a video and thus decide whether the video is promoted by the platform algorithms. These recommendation algorithms can be based on the users' watch history or on data from users in similar user groups (e.g. classified by interest, age or gender). The so collected data also retroactively influence the video production of other video producers, which creates a cycle that generates trends and might also be responsible for so-called "filter bubbles" and "echo chambers" (Pöchhacker et al., 2017).

While the recommendation algorithm seems to constantly change and adjust to detect impactful videos and increase revenue, users and producers influence its "behaviour" as much as the software developers who create them. van Dijck and Poell (2013) describe these negotiations between algorithms and users to shape the programming of content with the term programmability. Programmability can be seen as the platform's attempt to foster the user's creative and communicative potential, while the users influence the communication and information flow of the platform. Programmability is one of four characteristics (programmability, popularity, connectivity and datafication) van Dijck and Poell (2013) use to introduce a social media logic. Starting from the term programmability, I will use the term "negotiations" in this thesis. For me, negotiations describe an interactive, techno-social process between users, producers and algorithms[30]. This process is based on the expectations and experiences of producers and users. On the one hand, it describes the multidirectional influence of socio-technical interactions, similar to the term programmability as presented by van Dijck and Poell (2013). On the other hand, the term "negotiations" illustrates a continuous process of changing conditions and hierarchical orders on the platform, which are oriented according to the algorithms. As described above, algorithms shape content presentation and interactions in an invisible manner.

[30] In using the term negotiations, I am also guided by Goffman 's (1983) "Interaction Order". Therein Goffman postulates the potential fluidity and permanent fragility of the social order rather than its factuality. In processes of interaction, there are structures that exist independent of the individuals to which actors refer and which therefore always reproduce themselves.

For Gillespie (2010), those algorithms might replace editorial experts we formerly relied on but at the same time contain automatically processed editorial selections by humans (Gillespie, 2014). In addition, the data collected on user interactions help to track usage behaviour and make predictions about future trends and developments. For van Dijck and Poell (2013), the term datafication therefore is another characteristic of social media logics and thus influences the curation of the platform by algorithms.

Algorithmic components are also important for another characteristic of social media logics, namely popularity (van Dijck & Poell, 2013). In standardising metrics, such as watch time, views or the number of subscriptions, by creating specific sections to promote trending videos, YouTube follows similar logics as mass media regarding popularity. TV shows, series and movies evolve around the idea of the popularity of individual persons based on socio-economic components. However, van Dijck and Poell (2013) identify a difference between social media logics and mass media logics regarding popularity, namely, the possibility for users to influence and manipulate the popularity of certain topics in a more direct way. YouTubers, for example, can promote a particular topic by spreading it in their own (social) networks as well as by repeatedly addressing the topic in new videos in order to gain a place among other trending videos. The possibility to influence and manipulate popularity is based on the knowledge of how the recommendation algorithms work and on the connectivity between users, also described as human connectedness (van Dijck & Poell, 2013).

As the fourth characteristic of social media logics, van Dijck and Poell (2013) describe connectivity as “an advanced strategy of algorithmically connecting users to content, users to users, platforms to users, users to advertisers, and platforms to platforms” (p. 9). Connectivity thus describes not only the human connection in communities but also the algorithmic connection between content, advertising partners, producers, viewers and other (social media) platforms as well as to the platform's own services, such as the YouTube Creator Academy. In this sense, connections are always established in a co-creational manner between humans and a largely invisible technology. Gillespie (2015) rightfully reminds us that “platforms pick and choose” (p.1) “based on explicit and implicit norms, cultural presumptions about taste and etiquette, at the behest of offended users or concerned lawmakers, and in ways that best suit their economic aims” (p.2), which inscribe

into the algorithmic attribution of relevance and thus co-design and curate the contents of the platform.

In this interplay of algorithmic determination and user-driven negotiations, producers have to decide to what extent they want to submit to these rules. This leads to new communication patterns within the platform, which influence reception and define new relevance criteria. Channels, which are technically simple collections of videos, increasingly serve the producers to establish their own brand as well as to assign them to different genres. It also leads to the need to become part of the YouTube community. Observing changes on the landing page, watching trending videos, but more importantly exchanging knowledge and strategies with the YouTube community are necessary to become visible on the platform. This, of course, also affects producers who create videos with scientific or educational content. Accordingly, it is not surprising that this professionalisation of science YouTubers to gain public attention led Morcillo et al. (2019) to rethink the idea of professionally produced content and instead describe a new category of YouTube professionals that can no longer be considered as part of an amateur movement.

A study published in 2017 states that, since 2012, social media platforms are increasingly used to retrieve information (Newman et al., 2017) while educational content and knowledge distribution still remain niche topics on the platforms (Rieder et al., 2020). However, although the report by Newman et al. (2017) shows that users still do have more trust in traditional media than in social media, it at the same time displays a growth of preferences for algorithm-curated content to retrieve information. As a result, YouTube was rated as the second most used source for information in 2017 (Newman et al., 2017). Already in 2010, Gillespie described YouTube as a social video platform which undeniable influences the way how audio-visual content is disseminated, received and shared. This also includes the emergence of new genres that primarily serve niche topics on the platform - such as videos on computer games or make-up tips. Since YouTube was founded a number of genres[31] have emerged, partly rebuilding genres known in traditional mass media (e.g. documentations) and partly addressing new communities around specific niche topics (e.g.

[31] I will use the term genre to describe YouTube channels that deal with specific common themes and are consumed by a common genre community.

Let's play videos displaying live gaming). One of the most typical genres are How To videos (Allocca, 2018), which Morain and Swarts (2012) describe as tutorials to explain how specific things work or which give answers to daily questions. Some of those genres or topic-related communities display specific characteristics regarding production, presentation and communication. YouTube itself promotes this genre-specific development by offering genre-related services, for example, YouTube Creator Academy courses for video producers in the beauty genre[32] or in the gaming genre whose community has been described as a specific form of fan culture (Ackermann, 2017).

When looking at science YouTube channels, professionally produced content from media broadcasters, universities or cultural institutions are often observed to be not as popular as one might suggest (Breuer, 2012). Instead, a lot of the most famous science channels are produced by professionalised amateurs, using cinematographic and other standards in their videos (Morcillo et al., 2016). While some of those science channel producers are PhD students or senior researchers, others build their expertise on audio-visual storytelling rather than specific scientific knowledge. In this context, (successful) science YouTubers especially seem to embrace the platform's potential for audience and community engagement, while YouTube channels of research institutions often seem to neglect these possibilities and use their channels more as an archive to disseminate image films and documentations. With the rising importance of the video format for education and science communication, YouTube seems to have a great potential to reach new audiences with a variety of formats (e.g. animations, time-lapse, slow motion, descriptions or subtitles) but also poses great challenges for science communication. Throughout this chapter, it became clear that not only the producers but also the politics of the platform (Gillespie, 2010) have an influence on how topics are communicated and received. The question remains to what extent these politics influence science communication and the concept of expertise. In order to get closer to answering this question, in the next chapter, I will give an overview of the historical development of science communication, including developments and the influence of social media platforms in recent years.

[32] See, for example, the course on "Develop a beauty channel" where two beauty channel producers give insights on how to create a community and how to learn from others: https://creatoracademy.youtube.com/page/lesson/policy-harassment?hl=de (accessed: 07.06.2020).

How science communication became a part of YouTube

The question of how YouTube might influence science communication requires taking a closer look at the science of science communication, how science communication evolved over time, and how the rapid development of new technologies, such as smartphones and social media platforms, in the last couple of years has influenced the way we communicate science. It also requires discussing differences between science communication, edutainment, education and science journalism in general as well as in digital media to define science communication. In this chapter, I will first introduce the public understanding concept before presenting an overview of the history of science communication, with a focus on the development of the field in Germany. Subsequently, I will focus on current publications on science communication on YouTube. At the end, I will briefly discuss the term "science communication" in my research. I am aware that in this chapter I can only provide a broad overview of the extensive literature on science communication in general and with regard to social media platforms in particular. A more detailed discussion would go beyond the scope of this thesis. Therefore, the aim of this chapter is to give a concise outline of historical and current developments within science communication in order to better understand developments within science communication on YouTube.

Public Understanding of Science

With the publication of the Bodmer Report by the Royal Society in 1985, entitled "The Public Understanding of Science" (PUS), new ideas emerged with regard to the tasks that science communication faced (Miller, 2001), addressing the fear that the funding of research has become politically vulnerable (Miller, 2001, p. 115). The paradigm was based on the deficit model but also on the assumption that citizens did not have a positive enough attitude towards science and technology (Bauer et al., 2007). The assumption of a public deficit regarding scientific knowledge led to the introduction of the paradigm of Science Literacy already in the 1960s (Bauer et al., 2007). It was driven by the assumption that citizens do not understand how science works and which research projects should be supported due to this assumed lack of knowledge. Because research is publicly funded, misunderstanding and resulting mistrust in science should be prevented, for example, through science

communication programmes. Accordingly, the aim was to improve the public's understanding of science based on this deficit model.

The model brought into institutionalised science communication (Bauer, 2017) was thus creating a barrier of lack of knowledge between science and society, which must be overcome through science education. Frequent criticism of this deficit model is, for example, based on the pure checking of factual knowledge (Irwin & Michael, 2003). In addition, in contrast to scientific knowledge, knowledge in areas such as history or finance is also disregarded in terms of the deficit model (Bauer et al., 2007). The idea behind this model also implies that science communication or scientific education leads to overcoming public literacy and, as a consequence, to a more positive attitude towards science. However, the claim “the more you know, the more you love it” (Bauer et al., 2007, p. 84) could not be proven empirically. As a result, the numerous criticisms of the deficit model, which played a central role in both the literacy and the PUS paradigm, led to a change around the discussion of the attribution of deficit. Not only society may show a deficit of knowledge but also science itself can display a deficit on the part of its representatives and their communication experts (Bauer et al., 2007).

This means that the public cannot be categorised as ignorant and scientists cannot be categorised as knowing, but rather that knowledge in relation to science seems to be distributed gradually. This can also be seen in the increasing differentiation of scientific disciplines. The greater the differentiation, the fewer people have a deeper understanding of the respective research field. Since it could not be proven that more knowledge is accompanied by more trust in science, and at the same time the division into those with and without knowledge could not be clearly established, new concepts for science communication became necessary. With the publication of the "Science and Society" report in the House of Lords, the focus switched from the deficit model to a paradigm promoting participation and deliberation (Miller, 2001)[33].

[33] For a closer look on the discussion of the different paradigms of science communication and the concept of science literacy, see, for example, Trench and Bucchi (2010), Lewenstein (1992b), Shinn and Whitley (1985), Dernbach et al. (2012), Burns et al. (2003), Weigold (2001), Logan (2001), Miller (1992) or Einsiedel and Thorne (1999).

While PUS seems to manifest the relationship between science and the public based on the deficit model and the necessity to overcome scientific literacy, the "Science and Society" report advised to focus more on the importance of a dialogue between science and the public (Pitrelli, 2003) and later on led to the concept of "Public Engagement of Science and Technology" (PEST). Accordingly, activities in line with this paradigm foster the active participation of the public in science and research, e.g. through citizen science programmes. Here, citizens can participate directly in research projects, e.g. by collecting or evaluating data (see, for example, Bonney et al., 2009; Irwin, 1995).

In line with this shift from the deficit model to the science and society paradigm as well as the discussion of methodological approaches in public understanding of science and technology, the journal "Public Understanding of Science" was founded in 1992, marking the beginning of a still young history of research into science communication (Bucchi, 2014). In Germany, considerations led to similar developments along with a more professionalised approach to science communication (Dernbach et al., 2012). After initial projects, such as the introduction of the Year of Science by the German Federal Institute for Education and Research (BMBF) in 1998, various science organisations signed the "PUSH (Public Understanding of Science and the Humanities) – Dialog, Wissenschaft und Gesellschaft" (Dialogue Science and Society) memorandum. In doing so, they committed themselves to an active and increased promotion of science communication in the Federal Republic of Germany (Dernbach et al., 2012). Even though the deficit model was initially the focus of the memorandum, the distinctive mentioning of the humanities, which are all too often left out in the design and research of science communication activities, is worth noting. In my research I have therefore explicitly included YouTube channels communicating issues from the humanities.

As already mentioned above, critical examinations regarding the deficit model as the underlying concept of PUSH (Bauer et al., 2007; Weingart, 2005) as well as PUS finally led to the concept of PEST, announced by British scientists in 2002 (Pitrelli, 2003). Following the criticism as well as the results of the "Science and Society" report, PEST introduced programmes and methods to foster participation and dialogue with the public (Pitrelli, 2003; Weingart, 2005). The abandonment of the deficit model was in the following further

strengthened by the call for greater public participation in knowledge production (Daum, 2006). However, the existing models are still based on a need for legitimisation to ensure public funding of research. This also includes the desire of institutionalised science to continue determining which contents should be publicly communicated or discussed (Bucchi, 2014). In this sense, the process of science communication follows clear rules to ensure that research results only reach the public after they have been reviewed. Procedures such as the peer-review process, in which scientific publications are first discussed and consolidated within the scientific community before they are made public, are correspondingly important (see, for example, Rowland, 2002; Spier, 2002). The role of mediators and thus translators of scientific knowledge for the public is then performed by science journalists or public relations departments.

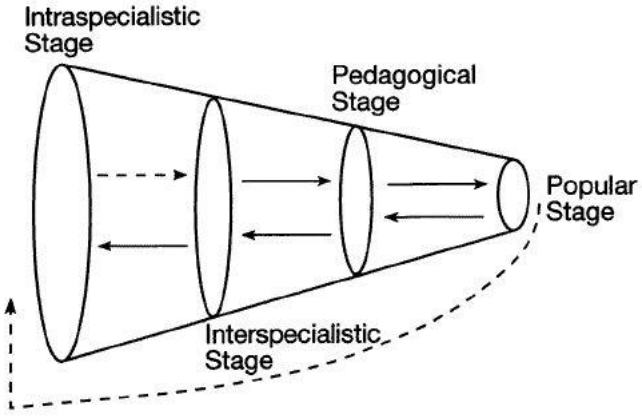


Figure 3: Continuity model of science communication (Bucchi, 1996, p. 381).

The process of institutionalised science communication is often described along a continuous model. Bucchi (1996) refers to this model using the four stages of Cloitre and Shinn (1985) as a kind of funnel (see figure 3), which illustrates how knowledge is consolidated and simplified from stage to stage (Bucchi, 1996). On the intraspecific level, knowledge is disseminated within one's own discipline by publishing articles in peer-reviewed journals and conferences. On the interspecific level, knowledge is then discussed across disciplinary boundaries, for example, in meetings between researchers from different disciplines. At the pedagogical level, the knowledge thus secured is then passed on as "textbook science" within courses and other forms of education. Finally, at the popular level scientific findings are published in the daily press or on television (Bucchi, 1996).

For Bucchi (1996) this model can help to illustrate the idealised process of science communication. However, he also emphasises that the actual process is more complicated; science can be published simultaneously at different stages and not every topic may transmission from one stage to another stage. The transitions between the levels can be fluid and slightly blurred. For example public relation (PR) departments may decide which topics are published on the popular stage, independent of publications on the other stages The popularisation of science on this level requires a closer look, generally under the aspect of the demarcation of popularisation in the form of simplification of knowledge to a distortion of knowledge as described by Hilgartner (1990). Nevertheless, it also needs to be considered in terms of its increasing importance with the establishment of social media platforms, where scientists now have even more direct access to public discourse - bypassing gatekeepers such as journalists or public relations departments.

The question arises as to whether it is precisely this mediator or gatekeeper role between the internal and external transfer of knowledge that is changing with the advent of Web 2.0 technologies such as social media platforms. However, before taking a closer look at how science communication takes place on social media platforms, we first take a look back at the history of science communication. In doing so, I want to give insights into how science communication developed over time and how modern concepts are mirrored in this very development.

From courtly lecture to medialisation 1.0

Looking back, we can tell that science communication as the dissemination of scientific content to the public is not new. Prominent examples are the chemist Justus von Liebig, who wrote the "Chemical Letters"[34] to explain his research to the public (Volhard, 1903) or the psychologist B.F. Skinner, who published popular scientific articles in newspapers and journals (Rutherford, 2004). Already in 1630, Galileo Galilei made a significant contribution to the development of science communication with the completion of his work "Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican". The form of the dialogue and the publication in Italian made the knowledge accessible to a broad public.

[34] The letters are available online: https://soilandhealth.org/wp-content/uploads/01aglibrary/010118liebigletters/liebigsletters.toc.html (accessed: 05.07.2020)

Following his advocacy for the Copernican world system, contrary to the opinion of the Catholic Church, Galileo had to face an inquisition trial. For Lüthje (2013), the case of Galileo Galilei illustrates three central themes of science communication that are still relevant today: Science communication as public communication and transfer of knowledge, the internal science communication as well as the interlocking of science and politics.

Although these prominent examples demonstrate that science communication already played a role before the emergence of the PUS paradigm, there is hardly a consistent historiography of science communication to date (Bauer, 2017). Nevertheless, in the following, I will try to give a short overview of the history of science communication in order to illustrate that there have always been efforts by institutions and individual scientists to share their results with the public - and that there have also been creative and experimental approaches. Admittedly, this review refers mainly to the history of science communication in Germany and parts of Great Britain and the USA and therefore reflects a Western-influenced view. To delve deeper into the history of science communication in its historical context I suggest to read, for example, Bauer (2017), Bonfadelli et al. (2015), Gregory and Miller (2000), or Rödder et al. (2012). With regard to the historical development of science communication in other countries, there are a number of publications, of which only a few are mentioned here: Burnham, 1987; Huang, 2016; Knight, 2008; Le Marec & Schiele, 2018; Lewenstein, 1992a, 1992b; Massarani et al., 2015; Papanelopoulou et al., 2016; Raichvarg & Jacques, 1991; Sahoo, 2009; Trench & Bucchi, 2014; Wu & Qiu, 2013.

Daum (2006) marks the beginning of the history of science communication with the critical examination of the dissemination of knowledge at the time of Gutenberg and Copernicus. But it is only with the beginning of the Enlightenment in the early modern era that we also begin to consider the popularisation of science as an effort to consciously build a relationship between knowledge and society (Daum, 2006). Until the 17th century it was mainly the court's duty to determine the credibility of scientific representations in public demonstrations (Weingart, 2005). Shapin (1984, 1991) introduced the term of the "modest witness" to describe how the audience of the court witnessed public presentations of scientific experiments to attribute credibility. In this regard, science and audience have always been dependent on each other (Weingart, 2005). Even back then, the aim was to legitimise scientific experiments, but less to secure public funding and more to guarantee

testimony to scientific findings. At the same time, society at large had little or no access to knowledge, not everyone could go to school, and accordingly, the transfer of knowledge to society was often a matter of concern for individual scientists.

While the founding of the Royal Society in London and the Académie des Sciences in Paris in the late 17th century marked the first efforts towards the institutionalisation of science (Lüthje, 2013), Weingart (2005, p.14) describes the 18th century, especially with regard to Germany, still as the golden age of amateur scientists. He justifies this statement with the less strict institutional separation between scientists and non-scientists and the popularity of public experiments. In view of how the boundaries between scientists and non-scientists are once again blurring in social media, and how the amateurish represents authenticity and thus success, the question arises as to whether we are once again in a golden age of amateurs in science communication.[35] Back in the 18th century, science became more differentiated, which was reflected in a stronger demarcation of the role of the scientist and the place of research. This also led to a gradual shift of credibility attributed to institutions instead of individual scientists. Following, science communication was divided into primary (primarily internal scientific) and secondary (primarily external) science communication (Weingart, 2005). However, it is difficult to draw a clear line between internal science communication and external science communication. The increasing differentiation of research topics in particular has blurred these boundaries even more in recent years.

In Germany, Alexander von Humboldt addressed the general public in 1827 and 1828 in 16 lectures on "physical geography" (Lüthje, 2013; Wulf, 2015), promoting the development of German educational idealism (Faulstich, 2006) as well as the rising importance of the natural sciences. For Daum (2006, p. 38), the period after 1848 is the actual dynamic phase of the popularisation of science. Statements and recommendations were formulated primarily in the practice of knowledge transfer and education, which, in addition to an increasing differentiation of the target groups, also resulted in a greater variety of forms of popularisation (Daum, 2006). Various forms of popularisation of science can be observed again today, for example, in the use of social media platforms. As a result of the idea to

[35] Orthia (2016) also identifies commonalities of modern science communication ideals and the Sketch for Historical Picture of the Progress of the Human Mind (1795) - a work on the democratisation of science in the 18th century.

educate the public, there was now a greater differentiation between scientists and non-scientists, between those who belonged to a scientific institution and those who did not. In the following, boundary work (Gieryn, 1983) as a demarcation of scientific practice from the church or pseudo-sciences became more important to consolidate the institutionalisation of science[36]. At the end of the 18th century, the bourgeois self-image and thus the role of the public changed (Faulstich, 2006).

The demand for more democracy in the following led to the development of popular science communication (Daum, 2006), resulting in new structures of public communication, such as the table societies in Germany. Particularly at the beginning of the early 19th century, more and more such reading societies were formed as a counter-draft to education outside academic institutions (Faulstich, 2006). The introduction of scientific journals, the peer-review procedure for formalising communication, particularly within the scientific community, marked another step towards a more differentiated and professionalised form of science communication. The founding of scientific associations and journals and the opening of zoological and botanical gardens as well as natural history museums characterised the peak phase of popularisation throughout the entire 19th century (Daum, 2006). At the same time, this period marks the formalisation of science communication through scientific journals and public relations departments. A little more than 200 years later, there is now a network of over 50,000 journals with several million publications per year (Bauer, 2017).

It was only towards the end of the 19th and beginning of the 20th century that science communication started to change (Weingart, 2005). Initially, this change was based on an inner-scientific pluralisation of disciplines and the beginning of industrialisation. The faster production of knowledge led to a growing gap between science and the public. Together with the emergence of the mass media and a concomitant commercialisation of science communication in the 20th century, intermediaries or mediators in the form of science journalists became increasingly important for maintaining communication between science

[36] With the emergence of Web 2.0 and the negotiation of science in the internet, boundary work can also be observed in current cases, e.g. in science blogs, see Wenninger (2019).

and the public (Bauer, 2017; Daum, 2006; Weingart, 2005)[37]. In the USA, the Association of Science Writers was founded in the 1930s, and similar efforts to professionalise science communication can also be observed in the UK and other countries (Bauer, 2017). Figure 4 not only displays the growing importance of science journalism but also of public relations in science in the mid-20th century (see, for example, Bennato, 2017). The discussion on the extent to which science journalism and public relations can be counted as science communication, and whether non-scientists, like journalists, have sufficient knowledge to communicate science to the public is a discussion that is still ongoing today (Bauer & Bucchi, 2010; Shipman, 2014). After the end of World War I, science increasingly lost the support of the public and explicit consideration was given to establish concepts of science communication. Losing trust, the so-called problem of legitimacy for science then displaced the claim to autonomy that had been consolidated since the 17th century (Weingart, 2005). The defence against direct influences of society on the production of knowledge could no longer be maintained.

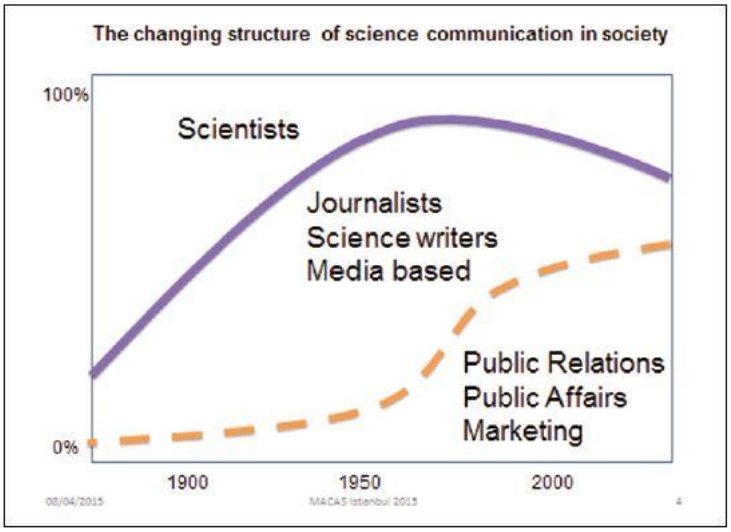


Figure 4: The changing structure of science communication in society (Bauer, 2017, p. 22).

These developments led directly to the emergence of the deficit model and hence PUS, which was described at the beginning of this chapter. They also demonstrate the importance of legitimising scientific work from a historical perspective. Even modern models such as

[37] There are a large number of publications on the historical development of science journalism, especially with regard to mass media science communication (also known as mediatization). I will not go into this in detail in my work, but want to recommend a selection of publications on this topic: Bauer and Bucchi (2010), Rödder and Schäfer (2010), Peters et al. (2010), Ivanova et al. (2013) or Schäfer (2008).

PEST continue to be based on this need for legitimacy - even if they emphasise the dialogue between science and society and thus reject the concept of scientific literacy. The emergence of social media platforms in recent years has brought new actors into play and may call the need for legitimacy into question. Social media platforms focus on the direct exchange between users and producers and underline the dialogue at eye level. They again enable scientists to communicate directly with the public, to experiment and thus possibly generate mechanisms similar to those we have observed in historical retrospect. At the same time, they provide new actors access to science communication and knowledge transfer.

Medialisation 2.0: What is new about the new media?

Since the development of Web 2.0 technologies, scientific topics have been discussed increasingly on private blogs and are also present on social media platforms such as Twitter, Facebook, Instagram or YouTube. It seems that science communication is experiencing a similar peak of amateurism as it did in the 18th century. However, the internet and social media platforms today allow a faster and wider dissemination of knowledge. Thus, the question arises as to what effects this will have and how new formats will develop accordingly. Although digitalisation and the increasing importance of social media platforms are creating new opportunities, they also present challenges for science communication. A wider range, diverse formats of presentation (e.g. video formats, music, games) as well as an improved opportunity for participation can initially be seen as positive and may possibly lead to a popularisation of science (Bubela et al., 2009). However, it seems uncertain whether content reaches the audience and some publications warn that the popularisation of science in the internet may lead to a possible loss of credibility of science due to the lack of gatekeepers (Bubela et al., 2009; Peters et al., 2014).

The new technical infrastructures allow access to information at any time and any place and enable everyone to publish and disseminate information. It also contributes to revealing the uncertainty of epistemic processes as well as the uncertainty in the communication of these processes as part of scientific work (Trench, 2014). With the growing number of scientific information as well as the inevitable visibility of uncertainties in science, it becomes more difficult for users to identify which information is relevant and which sources they can trust.

The observable effects of Web 2.0 technologies on the working practices of science journalism seem to be similar. Even though new niches, such as online journalism, and new business models in journalism in general are developing at a slower pace (Peters et al., 2014), the effects can be seen, for example, regarding an increasing plurality of roles in science journalism driven by essential skills of criticism, synthesis and analysis (Fahy & Nisbet, 2011).

This is also reflected by the fact that journalists need more time for research on breaking news but correspondingly have less time for detailed coverage (Granado, 2011). It also shows the ongoing difficult relationship between scientists and journalists. With the possibilities of Web 2.0, scientists who are critical of how scientific topics are covered in traditional media can now avoid journalists as gatekeepers (Colson, 2011). They can publish their work via blogs or social media platforms such as Twitter, Facebook, Instagram, TikTok or YouTube. For Colson (2011, p. 900), "the creation of a science blog is thus mainly based on the desire to bypass traditional media". On the other hand, science journalists still seem to prefer to get information from peer-reviewed journals rather than through science blogs. However, the effects of Web 2.0 are also apparent regarding the publication process in science (Dickel & Franzen, 2015; Trench, 2014).

With the growing number of social media platforms, the possibilities for new forms of science communication are also increasing. In addition to text-based formats such as Twitter and blogs, platforms that support (audio) visual formats are particularly popular. On Instagram, TikTok, YouTube and others, scientific content is communicated primarily visually. This also corresponds to research on visual literacy and the importance of the visual in science communication (see, for example, Trumbo, 2000) [38]. Bucchi and Saracino (2016) emphasise that visualisation is better remembered and offers more opportunities for public engagement. In a similar way to how Daum (2006) describes the consequences of popularisation in the 19th century, the explosive growth in the diversity of digital media and social media platforms may also lead to recommendations and commitments from institutionalised science to foster science communication and public engagement. Specific

[38] For a deeper insight into the importance of the visual in science and science communication, see e.g. Burri (2008), Tuma and Schmidt (2013) or Traue (2013).

groups can now be addressed in a more targeted manner and the number of communicators entering the stage of science communication and experimenting with diverse and creative formats has increased throughout the last couple of years.

As a result, institutionalised science seems to increasingly lose control over what content is brought to the public by whom and in what form. For science, this recalls the role of the observer instead of a participant in the development of new communication formats on less controllable platforms than before (Peters et al., 2014). I argue at this point that only through the acceptance of this communicative evolution and the accompanying research can science learn how to integrate proven models and how they can be expanded or renewed in the modern infrastructures of digital media. Nevertheless, the number of published research papers on social media platforms is extremely small in comparison to papers published on journalism and mass media (Gerber et al., 2020). At the same time, the number of people who inform themselves about science in social media is growing (for Germany, see Wissenschaft im Dialog/TNS Emnid, 2015, 2016, 2018).

With regard to YouTube, the figures collected by the “Wissenschaftsbarometer” (Science Barometer) 2015, 2016 as well as 2018 (Wissenschaft im Dialog/TNS Emnid, 2015, 2016, 2018) illustrate the growing relevance of audio-visual content in the digital environment in Germany. The representative survey conducted by the non-profit organization “Wissenschaft im Dialog” (Science in Dialogue) states that already in 2015 about 60% of the 14- to 29-year-olds use video platforms such as YouTube to obtain information on scientific topics (Wissenschaft im Dialog/TNS Emnid, 2015). However, in 2015, there were hardly any scientific publications or studies on science and technology communication on video platforms in general and on YouTube in particular. Unsurprisingly, Allgaier (2013) demanded the need for more intensive research in this area and called for a sociological approach to better understand how videos are shared and how they affect the public and science itself. Not only the increasing availability of information everywhere and at any time but also the rising importance of visualisations in science communication may be reasons why YouTube is becoming more and more relevant for science communication and knowledge transfer (see e.g. Rat für Kulturelle Bildung e.V., 2019).

As described in more detail in the previous chapter, studies on various topics regarding e.g. the video interaction and video sharing (Benevenuto et al., 2008; Benevenuto et al., 2009; Cheng et al., 2008; Haridakis & Hanson, 2009; Snelson, 2011) as well as on participatory factors of YouTube (Burgess & Green, 2018) do exist. However, research specialising on science communication on YouTube is hard to find. Scientific or educational content on YouTube is often assigned to the category of How To videos (Allocca, 2018; Morain & Swarts, 2012). Especially since 2012 (Allocca, 2018) this category has gained in importance and has contributed significantly to the steadily growing popularity of YouTube. Looking for How To videos, people display a range of interests from practical to creative, from style to cuisine, mainly using the possibilities of mobile technology and expecting immediate answers (Mogensen, 2015). Based on a Google Consumer Survey done in April 2015 (U.S. Online population aged 18-34, n = 385), 67% of millennials agree that they can find a YouTube video on anything they want to learn (Mogensen, 2015). One very popular example of the importance of this form of audio-visual online learning is the Kenyan athlete Julius Yego, known as "Mr. YouTube Man", who taught himself to throw the javelin with the help of YouTube videos and finally won a silver medal during the 2016 Summer Olympics (Howell, 2016).

In the inner-scientific communication context, YouTube seems to have received little attention so far (Geipel, 2017). A look at the platform reveals only isolated examples. One such format is the "Video Abstract". Journals such as "The Cell Press" or the "New Journal of Physics" have been using this format since the early 2000s (Berkowitz, 2013) as an audio-visual summary of scientific publications. Both journals are, among others, represented with their own channel on YouTube. Journal editors and scientists alike hope that this format will attract more attention to the articles published. However, whether the publication of such videos actually positively influences the impact of scientific publications could not be proven (Spicer, 2015). Further examples can be found in the scientific peer-reviewed video journal (Journal of Visualized Experiments - JoVE), which also maintains a channel on the platform, as well as in individual recordings of symposia and conferences uploaded by research institutions.

YouTube seems to be of greater importance for external science communication. For example, 44 % of the 1,004 respondents living in Germany use YouTube or similar video platforms to obtain information about science and research (Wissenschaft im Dialog/TNS Emnid, 2015). Higher education institutions use the video platform for science PR as well as for the archival provision of teaching content and aim to reach a potentially broader public beyond their core student group. Channels of individuals, however, attract considerably more attention than channels of scientific institutions (Allgaier, 2016). The central reason for channel creators producing science videos on YouTube is often described as a personal interest in a specific scientific field or the passion to create creative and entertaining scientific content (Geipel, 2018). That science communication on YouTube holds great potential is also recognised by institutionalised science communication, which accordingly attempts to promote formats that meet scientific criteria. Since 2013, for example, the jury of the German web video competition “Fast Forward Science” of the initiative “Wissenschaft im Dialog” award science online videos regarding their entertainment value, originality and scientific correctness. Furthermore, the journal “Spektrum der Wissenschaft” (Spectrum of Science) publishes reviews of web videos on its website and thus attempts to curate audio-visual contributions on scientific topics published online (Körkel, 2016).

On YouTube, the audio-visual offer of science communication and education is just as diverse as that of the entire platform. Users may find videos of well-known scientific institutions, next to documentations uploaded on channels of public broadcasters as well as channels of scientists, journalists and other content creators presenting scientific content. In addition to How To videos, there are many other formats, such as comedy content, animations or music videos. YouTube videos may be used in schools or at universities for educational purposes (Mitra et al., 2010; Rat für Kulturelle Bildung e.V., 2019; Seyffarth, 2016). Students and teachers seem to use the videos to prepare for lessons or examinations but also to introduce new ways of learning. However, tutorials and educational videos are only one part of the reason why the importance of YouTube for science communication is increasing. Channels not only address children and students but also grownups, scientists or journalists to inform, educate or entertain (Alegre-Martínez et al., 2020; Garg et al., 2015; Snelson, 2011; Tan, 2013).

In 2015, Welbourne and Grant published results of a content analysis of 390 videos from 39 YouTube channels and displayed content factors that affect the popularity of science communication videos. In an online article, they summarised their results to seven factors that can help make science YouTube videos successful (Welbourne & Grant, 2015). The first factors relate to general characteristics of a channel like style and topic. Others recommend producers to publish short presentations but also to become part of the community, highlighting how important the personality of a regular communicator is. While it seemed to be important which topic producers pick for their videos, and the techniques they use to present their content, how they tell their story does not seem to be important for a successful science YouTuber. However, when it comes to video production in general, storytelling has often been pointed out to be an important online and offline tool (Davidson, 2013a). The YouTuber Magazine stated in a blog post that "they [YouTubers] take storytelling to a new dimension" (Vierra, 2017). Storytelling has also been discussed for its usage in science communication. In 2014, Dahlstrom stated that storytelling and narratives are important tools when communicating science and might become even more important in new media.

When style seems to be one important marker for successful science communication on YouTube, the question arises how style can be defined. In their contribution on the typology of science web videos, Morcillo et al. (2016) identify a large number of different genres (most frequently: documentation, animation and reportage) and subgenres (e.g. within the genres documentation and animation the subgenres question & answers, live drawing, live writing or live experiments)[39]. In analysing 200 videos of 100 channels on YouTube, vimeo and the Tesla blog, they described several factors such as video editing techniques and narrative strategies. Although they did not provide markers for successful online science videos, they stressed the fact that YouTubers and other online filmmakers must be storytelling experts to become successful. Moreover, they argue that a well-told story can outbalance bad video quality and minor sound problems. In a follow-up paper on the same dataset, Morcillo et al. (2019) focused on the producers of science online videos, arguing

[39] While Morcillo et al. (2016) use the term genre to describe different formats of science online videos, I use the term to describe different topic-related communities on YouTube – like the genre of Beauty Tutorials or Gaming videos.

that science YouTubers display a high level of professionalism which distorts the distinction between the categories of professionally generated and user generated content (as introduced by Kim, 2012 and others). Instead of high audio-visual quality, a high production frequency as well as storytelling seem to be linked to success. They demand more research to get a clearer picture of how platform-specific professionalism and expertise can be defined, as well as how success is defined by the platform as well as by the producers.

In 2016, Erviti and Stengler conducted in-depth interviews with five professional science YouTube producers from the UK to identify strategies of successful science channels. They argue that established TV producers pursue interactive science communication formats in focussing on a high level of performativity and community-building. In this context, they compete with non-professional content producers with the advantage of having more resources and staff to create high quality content. Regarding the question of success, the answers stressed the importance of video sharing and the news value of the presented story. To what extent, for example, the sharing of science videos depends on the infrastructure of the platform and how this in turn influences the production of such videos needs further investigation. However, it seems to be clear that through the algorithmically determined infrastructure of the video platform, communication patterns, including those of science communication, are changed and subjected to new rules.

In 2018, Erviti focused her research on online video producers dealing with the topics climate change, vaccines and nanotechnology. In a content analysis she focused on the producers, including the type of producer, as well as age and gender of presenters, video formats, and objectives pursued by the producers. She identifies new subgenres in science YouTube videos following the work done by Morcillo et al. (2016) and therefore once more highlights the wide range of different science video formats on the platform. Regarding the objectives pursued by the producers, she identifies information dissemination, awareness, commercial imperatives and infotainment as being more important than entertainment as the sole goal. This publication has been published together with others on the topic of science communication in online videos (León & Bourk, 2018a).

The other contributions deal with classifications of different formats (García-Avilés & Lara, 2018; León & Bourk, 2018b), controversies (Erviti et al., 2018) and rigour (Francés & Peris,

2018) in science online videos, the use of audio-visual formats in University Corporate Communication (Ùbeda & Llorca-Abad, 2018), the transformation of narrative environmental documentaries (Davis & León, 2018) and the framing in videos on climate change (León et al., 2018), as well as the question of the usefulness of entertainment in science videos (Bourk et al., 2018). A more practical view on science online videos can be found in the publication by Körkel and Hoppenhaus (2016). Alongside links to science YouTube channels, the contributions encompass comments on popular culture (Allgaier, 2016) or general success factors described by the founder of the first German YouTube network Mediakraft (Krachten, 2016) as well as other research papers and interviews with experts.

Reif et al. (2020) recently published work on the trustworthiness of scientific experts in YouTube videos, taking the role of emotion in science communication into account. In an experimental online survey of 155 people (aged 18-80), they examined expertise, integrity and benevolence as variables for trustworthiness using six different video stimuli regarding format (TV interviews vs. YouTube videos), gender (male vs. female) and age of the expert (old vs. young). For the emotional assessment, three different types were defined: affective regarding the feeling of being entertained, cognitive regarding comprehensibility, and stereotypes related to the scientists. The results suggest that while scientific experts in TV interviews seem to be perceived as more competent, science YouTubers were attributed with integrity and benevolence regarding their communication skills and based on emotional assessments. The authors point out that the differences might be influenced by the fact that the science YouTubers (here referred to as "sciencetubers") are "professional science communicators" (Reif et al., 2020, p. 202), while the scientists interviewed are seen as less skilled regarding their communication skills.

Here the question arises whether science journalists (e.g. presenters of science formats on television) would not be a better reference group. At the same time, this study does not consider the influence of the communication platform (TV vs. YouTube) itself and its conditions, both in terms of attributing a professional communication strategy as well as attributing credibility and trust. They concluded that "If audiences feel more entertained by, and/or understand scientific experts' explanations, this can have a positive effect on

perceived trustworthiness" (Reif et al., 2020, p. 203). However, it remains unclear which factors cause the feeling of being entertained. It is also unclear to what extent this emotional attribution is subject to mutual negotiations between science YouTubers, viewers and the platform, and how trustworthiness is attributed when science is presented on YouTube by non-scientists who are still perceived as professional science commentators.

In another study, Luzon (2019) investigates which multimodal strategies are used by research groups in their online videos to construct credibility and authority, to generate persuasive arguments, to adapt information to the presumed knowledge of the viewers, and to engage and bond with them. Luzon (2019) argues that credibility and authority are established by naming the affiliation to the research institution as well as by verbal and visual modes of demonstrating and explaining science (e.g. by using discipline-specific equipment). Images are used to support arguments and narratives. They also serve to improve comprehensibility, for example, by enriching the understanding of definitions. Strategies to engage viewers are based on the interplay of speech (e.g. grammatical forms to support intimacy or affinity), images and gestures. However, it remains unclear how exactly this interplay occurs and what influence platform-specific requirements might have on it.

What these and other publications on science communication on YouTube share is the fact that they often focus on the accuracy of scientific content (e.g. Allgaier, 2013), the typologies of science online videos (e.g. Morcillo et al., 2016) or the producers of those videos (e.g. Morcillo et al., 2019). This is often accompanied by the question of whether entertainment or science communication in social media in general is useful (e.g. Bourk et al., 2018). Only a few studies exist on the reception of science YouTube videos (e.g. Reif et al., 2020). And even fewer exist combining the concepts of platform studies presented in the previous chapter with the concepts of science communication research, asking for production mechanisms and reception patterns in reference to the platform mechanisms. In addition, science video producers who are neither scientists nor journalists are disregarded in these investigations. These new actors of science communication on social media platforms are described, for example, by Könneker (2020) who introduces a new model of science communication alongside the developments of science communication on social media platforms (p. 27). Here those new actors appear next to scientists, PR departments of scientific institutions and science journalists.

However, we still know too little about who the producers of science YouTube videos are, what communication concepts they use, how their production processes are influenced by YouTube's platform politics and how this affects the reception of science communication on YouTube, for example, in terms of trust and credibility. Especially, when considering the increasing professionalisation of the platform in recent years, the question arises as to whether professionally produced content – in particular from non-scientist individuals - and other factors influence the success of scientific online videos. To what extent does the perception of expertise change in this context and does this possibly even influence how we communicate science outside of social media platforms?

Before I present my research questions in detail in the next chapter, I will first discuss the conceptual problems in doing research on science communication on YouTube. As has already been outlined in the description of the history and the different formats of science communication on YouTube, the term science communication can cover numerous aspects. For example, science communication can mean the communication of new scientific findings or the communication of scientific methods (e.g. science journalism) as well as the passing on of already consolidated knowledge in an educational context (e.g. in the How To videos on YouTube described above). While a distinction is made here not only with regard to the objective of communication but also with respect to the content to be communicated, the division into internal and external science communication (Weingart, 2005) is just as prevalent - i.e. communication between scientific disciplines as opposed to communication between science and the public(s). In the case of the latter in particular, the question arises as to whether members of other scientific disciplines also belong to the public and whether the boundaries between internal and external science are thus difficult to define (see also Collins & Evans, 2002).

Burns et al. (2003) therefore define science communication based on the reactions to science: Awareness, Enjoyment, Interest, Opinion-forming, and Understanding and thus present an outcomes-type view of science communication. This view can probably best be transferred to YouTube as a social media platform. Especially here one can directly observe the reaction of the audience to uploaded videos. The intended expectations of the viewers are correspondingly significant, which in turn influence the video production and thus the

selection of content. In my work, however, I have decided to use the term "science communication" as broadly as possible. By this, I mean that the term represents both internal and external science communication, and encompasses educational aspects (science education), entertaining aspects (edutainment) as well as informative aspects (science channels also often present journalistic or news related content). Instead of defining science communication, I follow the platform's "definition" for my empirical research. This implies that for me, all videos tagged with "science" fall under the term of science communication on YouTube for the time being - this also includes YouTubers who describe themselves as science YouTubers and may encompass channels presenting scientific knowledge alongside entertaining and or news-related content. In this context, it is also important to mention that the term science communication, as used in my research, does not only include the communication of the natural sciences but also the communication of the humanities (e.g. history or sociology).

Asking the right questions

Having described how YouTube as a platform works and how science communication has evolved throughout history until the point where we can observe a rising number of science online videos produced by amateurs, several questions arise which I addressed in my research. When looking at YouTube, the convergence culture and discussions regarding platform studies as well as theories on the platform politics, such as restrictions to become part of the platform and of public discourse, are prevalent. Here, the technology as well as the actors surrounding and influencing it are at the centre of interest. By focussing on them, we learn to understand functionalities and rules specific to those platforms: How to upload a video; why specific videos become visible and others don't; how the interaction between several platforms in an infrastructure of sharing and popularity works and how this might influence public debates on social network sites. We also learn specific aspects of becoming an expert on those platforms, which rules to follow and which communities to become part of to gain more knowledge as a science YouTuber.

On the other hand, the history of science communication displays several discussions about how to communicate science based on different theories, such as the deficit model or the results of the "Science and Society" report. It also became apparent that direct

communicative and amateurish formats have a long tradition in science communication. In addition, it was shown that discussions in science communication, for example, regarding the question who should be allowed to talk about science, often evolve around the question whether the content is presented correctly. Especially regarding the growing importance of storytelling in online science communication, the question arises of whether telling correct stories instead of telling engaging and entertaining stories is more important. In line with this question is the discussion evolving around concepts, like PEST, on how important the engagement and participation of citizens might be for modern science communication. Accordingly, also the importance for science communication of connecting to the audience via emotions has been discussed in recent years (see, for example, Davies, 2019; Reif et al., 2020).

The focus of the evolving research around science communication on social media platforms so far was either on how scientists use those platforms for their work, how the audience uses those platforms to inform itself or whether the presented content is correct or incorrect. We learned that the number of people (especially young people) using social media platforms to inform themselves is increasing – as is the number of students using social media platforms as a resource for learning and education. We also learned that scientists use social media platforms mainly to increase their popularity, to spread word about their research and to foster their career. And we learned that social media platforms are places where a lot of conspiracy theories are spread but also where new formats and actors present the rather entertaining parts of science and science communication.

When looking at both of those parts, YouTube in the light of platform studies and science communication research on social media platforms, there seems to be a missing link. Namely, how those platform politics influence science communication. It becomes more important to rather ask HOW the two are connected than to ask WHAT is presented. When I started my research in 2015 only a couple of studies on science communication on YouTube had been published. Most of them displayed the typology of science YouTube channels or the arising possibilities and problems with content presented by non-scientists/amateurs. Looking at the number of science YouTube channels, I therefore initially wondered how YouTube's platform politics might influence science communication.

How does YouTube influence science communication?

In order to answer this question, I wanted to get to know the culture of YouTube in general and of the science YouTube community in particular. Therefore, the first steps were to get a multifaceted view on how the platform politics can be described in the science YouTube community. I started with a document analysis and watched a lot of science YouTube videos to get a deeper understanding of how the platform works and who the producers are. When I realised that only videos which enable comments and foster discussions in order to create a community would be relevant to answer this question, I decided to focus on the production of those videos and how this process is influenced by the platform's politics.

How does YouTube influence the production of science YouTube videos?

When asking the question of how YouTube's platform politics influence the production of science YouTube videos, I started my data collection in applying interviews and ethnography. In doing so, I learnt that science YouTube producers can be described as a new kind of experts. Experts of the platform and thus professionalised amateurs as described above. I therefore started to wonder how those science YouTubers become experts of the platform but also how their communities define them as experts. And further on, how they specifically challenge concepts of expertise in the field of public understanding of science.

How does YouTube influence how science YouTubers become experts?

For this question, I also took the community and the viewers into account. While science YouTubers are communicators, they only rarely see themselves as journalists – or as scientists – even if they are one of the two outside of YouTube. Instead, they describe themselves as YouTubers. The question arises as to how those science YouTubers are seen as experts by their audiences. When do the viewers decide whom to trust and whom not to trust? And what are the characteristics of expertise when it comes to science communication on YouTube? And lastly, do these characteristics influence science communication in general?

In the following, I will first present my methodological approach and describe in detail the methods used and the selection of cases. Subsequently, I will present my analytical concepts based on the data collected.

2. FROM CHALLENGES TO METHODS – HOW TO DO RESEARCH ON YOUTUBE?

In this chapter, I will start by taking a look at the challenges one faces when exploring social media platforms in general and YouTube in particular. Based on this, I will show why a mixed-methods approach is the most promising way to answer my research questions and why I have chosen Grounded Theory for the analysis of the collected data. Afterwards, I will go into detail about the methods used, before I explain my case selection and the key terms used in my work at the end of the chapter.

How to deal with challenges

When asking the question of how YouTube as a platform influences the expertise of creating science YouTube videos, YouTube not only serves as a social video platform distributing videos but rather becomes an object of study itself. With the possibility to not only watch videos but to also upload, share and comment on them, YouTube can be defined as a social network site (SNS) enabling "users to articulate and make visible their social networks" (boyd & Ellison, 2007, p. 211). SNS are also well known for ongoing technological changes, their growing numbers of users and their even faster growing body of content. The question arises how to do research on social network sites especially when focussing on the social characteristics of digital observations. A, in this sense, established social scientific methodology is only just emerging (Jürgens, 2012). It is therefore necessary to study a social network site, like YouTube, in its whole technological, social and cultural entity. This means taking into account the algorithms that are created by the software developers, as well as the content creators, the videos themselves and the interactional processes of watching, sharing and commenting.

In his essay "Representing Television", Heath (1990) wrote about the difficulties in approaching television. According to him,

> (…) television is a somewhat difficult object, unstable, all over the place, tending derisively to escape anything we can say about it: given the speed of its changes (in technology, economics, programming), its interminable flow (of images and sounds, their endlessly disappearing present), its quantitative everydayness (the very quality of this medium each and every day), how can we *represent* television? (p. 267)

For Heath (1990), representing television brings up several methodological challenges, such as the speed of changes not only regarding the technology but also the programming, along with the ever changing audio-visual content presented. 30 years ago he was describing the number of things covering the term television – things like developments over time, geographical differences or the relation of television to video – not knowing that with the emergence of YouTube in 2005 it would be an even more difficult and unstable object to study, "marked by dynamic change (both in terms of videos and organisation), a similar quotidian frequency, or 'everydayness' to television and an almost incomprehensibly large and highly diverse archive of video content" (Burgess & Green, 2018, pp. 13–14). With more than two billion users in 91 countries watching one billion hours of video material per day (YouTube, 2020c), YouTube can undoubtedly be described as a very large and highly diverse archive of video content. In addition, treating YouTube as an object of study becomes "further complicated by its dual function as both a 'top-down' platform for the distribution of popular culture and a 'bottom-up' platform for vernacular creativity; and the ongoing blurring of the boundaries between the two" (Burgess & Green, 2018, p. 14).

This again highlights the difficulties in the algorithms created by the software developers and the users constantly interacting and, in this sense, shaping those algorithms. While on one day you might want to analyse a certain trend, this trend might be gone on the next day – and, even worse, the videos you wanted to study are no longer there. Even if you are lucky and the video is still there, it will be hard to get access to all the data you are interested in, due to proper software tools, anonymous comments and unclear offline behaviour that may have affected the trend. In his 2012 paper, Jürgens formulated challenges in social media analysis capturing the examples mentioned above. Next to the temporal instability of social media and the unclear relation between online and offline behaviour, ethics regarding anonymised datasets as well as data logistics regarding proper software tools, hardware and storage might be obstacles in the process of studying social media. While there are also opportunities in social media analysis, such as higher measurement precisions in digital traces, Jürgens (2012) highlights that "statistical approaches summarized under the label of data mining, cannot produce insights without human interpretation" (p. 191).

In this sense, a mixture of several methods with reference to three different groups of approaches – ethnographical approaches, statistical approaches, and computational approaches (Ricolfi, 1997 cited in Giglietto et al., 2012)[40] – becomes beneficial in order "to understand the distinctive affordances of each platform, their cultures of use and social norms, and how the co-evolution of their business models, technologies, and uses are shaping and reshaping media and communication" (Burgess & Green, 2018, p. 14). While computational approaches[41] can be pursued with digital methods as introduced by Rogers (2013) and the "Digital Methods Initiative"[42], ethnographical approaches[43] help to contextualise the analysis, to re-connect the offline with the online behaviour. Using APIs (application programming interfaces) to retrieve comments, description and other metadata of single videos or entire channels helps to get a closer look at different forms of interaction.

Giglietto et al. (2012) describe three forms of interaction on YouTube: audience interactions, social interactions and platform interactions. Different metrics measured can be assigned to different forms of interactions, e.g. the number of views display audience interaction and the number of comments display social interaction, whereas the platform interactions are measured by metadata, such as title, date, tags and others (Giglietto et al., 2012). For the investigation of YouTube, however, not only the metadata assigned to the video or the comments by the viewers play a role but also the video itself. Unfortunately, we still lack tools for analysing audio-visual content in comparison to tools automatically collecting metadata and other text-based content via APIs. Ethnographic work, such as interactive video analysis in combination with digital methods, can help to bridge this gap and draw a picture of the platform's different forms of interaction as a whole. "However, effectively combining digital methods with close, qualitative approaches to social interactions and

[40] For the sake of simplicity, I will use the classification Giglietto uses in his text as a starting point for his reflections on investigating social media platforms. I am aware that this rhetorical classification is not a final one. For example, not all qualitative methods fall under the concept of ethnographic approaches. For me, however, my concern here is to what extent Giglietto discusses computational approaches in relation to other research methods and what influence this had on my methodological work.

[41] Giglietto et al. (2012, p. 147) described the computational approach as follows: "The computational approach is different from the statistical one because data are not organized in a matrix of variables and cases. Data are instead organized in a structure that recalls more a relational database than a spreadsheet. This is the reason why computational approaches do not necessarily need the use of statistics, even if univariate or bivariate data representations are useful to visualize some results".

[42] https://wiki.digitalmethods.net/Dmi/ToolDatabase (accessed: 25.02.2020).

[43] Examples for ethnographic work in order to analyse YouTube, see, for example, Lange (2007a, 2007b).

critical analysis of digital media content remains an ongoing challenge" (Burgess & Green, 2018, p. 17). Still, "mixed methods approaches are often the most promising but the least frequently used" (Giglietto et al., 2012, p. 155).

Based on my research questions and the complexity of the platform to be investigated, I decided to apply a mixed-methods approach. Thus, I consciously decided to use different methodological approaches in order to combine the results into a unified picture of the platform and the platform's influence on science communication. While exploiting the entire methodological range makes it possible to provide different insights into a complex platform like YouTube, I am also aware of the fact that this did not allow me to apply the individual methods in their depth. Especially for my approach, however, it is the combination of different approaches that matters because it is the best way to create a comprehensive picture in order to answer my questions and at the same time to open up further questions for following research projects. Therefore, I used a mixed-methods approach combining ethnographic work with digital methods (see table 1).

Method	**Material**	**Analytical Questions**
Semi-structured in-depth interviews	5 science YouTube channels were selected as cases	How the YouTubers' concepts of science communication and of the platform politics influence the video production.
Ethnographic field work	Channel 1, 2 & 5	How science YouTubers display their concepts and those of the platform in their production process.
Video analysis & Comment analysis (Membership Categorisation Analysis)	2 videos of Channel 1	How authenticity is co-constructed in an interactional process between producers and their community.
Document analysis (collected from blogs, newspapers, etc.)	--	How are science YouTube videos, the platform's politics and the producers received.

Table 1: Methods applied.

I analysed five science YouTube channels in depth and overall focused on 15 channels communicating science or educational content. Watching over 500 videos and reading more than 2,000 comments, I analysed the social video platform YouTube, the science YouTube community and its features as a socio-technical phenomenon through observation and analysis for over 4 years. The analytical part was composed of interviews, ethnographic work, consisting of memos, notes of videos, comments, video design, the community and

several articles published in newspapers, blogs and the YouTube Creator Academy. I used grounded theory as an analytical approach to develop thematic codes and formulate connections between various socio-technical elements.

Why Grounded Theory?

When I started studying science communication on YouTube in 2015, the viewership in the categories "How To & Style", "Education" and "Science & Technology" was rising, after taking off around 2011 – 2012 (Allocca, 2018) (see figure 5). Starting with the first How To videos or tutorials such as "How to Tie a Tie: The BEST Video to Tie a Double Windsor Knot", uploaded by Ben Buie in 2008, using the platform as a search engine became a typical way to get quick answers to everyday questions. In line with that, the first science channels, such as "Crash Course", "SciShow", "Veritasium" or "AsapSCIENCE", started to grow. While, on the one hand, the number of science YouTube channels was increasing, only few empirical studies existed that answered questions about the producers, the content presented or the communities forming around those channels (see, for example, Allgaier, 2013; Allgaier & Svalastog, 2015; Both, 2015; Morain & Swarts, 2012; Muller, 2008; Pandey et al., 2010; Tan, 2013).

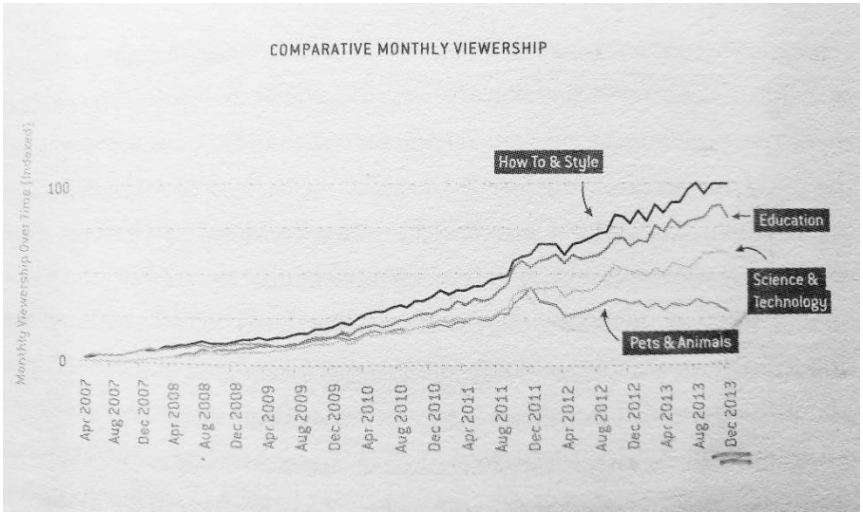


Figure 5: The rising importance of How To videos.
Comparative monthly viewership numbers for different YouTube genres displaying the sharp rise of 'Education' and 'Science & Technology' channels between 2011 and 2012 (Allocca, 2018, p. 159).

Therefore, I decided to work with Grounded Theory, a methodology to do exploratory qualitative social research and which is closely oriented towards social actors and their

everyday practices. This openness enables a multi-perspective approach to a new research field and allows me to combine the various methods used under one theoretical umbrella. In this sense, doing research applying the Grounded Theory approach is not based on hypothesis, it rather creates hypothesis to give hints for further research. In a continuing process of collecting memos and notes, the aim is to integrate a theoretical concept in order to describe a specific behavioural pattern of the observed community (Strauss, 1998).

Interviews with science YouTubers, analysis of videos and comments, memos and notes on published articles in newspapers and blogs as well as ethnographic field notes – these data are collected, coded and combined into a sample, whereby action and reflection continuously alternate. Herein, the leading idea is a constant comparative method (Strübing, 2008). With the help of empirical indicators, I was able to derive a concept that is initially provisional but may later be confirmed via following research projects. The comparison and replacement of indicators is only carried out until the ideas are exhausted. Therefore, data collection and the application of different methods is crucial because different data types represent different points of view and perspectives, which are taken into account by further coding for the emerging theory (Strauss, 1998).

How to apply a mixed-methods approach

To answer my research questions, I applied a mixed-methods approach combining digital methods with ethnographic work. Ethnographic work as one form of qualitative research aims to describe environments from the point of view of those involved for a better understanding of social realities (Flick et al., 2017; Knoblauch, 2001). I decided to apply interviews as well as ethnographic field work by visiting science YouTube producers at their production venue in order to compare both the YouTubers' statements and my observations. As given answers in interviews do not always reflect people's actions, e.g. while producing science YouTube videos, and observations may lack insights into concepts leading to action, combining both methods – as well as analysis of documents - help to complete the overall impression of how YouTube's platform politics might influence the production of science YouTube videos (Alkemeyer & Buschmann, 2016).

I applied semi-structured interviews (Flick et al., 2017) with creators of five science YouTube channels[44]. The questions were aligned to categories asking how the video creators decided to do science communication, how they started their YouTube channels, how they produce their videos in order to be successful and which feedback they get from their viewers (see table 2). The interviews enabled me to get a first impression of how science YouTube videos are produced, what are important aspects to take into account for becoming successful and how do science YouTubers define success regarding their personal motivation. The interviews were conducted via Skype calls or in person in 2015 and 2016, respectively, and lasted between 35 and 70 minutes. The interviews were transcribed with the f4 software using the GAT 2 system (Couper-Kuhlen et al., 2011). Four of the five interviews were conducted in German, which I therefore translated into English for this publication. I did a second interview with one channel producer, focussing on specific strategies to upload a video on YouTube and how to use metrics. I also recorded a talk of this YouTuber he gave to students in the humanities describing his work as a video creator on YouTube[45].

In addition to the interviews, I collected field notes (Flick et al., 2017) for three of the five cases, focussing on the production process. For two cases, ethnographic field work wasn't possible because of accessibility – e.g. when the producer didn't give permission. The field notes were collected in 2016 by visiting the producers in their living rooms or in their film studios. Time and dates were chosen according to the availability of the producers. For two cases, I observed the recording of one video, including preparations (e.g. setting up the camera). Additionally, I had the opportunity to spend two days at a video set of one case, observing the production of three videos, including preparations as well as discussions on post-production. I used a notebook to take field notes during and after the production process by hand and took pictures (if permission was given) to remember certain details afterwards. For ethical approval, the creators signed informed consent for the interviews as well as for the ethnographic field work. The channels will be described in detail in the next section. However, neither the content creators nor the names of the channels will be made public.

[44] For the question on how I built the sampling, see next section.
[45] While interviews will be presented in the next chapter with an I in the footnotes, the talk will be referenced with a T.

Semi-structured interviews

Main Question	Further Questions
How did you start with science communication?	What did you study? Why are you doing science communication?
How did you start your channel?	Why YouTube? How is it going? How many subscribers do you have? How much time and money do you spend? Is it worth it?
What are your goals for science communication on YouTube?	What do you want the users to do? What is the goal for every video? What is the goal of the whole channel? What do you think about the future of science communication? How important is YouTube? How do you see the future of YouTube?
What about the process of creating a video?	How long does it take to create a video? What about the process – single steps? Which tools do you use? What about the statistics? How do you do research on your topics?
Lessons learned – what is success? Can you give me some hints?	What is working what is not? Length of the videos? Content vs. design? Identity? Authenticity? Comments – participation/community? How would you define success?

Table 2: Semi-structured Interviews.
Example of questions I asked in the semi-structured interviews. I, however, adjusted details for different interview partners.

I further complemented my data collection by online-published interviews of science channel creators, modules of the YouTube Creator Academy as well as postings in a closed Facebook group of German science YouTubers, and articles published in newspapers and blogs. In doing so, I was able to follow up discussions between producers about YouTube's platform politics. Especially within the Facebook group, I could observe discussions on changes regarding YouTube's algorithms, e.g. about the demonetarisation of videos and the resulting adjustments in the production and uploading process. In addition, the analysis of published interviews of science YouTubers completed the impressions I already gained in the interviews and in the field work.

In order to further deconstruct the interactive communication process between the producers and their viewers, I did a video and comment analysis. This additional data served to gain deeper insights into the data already collected and to further consolidate the theory to be developed. In the sense of Strauss (1998), these are so-called "data slices" that provide a further perspective on the field to be analysed. Two videos of Channel I were selected for this analysis. This was done for several reasons. First, the producer of this channel was very open and, therefore, I was given additional information on the video production, on how the producer curates their comment section and how they adapt to comments of the channel community.

Second, the producer of this channel published a video in which he presented private information about his family. This was very uncommon and fell right into the time when I collected my data. The comparison of an unusual video with a typical video allowed me to take a closer look at the reactions of the viewers regarding the content as well as the producer. In doing so, I assumed that I could learn more about the relationship between the video producer and the viewers, especially concerning the video about the YouTuber's private life. Third, the analysis of a video that presented historical knowledge on a politically highly discussed topic seemed helpful in getting a closer look at whether and how viewers might differentiate between the producer's performance and the presented content. In choosing those two videos I wanted to compare different forms of interaction between the viewers and the producer to uncover how authenticity, as one part of expertise, might be negotiated.

Before applying video and comment analysis, I did a network analysis of the comments appearing under the videos to verify this assumption. By using a graph mining approach (boyd & Ellison, 2007; Giglietto et al., 2012) based on tools by the digital methods initiative, I was able to visualise the interactive behaviour of the two videos in a network graph[46].

The so collected videos were then examined in an extensive video and comment analysis, displaying different forms of how the producer tries to connect to the audience. Using Membership Categorization Analysis (Housley & Fitzgerald, 2015b), I focused on the intro sequence of each video to identify how the producer connects to the audience by analysing the YouTuber's demeanour and gesture, which words he used as well as the settings of the video. For Housley and Fitzgerald (2015a), the "Membership Categorization Analysis (MCA) refers to the study of the range of practices that members of a given speech community deploy alongside complementary and aligned ethnomethods in the routine accomplishment of everyday social interaction" (p. 1). The two videos were analysed sequentially to identify membership categories and their specific forms of communication. Therefore, the chosen sequence was transcribed using the GAT 2 system (Couper-Kuhlen et al., 2011).

[46] The network graph as well as the interactive behaviour underneath the two videos will be described in detail in Chapter 3.

The sequences were analysed in two sessions with experts in video analysis. Both sessions were recorded, and the conclusions drawn from them were incorporated into the overall analysis. In a second step, I conducted a qualitative content analysis (Flick et al., 2017) of the comments of the two videos. 2,334 comments for video I and 2,213 comments for video II were analysed by using tools published by the digital methods initiative[47]. I excluded comments that did not refer to the content of the video or the video producer (e.g. spam). I then selected the comments that contained feedback to the producer's performance and image. This process reduced the number of analysed comments to 198 for video I and 343 for video II. The remaining comments were then clustered into positive and negative categories, whereby positive comments include praise and encouragement and negative comments include criticism and hostility. In order to take a closer look at the interactional communication process between producer and viewer, I also identified comments where the producer directly responded to the comments of the viewers.

To better understand the platform politics, a research project together with students from the computational sciences was done to deconstruct the recommendation algorithms. This dataset again can be described as "data slice" which provides a further perspective on the field to be analysed. Looking at YouTube uncovers a pretty complex black box when it comes to recommendation algorithms and platform logics evolving around an incredibly high number of videos, channels and genres. The aim of this interdisciplinary project was to create a tool to identify the special characteristics of science-based videos on a frame-by-frame basis. The key question therefore was "how much scientific content do the videos of the YouTube-8M[48] data set contain, which are explicitly labelled as science" (Rummert et al., 2017). For this purpose, the students used the 2016 released YouTube-8M video dataset by Google (Abu-El-Haija et al., 2016). With around 8 million videos annotated with a vocabulary of 4,800 visual entities, it was the largest multi-label video classification data set. Using Knowledge Graph entities, Abu-El-Haija et al. (2016) tried to describe the main themes of a video: "The goal of this benchmark is to understand what is in the video and to summarize that into a few key topics" (p.3). They identified seven entities for the top category "science"; namely, Nature, Robot, Eye, Ice, Biology, Skin and Light.

[47] https://tools.digitalmethods.net/netvizz/youtube/ (accessed: 25.02.2020).
[48] https://research.google.com/youtube8m/ (accessed: 25.02.2020).

In our project, we wanted to take a closer look at these entities and define more detailed characteristics for science related videos. To accomplish this, the students first reviewed the literature and inspected related studies. This included analysing the YouTube-8M data set under certain factors, such as composition of the data set, the selection criteria for the videos and the associated characteristics of the videos. Unfortunately, YouTube-8M only provided very few labels for a whole video and the results of frame-level features were neither comprehensible nor reproducible, which denies the possibility of deriving science characteristics from the data. Another difficult aspect of the data set was that also the metadata of a video are used for labelling a video. It is difficult to understand how much weight the title or video description adds to the final labelling.

In addition, categorising scientific content was challenging since scientific characteristics were mainly displayed in the audio track than in the visuals. Also, the wide range of different formats (e.g. interviews, voice-over drawing or animation) used to display science in YouTube videos makes it difficult to detect specific characteristics. Therefore, the results of this project will only partly be included in my analysis. What could be learned from this project however is how recommendation algorithms are still mainly based on text instead of images. Therefore, labelling a video as part of the science category still lies in the responsibility of the producer, deciding on the title, the video description and the keywords selected.

How to define the sampling

For the selection of the five cases to which I applied semi-structured interviews and ethnographic field work, I chose an approach following the user's journey to study YouTube using the platform's paradigms (Jürgens, 2012). Based on the work of Rogers (2009, 2013) on digital methods, Jürgens (2012) highlights the importance of a platform-specific research, which focuses on the technological structure as well as the platform's culture to understand digital platforms in their entity. Following the user's journey could be to find an answer to a specific scientific question in using search engines like Google, to look up science channels on YouTube or to find a link to a specific video on other social media platforms or blogs. In all of those cases, YouTube's algorithm may recommend channels that are categorised as "how to", "science", "science & technology" or "education" regarding several characteristics such

as the words used in the video title, the description underneath the video and the keywords (resp. tags) selected by the video producer[49].

Producers as well as viewers only seldom have insights into why specific videos are assigned to one category or another. I therefore decided to not predefine the category "science" nor the terms "science communication", "science education" or "edutainment" but rather select the channels according to several search processes on YouTube with the word "science"[50]. This broad search produced a high number of diverse results. As mentioned before, videos with scientific content may, for example, belong to the category of How To videos. This means that videos in this category also deal with everyday issues, such as how to fix a drain. In addition, videos in the results may contain pseudo-scientific views, as well as topics presenting news or educational content. I have excluded videos that answer everyday questions as well as those with pseudo-scientific content. Since quite a few of the science YouTubers also deal with current world events, it is much harder to separate science from information or news. Often, scientific topics are derived from news, or a science YouTuber takes an active position on a political issue. At the same time, the areas of science communication and education overlap, as the target groups vary and both students and adults are addressed. Therefore, I didn't exclude channels that also present news or political topics as well as educational content.

As my research question didn't focus on the content but rather on how videos are produced depending on the platform politics, I also didn't decide on a specific scientific topic, nor did I exclude videos communicating topics from the humanities[51]. In disabling cookies and with cleaned cache memory data, I avoided interferences regarding the reliability of the findings due to search personalisation settings and filter bubbles (Pariser, 2012). The resulting list of channels included videos in the fields of science communication, education and edutainment dealing with topics from the natural sciences as well as the humanities. The languages of the channels selected were German and English.

[49] Although the algorithm of YouTube is a black box, there are some general assumptions on how recommendation algorithms work. For more information on recommendation algorithms, see, for example, Mager (2012) or Pöchhacker et al. (2017).
[50] See also Chapter 1 of the Main Part.
[51] As mentioned earlier, I use the term science communication very broadly, including the humanities.

In a second step, I decided to only include channels with videos that are exclusively produced for YouTube. This was done since the research question focused on the production process of science YouTube videos influenced by characteristics of the platform. Channels which contain material that was produced for other purposes, and therefore use the platform more as an archive than as a social network site, were excluded (e.g. promotional videos produced by universities or museums). I also excluded channels whose producers do not curate (resp. enable) their comment section and therefore do not take an active part in the interactional process of communication between the video creators and the viewers. Examples of excluded cases were channels created by institutions (e.g. universities, museums) but also TV documentaries or channels by broadcasting agencies. Nevertheless, one channel by a science centre as well as one produced by a public broadcaster were included in the sample.

In a third step, I compared the collected science channels with several articles published in newspapers (Süddeutsche Zeitung, Frankfurter Allgemeine Zeitung) as well as blog posts (American Scientist, SciViews, ScienceBlogs) and online articles (Wired, The Guardian, t3n) reviewing or recommending science YouTube channels. Regarding the work published by Morcillo et al. (2016), I decided to select cases displaying different forms of video production according to style (e.g. experiments, animations, interviews), presented content (e.g. physics, history, medicine, philosophy) and the producers creating the channels (e.g. designers, PhD students, professors). Since I wanted to gain insights into the production process and therefore decided to apply semi-structured interviews as well as field work, the selection of the cases was finally limited by the openness of the video producers to allow me access to their work.

Four of the five cases selected are produced in Germany, one is produced in the UK, three channels produce their videos in German, two in English. Channel I comprises videos about historical and political topics presented by a journalist producing the videos at home. In Channel II, a PhD student of computational science and a former student of physics present physics experiments to do at home. The videos are produced in a lab environment in a small film studio[52]. Channel III comprises animated videos about a broad range of topics (e.g.

[52] In 2019, the channel was re-named, and another content creator took over.

philosophy, astrophysics, medicine) produced by a collective group of designers. Channel IV is run by a science centre and presents videos of experiments to do at home. The videos are produced directly at the museum. Channel V is based on a TV show of a public broadcasting agency with a professor in physics and several young researchers explaining a broad range of scientific and political topics (but they do not use TV footage from the show).

When asking the question of how YouTube's platform politics influence the production of science videos, it is also necessary to ask the question of success. Success is also closely related to the concept of expertise on YouTube. Since YouTube's algorithm is a black box, the producers can only guess which markers lead to recommendations of videos and therefore which channels collect more followers. To deal with this insecurity they need to become experts to be successful. But what exactly does success mean on a platform like YouTube? Like any other social media platform, the obvious answer to the question of success are metrics such as the number of clicks, likes or how often content is shared (as, for example, in Welbourne & Grant, 2016). The same is true for YouTube. Throughout the last years, not only clicks and likes but also watch time (how many minutes a video was watched) and a high number of followers seem to be important markers for success (Cronin, 2019). Success, measured in this way, is often directly linked to the possibility of gaining money (see also Morcillo et al., 2019).

However, as science and education still are niche topics where only a few channels can gain more money than needed for the production, other markers for success replace quantitative measurements. In addition, monetisation sometimes isn't as important for science YouTubers as, for example, the popularity resulting from entertaining and extraordinary content (Erviti & Stengler, 2016) or the joy of transmitting their own passion for a specific scientific topic (Geipel, 2018). In addition, Weingart and Joubert (2019), for example, indicate that general motives for science communication are often political and accordingly suggest a distinction between educational /dialogic and promotional /persuasive science communication. Therefore, the question of success was asked in the interviews, whereby the individual definition was only partly important to answer the question of how the producers adapt to the platform's mechanisms in order to gain this specific success. When asked, science YouTubers defined success as ranging from the idea to share their own passion for a specific scientific field, to display that science isn't boring but rather fun, to

educate about how science works but also to promote themselves and support their own career (see also Geipel, 2018).

For my analysis, the definition was mainly important to understand how the platform works, how videos might be recommended as well as how individual concepts of success might influence the video production in close interaction with YouTube's recommendations. For answering the research question, the influence of science YouTubers' individual definition of success on the process of video production was as important as the influence of the platform itself. Both have an effect on how science YouTubers become experts. The concept of success also guided my field work and analysis to uncover how science YouTubers become experts. Therefore, both terms – success and expertise – will in the following be used synonymously, while success is more of a field term and expertise a theoretical term. Later on, the same can be observed when I further uncover the term expertise by taking a closer look at authenticity. As authenticity on YouTube is often seen as the currency of the platform, it is one major part of how the platform defines expertise. Authenticity at the same time is such a ubiquitous term that most people try to avoid using it when talking about YouTube. I could also observe this in my interviews. Instead of using the word authenticity, video producers described the idea of authenticity using words like personality, image or realness and honesty. Therefore, in my analysis I used authenticity as well as the many synonyms (e.g. personality, realness) as field terms, while coherence later on will be my theoretical term.

3. HOW TO BECOME AN EXPERT ON YOUTUBE – THE REAL STORY

In the following chapter, I will use the collected data to introduce my theoretical approach on how YouTube's platform politics influence how science YouTubers become experts. I will introduce the concepts that I believe explain how science YouTubers become experts based on specific knowledge about the platform as well as the negotiations between producers, users and the platform. For this purpose, I will use already known concepts that have discussed expertise in science communication or, respectively, in public understanding of science in recent years to then turn to the concept of authenticity on YouTube.

In the first subchapter, I will go into more detail on how negotiation processes between producers, users and algorithms determine the expertise of science YouTubers. I will compare the empirical material I have collected with theoretical concepts of expertise. Of central importance seems to be the process of achieving visibility on the platform. For this, producers must not only have sufficient expertise in production, experience-based expertise and negotiations regarding the experiences made between users and producers. The algorithms seem to be crucial as well. The second subchapter deals with the extent to which expertise is negotiated as soon as a video becomes visible, i.e. is viewed and evaluated by users. Here, I will first address the field concept of authenticity, which, however, turns out to be an empty signifier. Rather, negotiations of coherence can be identified following Fisher's narrative paradigm (Fisher, 1984, 1985, 1997). Expertise is thus negotiated based on coherent narratives regarding the channel brand, content and community affiliation. Finally, in the third subchapter, I summarise both concepts before and after becoming visible and describe the concept of the platform expertise of science YouTubers.

How expertise is negotiated on platforms

> The curtains are drawn in the mundane room on the third floor. The cameras are ready, and the set is in preparation. The topic of the next video is to build a projector to illustrate the physics behind it. Before starting, the YouTuber and the production manager discuss where the material will be placed and whether there are any mistakes in the script regarding the scientific facts. Then they change the subject and instead discuss the props. On a shelf behind the presentation table there is a mixture of figures and objects from science and popular culture, like from Star Wars. The objects have been arranged in the style of a famous German YouTuber, who presents similar references as decoration in the background of the videos. The discussion is about whether the objects should be rearranged, whether it would be a signature to change something for each shoot, whether the figures from well-known films can be shown at all or whether trademark rights are violated. Everyone agrees, however, that the colourful shelf is important in order to appear ‘nerdy’ and to not emphasise the image of a ‘dusty’ scientist. (April, 2016)
>
> On another setting, the YouTuber is adding final scientific explanations to the presented experiment. As soon as they are done, pictures from the set and from the YouTuber are taken. Already during the shooting the team discussed possible thumbnails for the video upload. Selfies from the set or surprising elements are supposed to animate the users to click on the video. Currently, however, the focus is on the outro - the last scene in the video. Here, too, users should be engaged and in the best case not only leave a like but also subscribe to the channel. The team discusses how long the outro should be and what should be said. They agree that the

> question "Did you like the video?" would not be promising because the viewers would know directly that this is the end of the video and switch off. Instead, they should stay tuned to watch the invitation to subscribe. Therefore, there is further detailed discussion about how to encourage viewers to keep watching. Maybe they could include outtakes, or they could shoot a surprise effect or a funny reference. Eventually the team decides to record an extra video in which the YouTuber will prove in a funny way that the built object from the main video really works. (April, 2016)

These two vignettes illustrate common aspects of observed production workflows which are not so much concerned with the current scientific content presented in the video. Instead, in both cases, the goal is to create content beyond the actual video production in response to specific platform mechanisms. In the first case, the aim is to create a particularly appealing thumbnail for the video, so that users who discover the video on the landing page or in the recommendation bar are more likely to watch it. In the second case, the aim is to attract new subscribers to the channel and to make the call for subscriptions as engaging as possible. Both vignettes are taken from data I collected during my field work (see Chapter 2). These examples demonstrate the influence of platform-specific rules on the production of science videos on YouTube. I was able to observe during my field work that scientifically correct presentation of the content as well as good storytelling and a professional video production are relevant to be successful on YouTube. At the same time, platform-specific production measures took a remarkably important role in this process. This may be related to the fact that science YouTubers also strive for a certain success on the platform. Based on the field term “success”, I will in the following explore how expertise is negotiated on YouTube as platform expertise and how this process can be described.

Having success and making money with videos on YouTube is probably the central motivation for most video producers on the platform. Accordingly, the YouTube Creator Academy is dedicated to supporting video creators in ways that will help them achieve maximum success with their uploaded content as quickly as possible. Science YouTubers, however, do not always pursue the goal of making as much money as possible with their channels. This seems to be because it is sometimes harder to make money with scientific or educational content. As described in Chapter 1, this is due to the fact that science and education on YouTube are still niche topics and therefore produce far fewer quantitative

measures of success than, for example, music videos or other entertainment content. Moreover, high revenues can be generated almost exclusively through product placements. Nevertheless, product placements would appear rather out of place and are difficult to reconcile with science communication and education. In addition, scientific content is often affected by YouTube's rules on demonetarisation. Demonetarisation describes certain rules according to which algorithms filter videos which can no longer make a profit. These demonetarisation rules are usually based on the requirements of companies that want to advertise on YouTube. Topics that lead to demonetarisation include, for example, political conflicts and war. This is especially relevant for YouTube channels that deal with these topics from a historical or sociological perspective.

However, science YouTubers display a whole range of different motives as to why they communicate science on the platform. Often, those motives are based on a special passion for scientific topics which they want to share in order to take the “dust” out of science. They also strive for a certain success in advancing their scientific or journalistic careers and, in the best case, in earning enough money to compensate for expenses around their YouTube channel (Geipel, 2018). The definition of success for science YouTubers seems to consist of both – the search for recognition and a more personal or altruistic interest. Even though the motivations to produce science videos on YouTube are similar, my interviews also revealed differences in the personal definition of success. Some combine a personal passion for e.g. singing or painting with their interest in science. Others simply like to produce videos and show themselves online. While the probability for science YouTubers to earn a lot of money is lower than, for example, for beauty YouTubers, they still want to be seen by as many users as possible. Therefore, they are interested in reaching the largest possible number of people, and thus are equally concerned with the quantitative measures of success that YouTube provides for channel owners. In this sense, the number of likes, views and subscribers are further important measures for the success of a video or channel. Furthermore, science YouTubers pursue the goal of attracting their viewers to science with a combination of entertainment and education. A science YouTuber describes the motivation as follows:

> So we’ve had a couple of videos which only had a couple of thousand views again, that’s really small fry in the scale of YouTube but then we receive comments on the video from people who have said I did that experiment at home with my children and we had the best day ever. Brilliant! (…) That is just maximum impact for us. And so

> that video is more successful in my eyes than the one that gets tens of thousands of views, but no one repeats that at home. (…) The views are nice, the views are important, and they give a good indicator (…) but it's not what it is about in the end (…).[53]

So, on the one hand, numbers count, especially to make success measurable and to guarantee reaching a critical mass of viewers. On the other hand, the qualitative part of success seems to be equally important. Science YouTubers want to get their audience excited about science, inspire them to engage with scientific themes and to spark their curiosity to learn more. Or in other words:

> If you manage to inform and entertain at the same time, then you are probably on the right track.[54]

However, as explained above, the question for me is not so much how science YouTubers define success but rather what expertise is needed to achieve this success. Both terms are closely related. It can be observed that success is often used to describe a form of expertise. However, the term expertise itself is rarely mentioned. This may also be due to the fact that YouTube still emphasises the narrative of the amateur as a central characteristic of the platform community. This is despite the fact that, as described above, an increasing professionalisation of video producers can be observed on the platform (Kim, 2012; Morcillo et al., 2019). However, a closer look reveals that a special form of expertise is developing in dealing with the platform and the viewers as well as with the video production itself. I therefore examine the influence of YouTube's platform politics on science communication in terms of expertise to theoretically approach the question of what drives the success of science videos on YouTube, and thus the question of the extent to which the platform itself influences the presentation of science in YouTube videos.

In the following, I will introduce several concepts of expertise from Science and Technology Studies, communication studies and anthropology and compare them with my empirical material in order to present a framework for the specific expertise science YouTubers display. While the discussion about expertise in Science and Technology Studies is often concerned with the question of who is allowed to participate in technical or political

[53] I#3, 00:41:47.
[54] I#1, 00:44:59, transl.

decision-making (see, for example, Maasen & Weingart, 2009), the question of expertise on social media platforms such as YouTube seems to be a different one. YouTube allows anyone, regardless of a certified expertise, to talk about any topic. Thus, it must first be clarified what kind of expertise the new actors in digital science communication, who are not scientists or journalists, exhibit. Of course, the opportunity of doing science communication can already be seen as indirect participation in decision-making processes. However, in my thesis, I will focus on who is actually able to communicate and provide educational and scientific offers on platforms such as YouTube, and what prerequisites have to be met for this.

According to Foucault (1971, p. 17), “none may enter into discourse on a specific subject unless he has satisfied certain conditions or if he is not, from the outset, qualified to do so”. In other words, joining the public discourse often depends on certain criteria regarding both the topics as well as the people who communicate them. For modern journalism, these criteria can be based on newsworthiness, a certain ability to connect to the audience's everyday life, as well as the general importance of the topic for the public. In communication and journalism research, the question of how topics are selected and how visibility is achieved in mass media is discussed by using terms like framing (see, for example, Entman, 1993), agenda setting (see, for example, McCombs, 1977) and gatekeeping (see, for example, Janowitz, 1975).

Entman (1993) describes the paradigm of framing as a way “to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described” (p. 52). In this context, framing is about drawing attention to some aspects of reality and, therefore, describes a criterion defining how specific parts of reality, e.g. in political news, are communicated. Building on this, agenda-setting is a more specific description of how topics in mass media are selected and, therefore, influence the awareness of public issues. Or as McCombs (1977) puts it, “While the media do not tell people what to think, they tell people what to think about” (p. 89).

Following this, gatekeeping describes how journalists “select the important from the mass of detailed information; therefore, the notion of the journalist as gatekeeper rested on this

ability to detect, emphasize and disseminate that which was important" (Janowitz, 1975, p. 618). According to Janowitz (1975), the "gatekeeper" model describes the journalistic expertise as well as the journalists' professional responsibility[55]. The public discourse is thus influenced by the way in which mass media weigh and present certain topics. Accordingly, scientific topics are also selected and presented based on the respective criteria (see, for example, Hilgartner, 2000; Schäfer, 2008; Weingart, 2005). Gatekeepers are often science journalists who select scientific topics according to agenda-setting mechanisms. One of their central tasks is the translation of complex scientific facts for society "to make scientific achievements more relevant and accessible for the public" (Bucchi, 1996, p. 376).

When science topics are presented to the public, they may, for example, originate from a press release of a research institute, peer-reviewed publications or are introduced in interviews with scientists. In these cases, (science) journalists rely on the professional expertise of the respective research institution or scientist to fulfil their role as gatekeepers. In addition to selecting the topics that will be presented to the public, it is also a matter of selecting scientists based on certain criteria. For scientists, in return, this means that they only become visible in mass media when they meet these measures. One central aspect of these selection criteria seems to be the reputation in specialist circles in terms of the number of their publications or citations (Broer, 2020). In addition, Broer (2020) states that availability and connectivity seem to be decisive factors in selecting scientists as experts. However, according to Reif et al. (2020), a professional communication strategy seems to count as well when doing science communication in social media. Therefore, scientists need to overcome certain hurdles (namely: gaining a high reputation in their field and working on a scientific topic which meets the agenda-setting criteria) to become visible in traditional (mass) media.

With the development of Web 2.0 technologies and the growth of social media platforms, however, possibilities have arisen to bypass these gatekeepers and enter into a direct dialogue with the public (Bucchi, 2017). Therefore, in communicating their research directly to the public, they are able to avoid the time-consuming processes of peer-reviewed

[55] Extensive literature exists on the topic of gatekeeping. For more insights, see, for example, Keyling (2017), Shoemaker and Vos (2009) or White (1950).

publications, journalistic selection criteria or regulations of PR departments. On the other hand, Web 2.0 technologies offer scientists who mistrust journalists and how they present science in traditional media the opportunity to decide for themselves which topics are communicated publicly and how. This point in particular should not be underestimated. In my interviews, freedom to experiment was often mentioned as a reason for running a science YouTube channel. Similar observations can be made on other social media platforms. I will briefly explain this in more detail with regard to a current case.

This case of direct communication of research findings is how virologists communicated in times of the COVID-19 pandemic (Bodenheimer & Leidenberger, 2020; Staudenmaier, 2020). The well-known German virologist Christian Drosten continues to use the classic ways of scientific communication, such as peer-reviewed procedures. At the same time, with the beginning of the pandemic in early 2020, he started to communicate daily updated research findings via a podcast in cooperation with a German public broadcaster and via his Twitter account (Kupferschmidt, 2020). This is mainly due to the high relevance of the topic. The worldwide pandemic makes it necessary to publish research results more quickly in order to exchange knowledge within the scientific community. In addition, the public demands quick updates in order to react to the unfamiliar situation.

However, this also means that scientists have to face the criticism of the media and it becomes apparent that the uncertainties in the research process are not easy to communicate. Therefore, Drosten used his Twitter account to invalidate a tendentious article published by the German BILD newspaper at the end of May 2020 by making his research and the newspaper's approach public before the article was made available. Via the social media platform, he also managed to contact the researchers cited in the article, who allegedly criticised his work and subsequently distanced themselves from the article and the newspaper (Arens, 2020; Grimm, 2020; Krauter, 2020). This is just one example which impressively illustrates how scientists use social media platforms when they distrust traditional journalistic publications and want to avoid them. On YouTube, it can also be observed that science YouTubers sometimes use the platform to distance themselves from traditional media in, for example, experimenting with new communicative formats.

However, the possibility of communicating science while bypassing different gatekeeping mechanisms not only promises advantages but also disadvantages and risks (Bucchi, 2017; Weingart & Guenther, 2016). This can happen, for example, when research is published without going through a peer-review process and then proves to be unsustainable. Especially when these findings have an impact on crucial public issues, such incidents can lead to a remarkable loss of trust in science. Nevertheless, at the same time, it opens up the possibility to present scientists in various ways, to eliminate stereotypes or even to improve the trust in science (see Reif et al., 2020). In addition, social media platforms open the stage for new actors in science communication (Könneker, 2020). It is no longer only journalists, PR departments of research institutions or scientists who decide which scientific topics are reported and how. Via social media platforms, practically anyone can now engage in science communication without having to meet specific selection criteria. At least that is what it seems.

However, as already described above, while YouTube fosters its narrative of a neutral and unbiased public sphere where everybody is equally enabled to speak and share individual opinions, it provides distinct technical affordances, which curate the content and shape communication structures and therefore neglect the idea of neutrality (Gillespie, 2010). For me, this raises the question of how video producers deal with these challenges in order to make their content visible. Accordingly, this also involves the question whether this can be described as a certain form of gatekeeping and thus a specific expertise in order to be successful on the platform. Therefore, the question is not how the scientific content presented was researched, whether it is accurate and thus provides correct information. Rather, the question is how content is made visible in the first place.

YouTube presents itself as a platform where anyone can publish content - independent of traditional gatekeepers or certified expertise. Neither journalists nor the PR departments of research institutions decide what is presented to the public. The YouTubers decide which content they want to present and whether this content is presented in a scientifically correct or non-correct manner. However, as described above, platforms establish certain rules in order to make money (Gillespie, 2010, 2017; van Dijck, 2013). Accordingly, producers have

to follow these platform-specific rules to become successful. While anyone can upload videos, success seems to depend on whether the uploaded video can be found and seen.

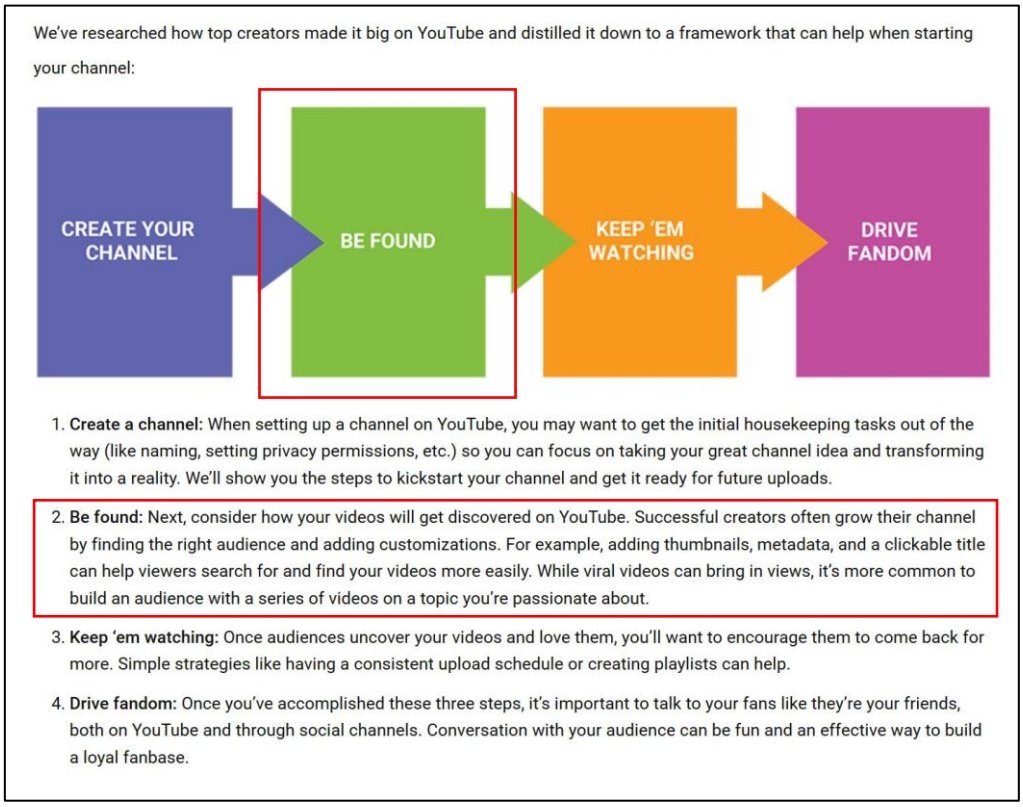


Figure 6: How top creators made it big on YouTube.
This is a screenshot of the YouTube Creators Academy's course on "How to start a channel" which highlights how important it is for YouTubers to be found first. (Screenshot from 03.02.2017).

Figure 6 displays a screenshot of a YouTube Creator Academy's course on "How to start a channel"[56]. As described in Chapter 1, the YouTube Creator Academy is a website accompanying YouTube as a learning platform. Here, video producers can learn how to create successful videos and how to build a channel community to gain money. They also find information on general video production, marketing, collaboration as well as information to succeed as video producers in specific genres (e.g. the creation of beauty tutorials or educational channels[57]). Being found is presented as one of the first major tasks for new video creators on the platform. To achieve this goal and eventually become

[56] The screenshots presented in this and the next chapter are part of my empirical material. As the YouTube Creator Academy changes the content on a regular basis, it is difficult to capture links. However, one can find similar advice like the one displayed in Fig. 6, for example, here: https://creatoracademy.youtube.com/page/lesson/subscriber-advantage?cid=bootcamp-foundations&hl=de#strategies-zippy-link-2 (accessed: 02.08.2020).

[57] See, for example, here: https://creatoracademy.youtube.com/page/lesson/edu-channel-start (accessed: 02.08.2020).

successful, the course recommends YouTubers, for example, to add thumbnails, metadata and clickable titles (see figure 6).

For Thompson (2005), visibility created by media is fragile because it is difficult for (political) actors to control whether and what is visible. Social media platforms, like YouTube, reveal the same form of fragile visibility. When it comes to the question of who is allowed to enter the public discourse, as Foucault (1971) framed it, it is about who is allowed to talk but also who can be heard. Or in the case of YouTube who can be seen. In the sheer mass of uploaded videos per day, the struggle is to become visible or as Bucher (2012) states: “Different media forms thus instigate different forms of visibility” (p. 1166). Bucher (2012) describes the new modalities of visibility on social media platforms such as Facebook. Taking Foucault's 1995 work on panopticism, she reverses his concept of punishment as a form of constant visibility (as cited in Bucher, 2012). Instead, she argues that the possibility of disappearance and non-visibility is a form of punishment regarding the intended participation on social media platforms.

Foucault’s panopticon is a specific architectural structure for a prison, where guards from a central surveillance tower can observe the rooms and the people in them in the building surrounding it (Bucher, 2012). Using the idea of the panopticon, he describes not only mechanisms of power and punishment but also modes of visibility that can be applied to social networks - according to Bucher (2012) “spaces of 'constructed visibility'” (p. 1170). For her, in these spaces, the punishment of invisibility rather than the punishment of visibility is of central importance. And to become visible, users must follow certain platform logics. “Essentially, becoming visible is to be selected for by the algorithm” (Bucher, 2012, p. 1174).

Similar to Foucault's understanding of the panopticon, disciplinary behaviour plays a role in dealing with the platform's algorithms in order to not be punished by invisibility (Bucher, 2012). This idea of discipline can be seen, for example, in the adaptation to those very same algorithms. For me, this adaption seems to be consolidated in a specific form of expertise, namely, a platform-specific expertise. As Bucher (2012) points out, this platform-specific expertise can be described as an adaptation to YouTube's algorithms. This special importance of algorithms is also reflected in my interviews. In the following statement, a

science YouTuber describes how it feels to be at "the mercy of the platform" as a way of dependency on how the platform's algorithms work.

> You are at the mercy of the platform. In the past it absolutely could happen that an algorithm was changed, and overnight channels die, the ones which had 30 million views per month with appropriate teams and equipment – which suddenly only have 3 million views.[58]

When the visibility of content on social media platforms like YouTube seems to depend on several factors, such as the video producers' choice of which content to present, influenced by trends and current events, the platform's algorithms but also the feedback from viewers, it seems not surprising that video producers sometimes feel they are at the mercy of the platform.

In this context, Singer (2014) speaks of a user-generated visibility, referring to the visibility of content published on media pages. Based on her work, the possibilities for interaction on the internet lead to a two-step gatekeeping process. While the first stage is still based on decisions made by the editors and journalists, the second stage is based on decisions made by the users regarding which content becomes more or less visible. This user-generated visibility is built around the modern possibilities of Web 2.0 technologies, such as the direct sharing and rating of published content. According to Singer (2014), in addition to different content ratings, this represents a remarkable difference to gatekeeping in journalism. With respect to social media platforms, I argue that the classically defined editorial gatekeeping (as described by Singer, 2014) may be accompanied by algorithmic gatekeeping. Following Singer's (2014) work, but also that of Keyling (2017) and Bucher (2012), I therefore suggest it is rather a three-step gatekeeping process on social media platforms.

In the first stage, the video producers, like editors, decide which content they want to make visible. In the second stage, however, the platform-specific recommendation algorithms decide on the visibility of uploaded content based on quantitative measures and other criteria. Finally, at the third stage users decide which content they rank higher or lower in terms of visibility. The three steps described do not always take place in the same order and independent of each other but rather influence each other. If algorithms have an influence

[58] I#4, 00:18:08, transl.

on which topics become visible, it is reasonable to assume that they also have an influence on which expertise science YouTubers need to become successful on the platform. However, other characteristics of the platform also influence how science communication is produced and received on YouTube.

Videos pushed by the algorithm may retroactively influence the decisions of video producers, for example, as to what content they will present in their videos. At the same time, trends and characteristics generated by the algorithms of the platform have an influence on the reception of the videos and thus on the decisions of the users. In the following, I will take a closer look at the expertise required to successfully handle the rules and algorithmic mediations on the platform. I will also reflect on how the knowledge of algorithmic behaviour influences the selection of topics and the production process of YouTube videos. What influence viewer decisions have on the visibility of content will be discussed in the next chapter, unpacking the platform-specific concept of authenticity.

Algorithms are crucial when it comes to social media platforms (Beer, 2008). For users and producers, they are black boxes which are hard to open. Instead, video creators have to find a way to work around the algorithms, uncover how they work and how they impact their negotiations with the platform by observing their behaviour. Recommendation algorithms on YouTube directly influence whether a video becomes visible or not. Based on specific markers, videos appear on the landing page or in the recommendation bar next to other videos. In my interviews, when I asked why certain production steps were necessary, I often received the answer that it was because of the algorithm. This seems to be particularly important for a niche topic like science and education. As already pointed out above, the proportion of YouTube channels with knowledge content is tiny compared to other genres such as music or entertainment (Rieder et al., 2018). Accordingly, scientific content is less important for YouTube to make money. Moreover, science videos rarely generate high revenues on the platform. The science YouTubers are aware of this, too. The adaptation to algorithms is correspondingly important for them. This is also made clear in the following quotation.

> This is because of the algorithm. The algorithm is also telling us that educational content is not that important because they [YouTube] can't make a lot of money with it. For them, entertainment and comedy are central.[59]

Therefore, for science YouTubers, it is specifically important to become visible on the landing page or to be recommended next to other videos by following the algorithmic rules of the platform. The more visible they are on the landing page, the more views their videos receive and the more likely they are to increase the follower numbers of their channels. Since some science YouTubers are financed by donations from their followers, the number of followers and the connection to them increases the probability that more money is generated. In order to reach this goal, it is important to constantly observe the algorithm and how it influences trends and fails but also the users' behaviour. Only by "becoming part" of the platform, checking new trends, watching successful videos, producers do not only learn what the users want but also which specific markers the algorithm emphasises. In one of my interviews, a YouTuber describes this procedure as a constant process of keeping track of everything that is happening on the platform.

> But, for sure, you have to keep yourself updated, always check what the people want, what comments they post.[60]

But science YouTubers also learn from information provided by YouTube or discussed in the communities of producers and users. Which markers influence the behaviour of recommendation algorithms is a prominent topic in online forums, blog posts or in direct exchange between video producers. In my interviews as well as in my observations within the informal Facebook group of German science YouTubers I could observe that several assumptions exist defining these markers and how they relate to the provided measurements of views, likes, comments or watch time.

Similar to the Matthew Effect in science as described by Merton (1968), where contributions by renowned scientists become more visible than those by authors who are less known, YouTube's algorithms promote already highly successful channels and videos by presenting them repeatedly on the landing page or in the recommendation bar. Channel owners often follow this approach by creating new videos in response to these successful ones and thus

[59] T#1, 00:40:41, transl.
[60] T#1, 00:21:38, transl.

benefit from the Matthew Effect in the algorithm by, for example, adjusting their video's metadata (e.g. similar titles). YouTubers not only adapt to these algorithmically curated trends in the short term but also integrate the knowledge gained about the functioning of the algorithms into their long-term production processes. These constant adjustments can already be observed at the metadata level, namely, when trends are reflected in titles, preview images or video descriptions. Also, science YouTubers are adapting their production methods to these trends.

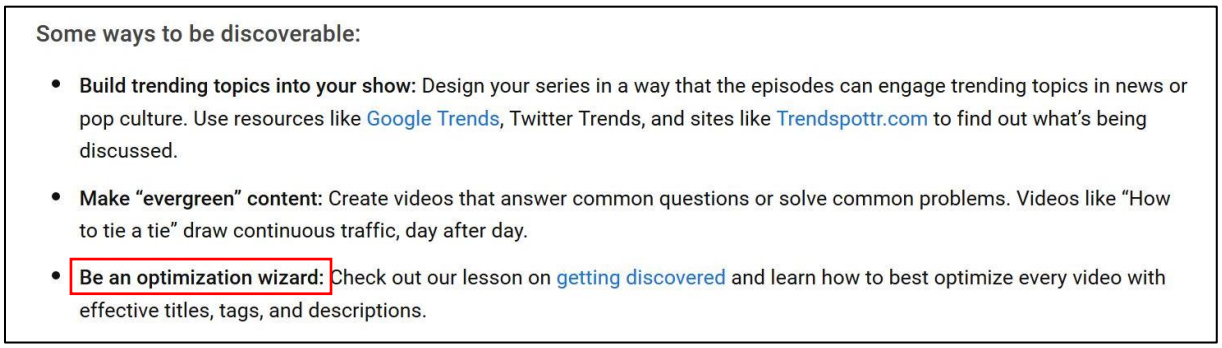
> Videos with fancy titles (…) are quite successful (…) But why is that? Why are there by now such thumbnails with such arrows (…)? This correlates with the algorithm. The algorithm of Google is merciless. On the one hand, for me as a person who runs a channel. (…) Only 10% of my subscribers watch my videos (…). And this is why people behave like that (…) because they want to be on the landing page.[61]

In the above statement, the science YouTuber explains why titles and thumbnails of science-related videos sometimes resemble attention-seeking characteristics as known from the tabloid press. It highlights how the decisions for video titles, thumbnails and descriptions correlate with the observed and reflected behaviour of the algorithm. The statement, however, also displays the importance of those continual adaptions not only for a single video but for the channel's overall strategy (Bishop, 2019). The adjustments described in the quote are necessary to attract new subscribers to the channel. Based on the experience already gained from the statistics provided by YouTube, the YouTuber knows that only a small percentage of the followers watch each video. Therefore, it is important to adapt to the current algorithm's behaviour for each video, to reach high numbers of views and to gain new followers. This does not mean that every new video requires completely new production mechanisms. Rather, science YouTubers gradually expand their knowledge of how to adapt to platform politics. This makes it clear that the recurring examination of the behaviour of the algorithms and their reflection is a central element of the platform expertise I observed. The expertise that can be identified in science YouTubers is thus not fixed but can rather be described as procedural.

Nevertheless, with each new video, it is necessary to compare the knowledge already acquired about the algorithm with its current behaviour, and elements of video production

[61] T#1, 00:40:26, transl.

may have to be adapted accordingly. In my field work, I could observe that this was evident, for example, in the choice of title and thumbnail. Throughout one of the video productions I observed, the question of how to present the video was an important and time-consuming topic. On one occasion the shooting was stopped a couple of times only to take pictures from the set to create thumbnails that attract the attention of the users. Creating a catchy thumbnail seems to be as crucial as the professional video production and the accurate presentation of the content.


Some ways to be discoverable:

- **Build trending topics into your show:** Design your series in a way that the episodes can engage trending topics in news or pop culture. Use resources like Google Trends, Twitter Trends, and sites like Trendspottr.com to find out what's being discussed.
- **Make "evergreen" content:** Create videos that answer common questions or solve common problems. Videos like "How to tie a tie" draw continuous traffic, day after day.
- **Be an optimization wizard:** Check out our lesson on getting discovered and learn how to best optimize every video with effective titles, tags, and descriptions.

Figure 7: Some ways to be discoverable.
Lesson on how to make videos discoverable published at the YouTube Creator Academy. Next to following trends and creating "evergreen" content, producers are advised to become optimisation wizards. (Screenshot taken February 2017).

The screenshot displayed in figure 7 is an excerpt from a tutorial for video producers available on the YouTube Creator Academy and highlights the importance of this permanent optimisation process. It explains how to produce more discoverable videos and therefore advises the producers to become "opitmization wizards", by optimising "every video with effective titles, tags, and descriptions" (see figure. 7).

However, if science YouTubers adapt to the algorithmic conditions and change titles or thumbnails accordingly, they likewise have to face criticism of their viewers. It seems that science YouTubers are more exposed to this criticism than, for instance, beauty YouTubers. This indicates a kind of conflict between the adaptation to the entertainment and attention-driven characteristics of the platform, on the one hand, and the expectations of the users towards science YouTubers, on the other. In the following chapter, I will discuss this negotiation process in more detail. It is mentioned here to illustrate that science YouTubers must also adapt their production mechanisms to these expectations. In the case of the YouTuber who described the adaption of the video's metadata to current platform trends, viewers of the channel criticised that these adaptions were not in line with how science

YouTubers should present their topics on the platform. In the following quotation, the video producer describes that viewers found titles and thumbnails of the channel too dramatic and that the production process was adjusted accordingly.

> I just try to choose exciting titles and thumbnails (...) so that it is interesting and gives an incentive for people to click. Which of course often leads to the criticism that it would be too much drama or too sensational. So for a while many people wrote this and then I took a self-critical look and found out that they are a little bit right (...) and now I'm a little bit more objective about the titles and it works, so I think it's pretty cool.[62]

As already mentioned above, it seems that especially science YouTubers seem to be subject to specific evaluation criteria (Geipel, 2018). Users do not seem to expect titles similar to the ones they know from the tabloid press. Instead, they demand more objectivity and neutrality. However, the statement above also illustrates that the knowledge of how algorithmic mediation processes take place on YouTube seems to be even more important for science YouTubers because they cannot simply follow the popularity-driven trend developments. It means that science YouTubers cannot simply copy trends but need to consider more carefully which topics they follow and how they pursue trends without losing their integrity. In the following, I will therefore focus on how the described algorithmic mediation processes influence not only the visibility of videos and channels but also which content science YouTubers choose to present. This means that the algorithmic curation of content on YouTube can also influence which scientific content is displayed and which is not. Science YouTubers are accordingly dependent on a detailed analysis of their channels in order to identify, for example, which topics could be relevant, when viewers interrupt the video or where they frequently jump back.

> Sometimes I find topics [in the search statistics] on which I haven't done videos yet. For example, there was for a pretty long time the topic of […] and I haven't had a video on this topic online, so I did one.[63]

In the statement above, the science YouTuber explains how to use the channel's analytics to decide which topics to present next. The analytics also include the possibility of retrieving search statistics. This allows the YouTubers to identify which topics users are searching for in

[62] I#6, 00:09:10, transl.
[63] T#1, 00:21:11, transl. (the topic was removed, in order to guarantee anonymity)

connection with a channel. In the present case, the YouTuber has found that, on the one hand, users search for certain videos on the channel more frequently and, on the other hand, that users search for other topics for which there are no videos on this channel yet. In analysing the statistics, producers, for example, focus on the different ways the users follow to find their videos and especially which topics they are looking for. I therefore argue that the platform's algorithms seem to have a specific impact on which scientific topics are discussed and how they are presented. In the given example, the producer could identify a specific topic in the analytics of the channel that people were looking for. As a result, the producer decided to respond to this search request and therefore produced a corresponding video. The next time users search for this topic, they will find a video about it in this channel. And possibly this strategy will lead to increased viewing of the video and, as a result, more users will subscribe to the channel.

Strategies like adjusting titles and other metadata to current trends or choosing topics based on user behaviour can be summarised under the term "platform-specific strategy" as introduced by Rieder et al. (2018). In their work on the modulation of visibility in YouTube search results, Rieder et al. (2018) emphasise that simple popularity metrics do not seem to control the visibility of videos. Instead, "complex ranking cultures that reward platform-specific strategies and audience activation through strongly opinionated expression" (p.64) appear to be crucially important. This platform-specific strategy or as the YouTube Creator Academy calls it the act of becoming "optimization wizards" seem to be central for this new form of expertise science YouTubers express in becoming successful.

If we speak of a platform-specific expertise in this context, this includes, as already described, dealing with platform politics, algorithmic mediation processes as well as the reactions of the producers and the audience. Both the behaviour of the algorithms and the actors are constantly changing. The algorithms adapt to the specifications of advertising customers or react to trends, and users and producers likewise adapt to the behaviour of the algorithms. What can be observed here is an interactive process of adaptation and negotiation. Since all these elements are in an ongoing process of mutual adaptations, platform-specific expertise is never fixed but can rather be gained through constantly collected experiences.

Collins and Evans introduce the concept of experience-based expertise in their work "Third Wave of Science Studies" in 2002. In response to the normative distinction between experts and laypersons in the First Wave and the complete blurring of boundaries between expert and lay knowledge in the Second Wave, they propose a diversification of the concept of expertise. With this diversification, they introduce the experience-based expertise as a normative framework to define expertise in the process of technical decision-making. This implies that while in the so-called First Wave all expertise was attributed to the scientific community, and in the Second Wave precisely this incorrect dichotomisation was eliminated, making it difficult to distinguish between different forms of expertise, the Third Wave as defined by them is intended to re-establish the distinction but to draw it at a different point within population, reconstructing knowledge (Collins & Evans, 2002)[64].

They start with re-defining the term "lay experts". For them, this term cannot be understood in any other way than as an oxymoron. After all, the word "lay" indicates that a person has no expertise. Thus, in combining the two words, they become mutually exclusive. Instead, Collins and Evans (2002) describe the idea behind the term as a special technical knowledge built on experiences instead of degrees or certificates and therefore introduce the term experience-based expertise (Collins & Evans, 2002, p. 238). Collins and Evans (2002) distinguish between three layers of expertise, ranging from "no expertise", where the knowledge is not sufficient to contribute to science, to "interactional expertise", where knowledge is sufficient to interact with and participate in science, to "contributing expertise", where knowledge is sufficient to contribute to research.

In 2009, Collins and Evans expand their framework and further diversify their concept of expertise in their "periodic table of expertises" (see figure 8). The table starts on top with ubiquitous expertise, describing expertises "which every member of a society must possess in order to live in it" (Collins & Evans, 2009, p. 13), such as natural language-speaking. While dispositions illustrate personal qualities, the specialist expertise is the row which is central in describing the different levels of expertise. This row displays a distinction of ubiquitous tacit knowledge, "knowledge of the kind of facts needed to succeed in general knowledge

[64] They emphasise that while the Second Wave has replaced the First Wave, the Third Wave is introduced as a diversification of expertise occurring in parallel with the Second Wave. See Collins and Evans (2002).

quizzes" (Collins & Evans, 2009, p. 13), and specialist tacit knowledge, which makes it "necessary to immerse oneself in a domain" (Collins & Evans, 2009, p. 14). The term specialist tacit knowledge includes the two concepts of interactional and contributing expertise presented by Collins and Evans in 2002. The two rows on the bottom finally introduce the terms meta-expertises and meta-criteria. While meta-expertises describe the judgement of experts without possessing the expertise in question (transmuted expertises) and the judgement of experts with the possession of one part of the expertise being judged (non-transmuted expertises), the meta-criteria describe "the criteria outsiders try to use to judge between experts" (Collins & Evans, 2009, p. 15). In the following, I will only refer to the row of specialist expertises to describe the way science YouTubers use platform-specific knowledge. This will help to better understand how science YouTubers deal with algorithmic constraints as a form of experience-based expertise.

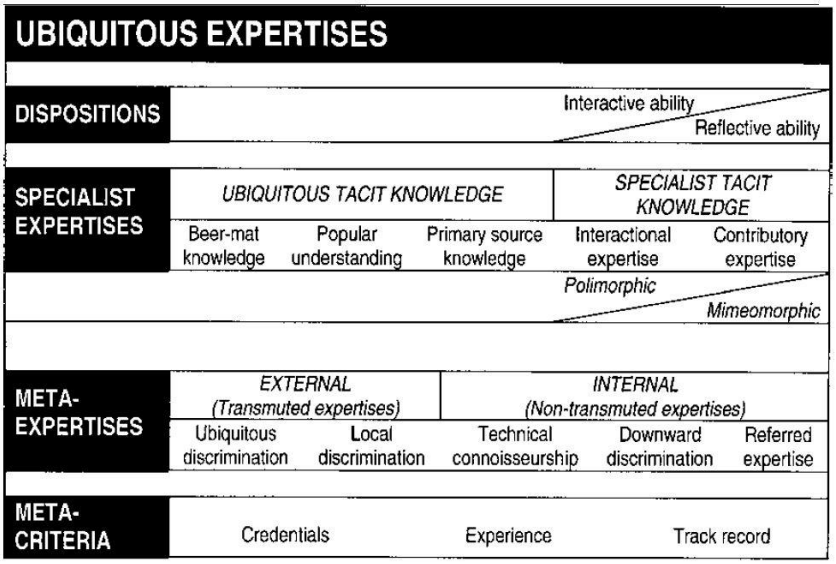


Figure 8: The Periodic Table of Expertises by Collins and Evans (2009, p. 14).

When considering expertise in the production of science videos on YouTube, the level of specialist expertise seems to be of particular interest (see figure 8). Ubiquitous tacit knowledge is "described as levels of knowledge – like knowledge of the kind of facts needed to succeed in general knowledge quizzes" (Collins & Evans, 2009, p. 13). One could compare this level of knowledge with the form of knowledge which is communicated in some of the science online videos on YouTube. Not every science YouTuber is a scientist, but they may have enough of this ubiquitous tacit knowledge or may be able to acquire it to convey scientific facts in their videos. Collins and Evans (2009) describe these low levels of specialist

expertise as the reproduction of factual knowledge. On the next level of knowledge – the so-called specialist tacit knowledge – one acquires to learn or know more than just facts. At this level, knowledge includes both the ability to speak a specialised language and to competently engage in an activity.

Therefore, if science YouTubers have actively done scientific research, they may have what Collins and Evans (2009) describe an interactional expertise at the level of specialist tacit knowledge. Only rarely, however, do full-time science YouTubers possess contributory expertise, which is also attributed to specialist tacit knowledge – in other words, the scientific and technical expertise to actively conduct research. However, the successful operation of a science YouTube channel is so time-consuming that active research is rarely possible at the same time. This does not, of course, exclude the possibility of science YouTube channels also being operated by researching scientists.

Nevertheless, it seems more interesting to look at the periodic table of expertise with regard to the basic skills required to operate a science channel on YouTube - for example, in terms of how science YouTubers become visible on the platform. If one considers the necessary expertise to become visible on a platform like YouTube, it can be described as contributory expertise and thus with the highest knowledge level when science YouTube channels become successful - e.g. have many followers. This distinction is important because the form of expertise that I describe refers precisely to the expertise of successfully running a science YouTube channel. It, on the other hand, does not or only partially refer to the expertise that is necessary to conduct research.

So when describing expertise based on Collins and Evans's (2002; 2009) approach, it is important to look at what kind of expertise in science YouTube videos is meant - the kind you need to communicate scientific content accurately or the kind you need to be visible on the platform. In the context of my research, it proves useful to apply the concept of experience-based expertise to describe how science YouTubers successfully deal with the platform-specific requirements. When expertise is based on experience, the question arises as to how this experience is acquired and how the knowledge gained is further deepened and applied. Especially the fast pace of the algorithms requires not only the knowledge gained through one's own experience but also the exchange with others. The exclusive

application of the concept of experience-based expertise therefore does not appear sufficient at this point to describe the complex emergence of specific platform expertise among science YouTubers.

While Collins and Evans (2002) introduce the Third Wave of Science Studies and thus the Studies of Expertise and Experience (SEE) to criticise the dichotomy of expertise and lay knowledge, in line with others such as Wynne (1992) or Irwin and Michael (2003), the presented framework is still a normative one (Rip, 2003; Sorgner, 2016) which has been criticised because of "a reductionist quality to their analysis that sits uneasily with the complex dynamics of expertise in modern societies" (Jasanoff, 2003, p. 391). I was able to observe something similar on YouTube. On the one hand, experience-based expertise describes how science YouTubers gain expertise by accumulating experiences in dealing with the algorithms and other platform politics. On the other hand, it can be observed that successful science YouTubers also compare their own experiences with those of other science YouTubers. In considering expertise as a requirement for successfully dealing with the conditions of platform politics, I therefore argue that we need both normative and relational frameworks to untangle how expertise is developed in the various negotiations between producers, users and the platform.

To be successful as a science YouTuber, it is not enough to gain experience on the platform, get to know the algorithm and become part of the platform community. Rather, active negotiation processes with other (science) YouTubers are needed in order to compare the self-made experiences or the self-acquired knowledge with that of others. After all, the knowledge YouTubers collect about algorithms cannot be described as factual knowledge to be applied. Instead, it is a fluid knowledge resulting from the changes on the platform in the interplay between algorithms, users and producers. The interaction between the three actors is multidirectional. Algorithms adapt to the behaviour of users and producers and vice versa. This dynamic results in the fact that the knowledge about it is also dynamic and has to be reflected accordingly and possibly renewed. Thus, it is important for science YouTubers to join networks to compare different perspectives and experiences with the platform's algorithms.

> But of course you have to make sure that your videos are presented in a way - and I don't mean the video itself, but rather the way it is presented with thumbnails and titles and that it is not too boring because nobody otherwise will click on it. Therefore, I look at what the others are doing and what their approaches are.[65]

Networks have a specific importance for YouTubers to help them become more professional in negotiating the platform's algorithms. In this context, however, I'm not referring to Multi-Channel Networks (MCNs) mentioned in Chapter 1, which sign individual YouTubers and help them make money. Although the possible access to a network of experienced YouTubers also plays a role here, I am addressing more informal networks to exchange experiences and knowledge about current trends and changes on the platform. Both cases - the professional MCNs as well as informal networks - are based on the formation of specific interest groups to exchange experiences. However, science YouTubers seem to rarely be contracted with an MCN. This may be due to a personal decision, or because MCNs sign up particularly successful and therefore highly profitable channels. As a niche topic, science channels hardly ever meet these criteria. In Germany, I was able to become part of an informal Facebook group of science YouTubers which has been set up to exchange experiences, provide mutual support in case of problems and facilitate collaborations. The group was founded by a science YouTuber and underlines the importance of an exchange with other YouTubers and their experiences. Or as one of the science YouTubers describes it,

> to dive into this YouTube cosmos and become part of the whole thing. It does not help to upload a video every now and then and to keep your distance. You really have to be a part of this community and then you will be accepted and that is also important.[66]

Bishop (2019) frames this form of exchange as algorithmic gossip. Based on an ethnographic approach of beauty vloggers, her work investigates the extent to which the exchange among each other affects the formation of an algorithmic expertise. The collaborative part of algorithmic gossip is displayed in how "creators who work on the same platforms impart their algorithmic experiences through formalised mailing lists (such as the Internet Creators Guild platform changelog), closed Facebook groups and through intimate requests for information from their fans" (Bishop, 2019, p. 2603). It is precisely this exchange about

[65] I#6, 00:08:37, transl.
[66] I#2, 00:25:31, transl.

algorithmic experiences that can be observed in the closed Facebook group for science YouTubers.

Figure 9: Networked expertise in informal groups.
In this post a science YouTuber asks how to overcome the gender bias the channel displays. (Screenshot: Facebook Group, 03.02.2017).

Figure 9 displays an example of such a discussion. Here, a science YouTuber needs help in interpreting the video statistics and the resulting consequences for the production of further videos. While the video seems to be aimed directly at women according to its title, the statistics show that compared to male viewers, only few women have been watching the video. In response to this question, tips and experiences are exchanged on how to better reach target groups and which adjustments to the presentation of the video (especially metadata) may lead to success. Other questions that are discussed in the group include how other science YouTubers are affected by YouTube's demonetisation strategy, the possible maximum length of a summer break before the algorithm “punishes” less video uploads, or the consequences of leaving a professional network. These examples illustrate that this platform-specific (algorithmic) expertise on YouTube is not acquired by one person but is rather created in a collective learning process whose outcomes are constantly reflected (Limoges, 1993). In the way science YouTubers collect their experiences and coordinate them with the experiences of other science YouTubers, reflexivity plays a role as a component of specific competence to become visible on the platform.

However, it should be mentioned that (informal) networks such as the German science YouTubers on Facebook are not only important for exchanging information. It is also about collaborating and thereby reaching a wider audience.

> (…) let one YouTuber appear in the video of the other and so on and so on then both increase their range.[67]

Especially new science video producers benefit from collaborations with successful science YouTubers. Jointly produced videos generate correspondingly more attention and thus possibly more followers. Being part of a network therefore helps to consolidate one's own expertise and at the same time extends their scope through joint projects.

Up to this point it can be stated that the platform-specific expertise required to become visible as a science YouTuber is composed of individual experience-based expertise, on the one hand, and is formed by collaborative expertise, as a constant reflective exchange (of algorithmic gossip) between science YouTubers, on the other. It seems obvious that a clear distinction between experts and laymen on social media platforms is hard to define. On the one hand, because video producers see themselves as amateurs, based on the narrative of the platform. On the other hand, in the context of increasing professionalisation, it can also be observed that transitions between laymen and experts are fluid. It rather seems that the necessary platform-specific expertise is composed of a multitude of actors, platform-specific characteristics and their interactions.

These mutual influences of own experiences, negotiations with other YouTubers, the algorithms of the platform as well as the users can be described with Irwin and Michael's (2003) concept of "ethno-epistemic assemblages". In their work, they describe the acquisition of expertise as a co-construction of different forms of knowledge which treats social groups more fluidly instead of assigning actors to specific groups of different expertise. The concept of ethno-epistemic assemblages, therefore, describes the local situating of knowledge and its reflective observation (ethno), the emergence of knowledge oriented towards truth claims (epistemic) and finally the territorialisation of enacted knowledge practices (assemblages) (Irwin & Michael, 2003). They argue that only the relationality and

[67] I#2, 00:31:59-7, transl.

the constant exchange of different perspectives, of experts and non-experts, gives room for the development of expertise.

Irwin and Michael (2003) also emphasise the importance of non-human actors (technical or natural) for the process of knowledge generation. For them, “science-lay ethno-epistemic assemblages might be simultaneously rigid and fluid” (p. 123) and “be populated not simply by human scientific citizens, but by hybrid mixtures of humans, technologies and natures” (p. 123). Similar observations can be made on YouTube. Not only is it the case, as already described, that the platform-specific expertise is composed of mutual exchanges between different actors (mainly users, producers, viewers, algorithms, but also software developers and advertisers). At the same time, the role assignments are constantly changing. Video producers can be users and vice versa. In addition, more indirect actors, like software developers and advertisers, who can influence the programming of algorithms, can slip into the roles of users, viewers and producers and therefore might influence the algorithmic behaviour through different perspectives. Even the algorithm can embody different roles - on the one hand, it is responsible for emphasising certain content on the platform, while, on the other hand, it is directly influenced by the behaviour of users, viewers, producers, software developers and advertisers and might change accordingly.

In a recent publication, Allgaier (2020) uses Limoges' (1993) work describing a networked expertise as well as Irwin and Michael's (2003) concept of ethno-epistemic assemblages to frame expertise in the context of science communication on YouTube. In this context, he uses the example of Rezo’s video, discussed in the Intro of this thesis. He highlights the importance of collabarations among (science) YouTubers and applies the concepts of Limoges (1993) and Irwin and Michael (2003) to describe how expertise develops through networks on YouTube. As an example, he describes Rezo's collaboration with other YouTubers for a second video published right before the European elections. However, the focus on networked expertise using the example of collaborations of YouTubers as a description for a specific expertise on the platform seems to be insufficient. Collaborations among YouTubers are important to attract more viewers and subscribers and thus be successful. This is also shown in figure 10 where video producers are told to choose compatible collaborators. However, as we have seen above, the collaboration between science YouTubers is only one element to describe how platform-specific expertise is

composed. Similar to Singer's (2014) description of a two-step gatekeeping process, Allgaier (2020) underestimates the importance of the negotiations between producers and YouTube's algorithms to become experts as well as the importance of networks for exchanging the fluid knowledge on the algorithm’s behaviour.

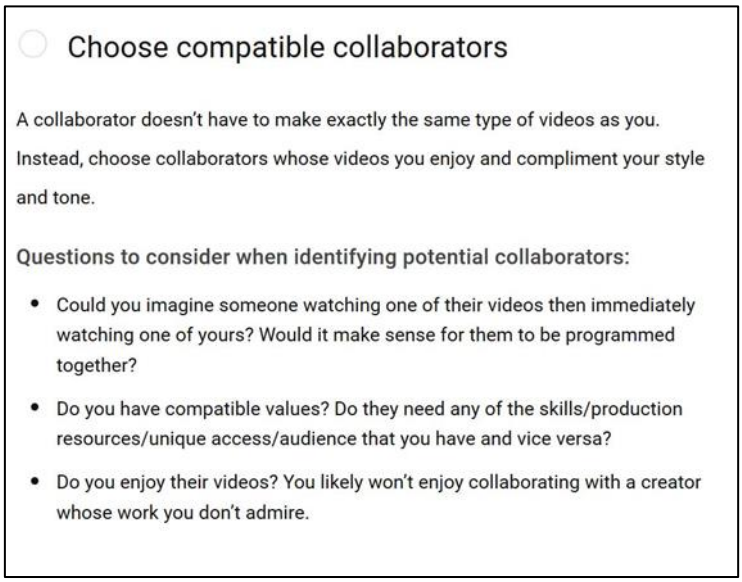


Figure 10: Choose compatible collaborators.
To become a successful YouTuber the YouTube Creator Academy suggests collaborating with other YouTubers (Screenshot, 03.02.2017).

This exchange of knowledge and experience via networks between algorithms, users and producers is also reflected in a jargon used by science YouTubers, for example, in the informal Facebook group. Carr (2010) describes expertise as enactment and thus as a process of becoming instead of being. According to her, this process is interactional and “involves participation of objects, producers, and consumers of knowledge” (p. 18). In this process of becoming, the development and display of a specific jargon is one important point to express expertise. On YouTube, only those who are part of the platform community and thus have a certain platform-specific expertise understand terms such as demonetarisation. However, “jargons are often not attempts to guard or obfuscate expert knowledge, as many have suggested, but are rather a way to signify it” (Carr, 2010, p. 20). Accordingly, those who understand the jargon can call themselves a member of the platform community and thus possibly also an expert. Or others may attribute this expertise to the YouTubers based on the jargon used.

This is the last point I would like to emphasise in the description of platform-specific expertise of science YouTubers: the attribution of expertise. As already described above, concepts and theories of expertise can be distinguished, for example, by whether they are normative or relational. Elements of both perspectives are used in my description by applying Collins and Evans' (2002; 2009) concept of experience-based expertise, as well as the idea of a networked expertise created in ethno-epistemic assemblages (Irwin & Michael, 2003) between human and non-human actors. I argue that, although expertise is acquired through experiences and negotiations with algorithms, users and producers, it also seems to be attributed by different actors in expertise networks. However, I am not referring to the collective attribution of expertise based on the membership to a particular group, such as the group of scientists, which Collins and Evans (2002) and others have rightly criticised. What can be observed on YouTube is rather an attribution of expertise based on fluid platform-specific characteristics. It also means that expertise emerges in the reflection and comparison of experiences in exchange with other science YouTubers as well as in the mutual attribution of expertise in these networks.

So far, I have described the platform expertise of science YouTubers as individual experience-based expertise in negotiations with an expertise emerging in networks and collaborations with human and non-human actors of the platform. On the one hand, video producers gain experience in interacting with the recommendation algorithms from YouTube. On the other hand, they constantly exchange these experiences with other video producers and their experiences. The goal is to become visible in order to reach as many viewers as possible. The expertise gained in this way is not fixed but constantly reflected, just as the algorithmic behaviour may change repeatedly.

Expertise is attributed in this sense by other science YouTubers - for example, based on the ability to master the relevant jargon. Attribution of expertise is therefore granted by the actors of the expertise networks but may also be gained through the algorithm. Thus, if video producers have sufficient knowledge about algorithmic behaviour, the algorithm rewards them by making their videos visible. This process can well be described as an algorithmic attribution of expertise. Expertise is thus attributed, on the one hand, by other science YouTubers and, on the other, by the platform's algorithms. But what happens when the video becomes visible? Or asked in another way: what role do the viewers play in the

emergence of platform expertise of science YouTubers? In the moment a video is found and watched, what counts for the video producer is the reaction of the viewers. Direct feedback from viewers is a central element of the platform. Videos can be liked or disliked, viewers can share or comment on videos or directly subscribe to the whole channel. At this point, the second step of the gatekeeping process described by Singer (2014) becomes apparent and the users become gatekeepers.

> What I think is very important is the possibility of participation, that is, the existence of a community. And this is a very important point for YouTube and also the reason why YouTube is so successful: Because people can not only watch the videos but also comment on them, share them, and communicate with the video makers.[68]

Expertise is thus attributed via participatory elements of the platform, such as likes, dislikes, comments or subscriptions. Rifkin and Martin (1997) describe this attribution of expertise as an iterative and interactive negotiation of expert status between participants of a conversation. Expertise in this context, "is a provisional and potentially changeable status resulting from confrontation, accommodations, implicit agreements, and a range of other processes of face-to-face interaction" (Rifkin & Martin, 1997, p. 32).

The question arises to what extent such negotiations of an expert status on social media platforms take place. After all, the communicative process between producers and viewers is not a face-to-face interaction. Rather, interactions on YouTube can be described as mediated interactions that take place at different times and in different places. In addition, most interactions occur in response to a posted video instead of in a direct dialogue between producer and viewer. Interactions between producers and viewers can only be described as direct, but still timely shifted, if they take place via a conversation in the comments. All other interactions - e.g. changed production mechanisms in response to comments from viewers - can at best be described as indirect interactions. Nevertheless, viewers' comments are correspondingly important for video producers, as they provide valuable feedback on uploaded videos and the video production process and therefore have a direct influence on changes in the production process.

[68] I#2, 00:07:24, transl.

> The comments are the first and only way to get feedback from the users, except for the number of clicks maybe. But just because you have a high number of clicks doesn't mean that the video is good, because it might have gone viral, because you misspoke and didn't realize it. So, the comments are actually already very good and every comment someone writes, no matter if it is good or bad, is actually a little present because someone took the time to write something.[69]

In the following chapter, I will take a closer look at the comments on videos and how the negotiations between viewers and producers lead to the attribution of expertise. My central question is which characteristics are used to attribute expertise. As described by Rifkin and Martin (1997), often not only the presented content is evaluated by the audience but also the identity of the presenter. Of course, this also raises the question of the significance of the scientific content presented. To what extent do accuracy of the presented content, entertainment characteristics or the performance, identity or brand of the YouTuber play a role in the attribution of expertise?

For science YouTubers, this is a constant process of adapting and adjusting to the feedback of their viewers. With their reactions, viewers and users not only decide which content is more and which is less visible, they also influence the behaviour of producers and thus the process of the video production. Carr (2010) describes this process as continuous "work to authenticate themselves [the would-be experts] as experts as well as to authenticate the objects of their expertise" (p. 21). The authentication of one's own expertise is what I will look at in the next chapter. Especially on YouTube, authenticity seems to be a crucial marker for the attribution of success and thus possibly also for the attribution of expertise.

How authenticity turns into expertise

In the previous chapter I introduced which expertise is needed to make a video visible or discoverable on YouTube. I described how this platform-specific algorithmic expertise is composed of individual experience-based expertise and expertise generated in networks or ethno-epistemic assemblages of human and non-human actors. At the same time, expertise is attributed by other producers but also by the platform's algorithms. This chapter is about how expertise is gained when science YouTube videos and channels become visible. From this point on, the attribution of expertise by viewers gains in importance. In the following, I will take a closer look at the negotiations and characteristics that contribute to the

[69] I#1, 00:50:19, transl.

attribution of expertise in science YouTube videos. The question arises how expertise is negotiated regarding the video itself, like e.g. sound, image, storytelling, the quality of the presented content as well as the producer's brand and performance.

As already mentioned above, success seems to be closely linked to the idea of becoming an expert on YouTube. While success, on the one hand, seems to be influenced by the above described platform-specific expertise, namely, in dealing with recommendation algorithms, becoming visible is only one part of being successful and therefore becoming an expert on YouTube. But what does make a video successful when judged by its content and the channel's brand? When looking at the platform as well as recommendations of famous YouTubers and social media professionals, the answer seems easy. YouTube's head of culture and trends, Kevin Allocca, frames it like this:

> But the 'realness' YouTube creators achieve has less to do with the cameras they use or their editing techniques and more to do with their general creative philosophy. Production value remains important to audiences, but authenticity is king. (Allocca, 2018, p. 35)

Likewise, the YouTube Creator Academy gives new video creators the advice that "Authenticity is a key component to success on YouTube" (YouTube, 2020a). Newspapers and blogs also suggest authenticity to be the key to success. Being authentic therefore is one of the most popular pieces of advice for young adults wishing to become YouTube Stars. Along with the success and growth of the platform, channel creators need to establish strong and identifiable, but overall authentic brands together with professional production strategies to become visible in the sheer mass of video content.

When YouTube started in 2005, the platform was known for home videos with cat content or funny moments captured on camera by non-professionals. As a social video platform, YouTube uses its image as a place where everybody can enter the public discourse (Bucher, 2012; Gillespie, 2010), and where everybody can upload self-produced content to emphasise the idea of the amateur as the authentic counterpart of public broadcasters and TV agencies. Therefore, it is not surprising that science YouTubers also frequently use authenticity to describe YouTube.

> It's just that in the beginning there was this whole YouTube thing and the authentic thing. Those were just single dudes with their cameras in their apartments.[70]

Shaky images, inadequate sound and nonprofessional editing became acceptable alongside an authentic story of "real people" (Burgess et al., 2013) or as Allocca (2018, p. 31) describes it: "We'd all developed an appreciation for web video as something created by real people to be consumed by real people". With the emergence of new technologies for smartphones and cameras, high quality production of videos became cheaper and therefore accessible to everybody. Even non-experts in video production can now produce content that is hardly distinguishable from content produced by experts in video production. Accordingly, low video quality as well as the concept of the amateur can no longer be regarded as markers of authenticity. However, authenticity seems to be even more important than ever. Not only does authenticity appear to be very important in general, acting authentic is also described as a quality to outbalance a lack in video production techniques.

> (...) and frequently one watches videos on YouTube lacking technical skills with lots of clicks which are just very authentic and the person doing this just likes what she does, and this is what counts very, very much for the viewers on YouTube. [71]

Unsurprisingly, successful producers advise newcomers that being authentic is the key to success. On the Streaming Media West Conference in 2015, Andy Stack, a manager with YouTube, was asked how important it is to create high quality content. In his answer, he stressed that authenticity is "one common thread" to being successful and that being "really authentic" is "what wins" (Dreier, 2015). YouTube itself published results where 16- to 21-year-olds rated YouTube channels as more authentic than TV Shows[72]. For many users of the platform, "YouTube stars feel more authentic and relatable than many traditional celebrities" (Dredge, 2016)[73]. Becoming visible, becoming successful, gaining money on a social (video) platform seems to be closely linked to the concept of being or acting authentic

[70] I#5, 00:12:21, transl.
[71] I#1, 00:25:45, transl.
[72] In this survey from 2016, forsa asked 309 16- to 21-year-olds to compare 12 relevant YouTube Channels with 14 German TV shows according to criteria such as authenticity, credibility and relevance. One result showed that they valued YouTube channels as more authentic (7%) than TV Shows: see Google (2016).
[73] Original statement by the Guardian in 2016 which was based on a survey conducted by the entertainment industry magazine Variety. Variety underlines these results by displaying that YouTube stars are more influential than traditional entertainment stars: see Ault (2015) and Dredge (2016).

or as Enli (2015) describes it: "Authenticity is a currency in the communicative relation between producers and audiences".

When asking the very same question of how to become successful as a science YouTuber in my interviews, I, too, received answers highlighting the importance of authenticity, honesty or personality. One of the interviewed producers stated:

> So, the most important thing is to be authentic in how you address the audience and that it is not too shiny but rather that you are recognised as a good mate who explains something instead of acting as a teacher in front of a class. [74]

The quote illustrates that for video producers, too, authenticity seems to be a central element for success. At the same time, the science YouTuber provides an explanation of what it means to act authentically. For him, authenticity seems to be related to the idea that science YouTubers should not act as teachers. Rather, performing as someone talking to their viewers at eye level seems to be crucial to be recognised as an authentic science communicator on YouTube. Authenticity is thus equated here with a notion of proximity between the science YouTuber and the audience. Correspondingly, the hierarchical self-representation as a teacher would not be considered authentic.

However, in another interview, the idea that only young people are successful who don't act like a teacher or professor seems to be disproved. At first, the producer of this science channel, too, thought that a professor talking about science won't be as successful on YouTube as in television. Therefore, the concept of the science channel was to combine videos by the professor with videos by a young PhD student to also address the suggested audience of young viewers. Producers assumed that the young science YouTuber would be more successful than the professor because he may seem more authentic in acting at eye level with the audience. However, it turned out that it was the other way around:

> That was actually a nice mistake of mine. I thought you have to be young to be successful on YouTube. We were very worried at the beginning that [the PhD student] would accumulate an unbelievable big number of followers and [the professor] will fail on the YouTube channel. That was our expectation and we were astonished that it went the other way.[75]

[74] I#2, 00:25:31, transl.
[75] I#5, 00:18:04, transl.

As it turned out, the professor was more successful than the PhD student. It seems that viewers found him more authentic as a science communicator and in tune with the channel's brand. Both examples illustrate ideas of how to define authentic, successful behaviour on YouTube. Comparing these two concepts of authenticity already indicates that there seems to be no consistent understanding of what it means to be authentic in science YouTube channels. This also becomes apparent in the next quote. For this science YouTuber, authenticity is

> (…) just a synonym of honesty. You can tell whether someone is like genuinely excited by the subject matter. So, if they are enthusiastic and you can see their excitement when they are talking about something - because that's engaging - you can relate to that. When you are excited, I am excited as well and I can feel that emotion.[76]

The producer emphasises the importance of presenting one's passion honestly in order to transmit this feeling to the audience. Even if there is no explicit mention of not acting like a teacher, the proximity between producer and audience seems to be important here, too. This proximity is described as something that comes through an honest enthusiasm. This also corresponds to the motivations of science YouTubers presented in the previous chapter, namely, to inspire the viewers with enthusiasm for science and to encourage them to engage with science. This also means that to be perceived as authentic seems to be related to the respective personality of the science YouTubers and that their motivation is recognised as honest and authentic. Therefore, for this video producer,

> (…) the most important thing is the personality of the person in front of the camera because that is going to be the most engaging thing. You can have the fanciest graphics in the world and it can look very professional but if the person who is in front of the camera is bored or you can't understand them or is just boring, un-engaging, then people aren't going to carry on watching the video.[77]

So, for viewers it seems that the personality of the video producer plays an important role in whether a science YouTuber becomes successful. In 2016, Welbourne and Grant published results of a content analysis of 390 videos from 39 YouTube channels and displayed content factors that affect the popularity of science communication videos. In an online article, they summarised their results to seven factors that can help make science YouTube videos

[76] I#3, 00:39:39
[77] I#3, 00:36:55

successful (Welbourne & Grant, 2015). The first factors relate to general characteristics of a channel like style and topic. Others recommend producers to publish short presentations but also to become part of the platform community. One factor highlights how important the personality of the communicator is. Here, too, the aim appears to be to credibly convey the interest and enthusiasm for the topic presented and thus to build a relationship with the audience. While the interviewed producers share this opinion, it is rather difficult to identify how science YouTubers define authenticity. It rather seems that there are many different concepts of what constitutes an authentic performance in a science online video. Even for the producers, the term seems to be an empty signifier:

> (...) so far, I consciously tried to avoid the term authenticity not only because it is hard to pronounce but because you hear it everywhere on TV; they also always stress that one has to be authentic blablabla. This is such a difficult word which has already lost meaning because everybody uses it and for sure you have to be authentic, otherwise you are inauthentic (...) and in this case one would somehow be doing something wrong.[78]

Concepts of authenticity seem to be, on the one hand, based on suggestions of how YouTube as a social video platform works. This becomes, for example, apparent in the statements above (I#2, 00:25:31 and I#5, 00:18:04) where science YouTubers should be young and rather avoid acting like a teacher. On the other hand, those concepts also seem to be based on common ideas of how actors in science communication and journalism should behave. In this case, concepts of assumptions about "objective reporting" as a central measure for journalism (Maras, 2012) may arise. While traditional journalism is based on the idea of keeping (emotional) distance to the topic as well as the audience, social media platforms, like YouTube, seem to challenge this concept (Chong, 2019; Peters, 2011). Especially on social media platforms it is important to provide a look behind the scenes and to talk about your private life. After all, on YouTube, it is first and foremost about entertainment (Krachten, 2012).

Acting authentic on YouTube therefore can also mean to overcome the distance between producer and viewer in adding insights into the producer's private life and talking about emotions (Allocca, 2018; Muelleneisen, 2017). The definition of authenticity on YouTube

[78] I#1, 00:44:59, transl.

probably lies somewhere between expectations of authentic appearance on social media platforms and expectations of credible and authentic appearance in traditional media. However, the question is not so much how exactly authenticity is defined but rather how it is negotiated between producers and viewers. Thus, how authenticity is negotiated in the interaction between producers and viewers. This seems to determine who is perceived as authentic and therefore as an expert. In the following, I will therefore take a closer look at these negotiations based on the interviews conducted as well as the commentary and video analysis. Before doing so, though, it is necessary to take a look at how the concept of authenticity in historical and theoretical terms has changed in recent years and what influence this may have on the expectations of producers and viewers on YouTube.

Authenticity is a term with a long history, and one that has been widely discussed. Originating in Greek, the term has been closely linked to authority before it found its German, English and French expressions in the 16th and 18th centuries (Knaller, 2006). Since then, the concept of authenticity has been reviewed in multiple areas, such as philosophy, music, theology or ethnology. Starting in the late 20th century, authenticity has been used as a normative term referring to truth, natural or sincerity (Knaller, 2006) which is very close to how science YouTubers define the term when mentioning honesty as one synonym for authenticity. In one of my cases, for example, there were repeated discussions about whether they should openly communicate that the channel is being established with the support of a production company. While, on the one hand, the aim was to promote the channel's image as authentically amateurish, on the other hand, there was a discussion about whether it wouldn't be more honest to admit that the production was professionally supported. This demonstrates the conflict of different ideas about which characteristics define authenticity, amateurism or honesty.

Authenticity as the perpetuation of sincerity has been discussed in multiple ways (Handler, 1986; Knaller, 2006; Trilling, 1972), especially since “persons are no longer necessarily defined by their position in the social hierarchy” (Handler, 1986, p. 3) and the rise of the individualistic culture. For Trilling (1972), a sincere life is related to being sound, pure or whole, in the absence of dissimulation, feigning or pretense. In this regard, he “links sincerity to modern notions of individual und society, those new ideas with which Westerners used to imagine themselves” (Handler, 1986, p. 2). In the use of sincerity as a social conception, it

privileges social relationships over individual selfhood. Authenticity therefore adopts the idea of the true self in contrast to staged public roles (Handler, 1986; Trilling, 1972), which seems to be in contrast to how authenticity is received on YouTube. Here, video creators become authentic when acting authentic, and therefore, when staging the role of a (science) YouTuber in an authentic way.

With the modernisation of institutions, the relative symmetry between the reality of the self and the reality of the social world has been demolished (Berger, 1973) and the discussion about self, identity and authenticity reciprocates between disciplines such as psychology, philosophy, anthropology and sociology. Following the identity control theory, Burke (2004, p. 5), for example, describes identities as "the sets of meanings people hold for themselves that define (…) who they are as persons, as role occupants, and as group members" which undergo a process of self-verification. Here, identity is based on role identities (i.e. people's location within society, e.g. student or worker), group or social identities (such as American or female) and personal identities (consisting of the meanings and expectations of the person), where the verification of the personal identity in negotiation with society may increase the feeling of authenticity as being who we really are.

Following this concept, identity or authenticity on YouTube may also be related to specific group or social identities, e.g. of a specific YouTube community. Science YouTubers accordingly have a role as video producers, a social identity as part of the YouTube community or more specifically as part of the (science) genre or channel community, and finally, a personal identity that is reflected in the way the video producers present themselves as science YouTubers - e.g. based on their motivation to engage in science communication on YouTube. And they may be judged by their viewers based on these identities. However, the celebration of authenticity in popular culture is also fabricated for profit or success (Ferrara, 2017) and therefore may not only consist of characteristics defined by a specific group identity but also by characteristics of the platform itself. With the rise of social media, authenticity and discussions on authenticity seem to be as ubiquitous as never before.

> The longing for authenticity thus has been, with ups and downs, an important impulse in twentieth- and early twenty-first-century culture. At present it seems that, once again, it takes a central position in cultural debates. (Heynen, 2006, p. 288)

Furthermore, with authenticity as key to success in online video publishing, but also in everyday life, the term seems to again be closely linked to gaining authority, which not only relates to YouTube. We are living in the age of authenticity, as the NY Times claimed in 2016 (Grant, 2016), where being oneself is the defining advice in life, love and career. We buy authentic food from authentic farmers; we follow authentic social media stars and we vote for authentic politicians. Examples are discourses about authentic buildings in architecture (Heynen, 2006), authentic tourism (Taylor, 2001), authentic food and the question of sustainable experiences (Sims, 2009) or authentic branding in management strategies (Avolio & Gardner, 2005).

If algorithms also play a role in determining how authenticity is negotiated, theoretical concepts of self or identity resembling the true self in contrast to a staged role seem insufficient to describe authenticity on YouTube. Social media platforms represent the individualisation of the media landscape and the associated increased personalisation. Viewers want to gain insights into the personal life of the YouTubers, their motivations and their production strategies. At the same time, YouTube, just like Instagram and other social media, represents the staging of the self in order to create an idealised impression among the viewers as described by Goffman in 1959. What we therefore can observe on the social video platform YouTube rather seems to be a performed as well as mediated authenticity. Goffman (2017) describes the performed self as dependent of the social situation.

Thus, the individual and the role the individual plays in a given social situation never completely coincide. Performed authenticity can be associated with one's social identity or role, and authenticity is therefore presented as being relative to norms within a certain group. In doing so, Goffman (1959) connects authenticity to one's position in society, where being authentic is an ongoing process of interactively creating one's identity in relation to a social environment. For Nothhaft (2012), the attribution of authentic behaviour is difficult because it is like a black box that can't be revealed. For him, authenticity is based on experiences of one's own behaviour and the behaviour of others. Tolson (2010) uses Goffman's concept on interaction when identifying several markers of authentic performance on YouTube, stressing that YouTube seems to involve the production of hybrid forms of talk between producers and viewers.

Therefore, Tolson (2010) describes acting naïve and amateurish as markers for an authentic performance on YouTube. Breuer (2012), too, concludes that on YouTube, authentic performance is related to amateurish filming. In reference to the increasing professionalisation of production processes, this statement seems, however, questionable. Several studies reveal that even user-generated content displays markers of professional video production (Erviti & Stengler, 2016; Kim, 2012; Morcillo et al., 2016; Morcillo et al., 2019). Accordingly, the question arises as to whether the amateurish can still be considered a marker of authenticity or whether other characteristics replace it. This is also because it seems to become increasingly difficult to identify which producer is an amateur and which is a professional.

Accordingly, these markers for authenticity do not seem to be fixed but rather tend to adapt to the expectations of the audience or even to the expectations of the producers regarding their audience's expectations. On the set of one of my cases this became obvious when the shooting of a video was stopped to first discuss if the science YouTuber might be too sporty to authentically represent a physicist. Thus, the producers assumed that the viewers would not consider a sporty physicist to be authentic. Rather, they assumed that the audience typically considers physicists to be unathletic. Therefore, it seems that social interactions between producers and viewers on the platform create certain expectations of what is perceived as authentic and what is not. This means that, on YouTube, persons and their contributions appear to be authentic when they act in a sense of the signalled expectations, experiences and perceptions (Näser, 2008).

This results in a mutual influence among the individuals through performances. One example illustrating these performances is how the community is forming around beauty tutorials[79]. This genre community shares a unique language, as well as a unique nature of their online and physical selves. Accordingly, interaction and the use of a common language contribute to the credibility of the users (Ledbetter, 2018). When characteristics of authenticity emerge in reciprocal negotiations between different actors based on expectations, it can be assumed that authenticity is attributed (Nothhaft, 2012). Therefore, in order to answer the question

[79] Beauty Tutorials are mainly created by women presenting information on how to improve makeup skills and foster beauty: for more studies on performing identity in YouTubes beauty community, see, for example, Anarbaeva (2016), Ledbetter (2018) or Bhatia (2018).

of how expertise is attributed by the viewers, we first have to answer the question of how authenticity is attributed, who is attributing it and based on which assumptions or cues.

Authenticity in this sense may be described as relative to social norms of a specific group or community (van Leeuwen, 2001), which means that "authenticity cannot be seen as an objective feature of talk, or of any other form of sociocultural production (…). Authenticity is about validity" (van Leeuwen, 2001, p. 396). Therefore, we need to ask the question of how authentic someone appears in reference to a community or as van Leeuwen (2001) states: "Authenticity is an evaluative concept and we should not ask the question of *"How authentic is this?"* but rather *"Who takes this as authentic and who does not?""* (p.396). Accordingly, Näser (2008) describes the users as the regulatory authority commenting on the videos and the brand of the channel, attributing authenticity and therefore, expertise.

To this point, I illustrated that authenticity is a concept that has been widely discussed outside of as well as on YouTube and yet remains difficult to grasp. While some concepts seem to be applicable to describe what form of authenticity is represented on YouTube, only a closer look at the negotiations between producers and viewers seems to provide more insights. Precisely because of the omnipresence of the term, the use of authenticity as a marker for success seems to be an empty signifier. Accordingly, it appears that authenticity has to be negotiated repeatedly and depends on individual as well as collective expectations of users and producers. In the following, I will therefore take a closer look at these negotiations. For this, I define the process of uploading a video by the producer and commenting on this video by the viewers as an interactional, mediated and timely shifted process.

Video producers start this communication in the moment they upload a video on their channel. When users watch the video and leave comments, they become part of an interactional process between them and the video producer. This may result in a conversation between the science YouTuber and viewers in a direct exchange in the commentary section, or in a time-delayed upload of a new video in response to certain comments. In the course of this constant communicative exchange, viewers may start to identify themselves with the channel of the video producer whose videos they are watching and shape the channel community by becoming a follower of the channel. For the video

producer, building a big community is key to success, as is authenticity and therefore expertise attributed by this very community. This indicates that for uncovering the process of how authenticity is negotiated on YouTube, it is central to look at the interactional process in channel communities. The importance of this interactional process for the success of a channel is also apparent to video producers. For them,

> this is one of the central things about videos for me. That's why there's always a question at the end of the video. And I also try to react to the comments and answer comments when questions come up or try to react when criticism comes up.[80]

In order to further deconstruct how authenticity is negotiated in an interactive process, I used a video as well as a comment analysis. Applying the membership categorisation analysis (Housley & Fitzgerald, 2015a) in combination with a comment analysis, I was able to identify how authenticity is co-constructed[81]. The producer of the selected channel presents historical content regarding actual political topics and enabled deeper insights into his work. Outside of YouTube, this science YouTuber works as a speaker and journalist for a public broadcasting agency. For this producer, YouTube offers the possibility to produce and upload content independently from a specific broadcaster, "to be [my] own boss"[82] and to directly interact with their community. This also becomes apparent in the way the audience influences which topics this science YouTuber is presenting in the videos:

> 60-70% of the topics I cover are requests from viewers - in comments, in e-mails.[83]

Since this video producer published the first video in 2015, he produces videos in his living room with basic equipment that he upgraded during a learning process on the platform. I selected two videos based on the discussions in the comment section and the content presented, with one video presenting information and one where the producer directly addressed the channel's audience. Video 1 can be described as rather typical for the channel, introducing the viewer to the history behind the conflict in Syria. Video 2 seems to be untypical because it promises insights into the science YouTuber's private life. The title of video 2 suggests that it will reveal more insights into becoming a parent, but the science YouTuber instead introduces a new book, a collection of funny facts in German history,

[80] I#2, 00:08:29, transl.
[81] For detailed description of the method, see Chapter 2.
[82] I#2, 00:16:40, transl.
[83] T#1, 01:04:36, transl.

which has just been published. With this second video, the video producer uses the concept of clickbaiting[84] to sell the book, which is rather uncommon for science YouTubers in general but also for this science channel.

In the video, however, the producer explains to the viewers that the video was intentionally designed to explain the concept behind the term clickbaiting. In doing so, the science YouTuber gives this video an educational touch. Furthermore, the producer links this video to a book lottery and, promises to draw vouchers for books among the viewers of the video and thus to promote interest in reading. In choosing those videos, I was able to compare two different forms of communicative interaction, one that relates more to the historical and political content of the video and one that revolves around the YouTuber's personality and brand.

This is displayed in a section of a network analysis in figure 11[85]. While in video 1 (red, mainly left side) discussions seem to be carried out mostly among the audience and viewers only rarely directly addressed the producer, the comments in video 2 (blue, mainly right side) seem to be centred around the science YouTuber, seeking for direct contact. The network analysis is based on the comments to the respective videos and illustrates the frequency with which comments were made and the degree of interaction through the font size and the distance to the centres. However, I have only used this analysis to visualise the different forms of interaction of the respective videos. If I were to continue this analysis, it would be necessary, for example, to visualise and discuss in detail the outliers that are not displayed in figure 11. However, as mentioned above, here it only serves to graphically illustrate what can also be observed in the comments.

[84] The Oxford Dictionary defines clickbait as "(on the Internet) content whose main purpose is to attract attention and encourage visitors to click on a link to a particular web page": see Oxford Dictionary (2020).
[85] For a more detailed description of this method, see Chapter 2.

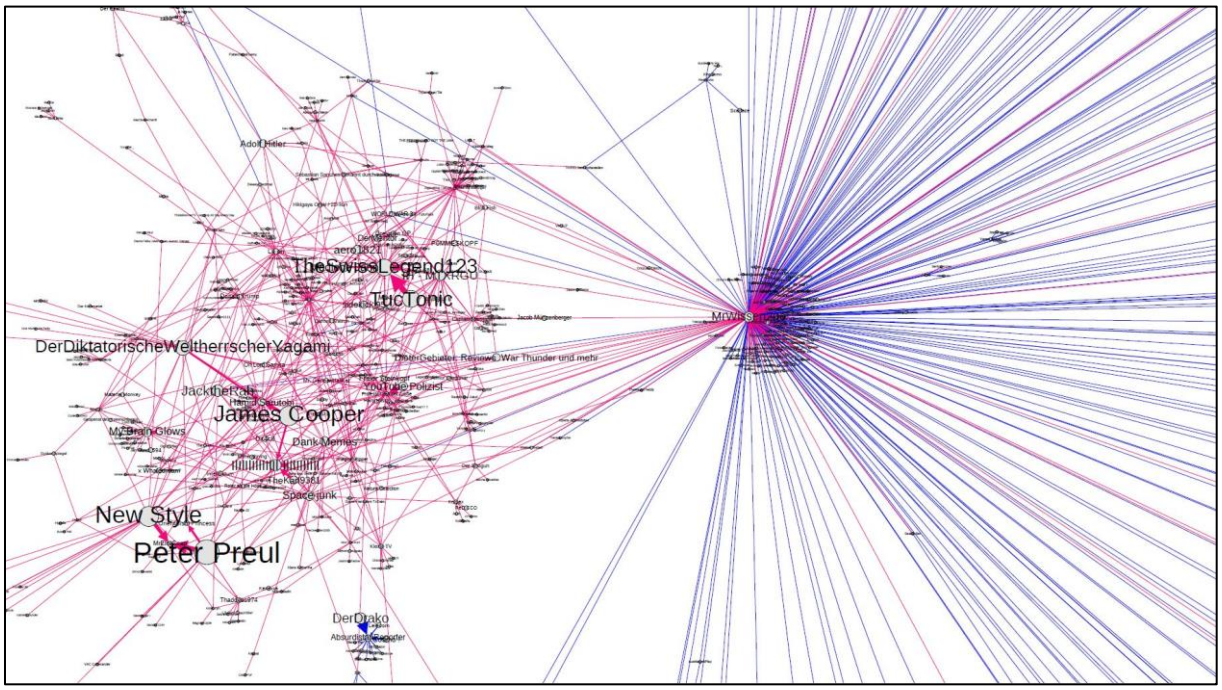


Figure 11: Communicational interaction in YouTube videos.
In video 1 (in red) viewers mainly discussed the content with each other and only infrequently addressed the producer directly. In video 2 (in blue) viewers almost always directly addressed the producer, either in valuing his work or criticising what he does.

As expected, video 1 appears to foster a more general discussion on a rather controversial political and historical topic, whereas video 2 results in a discussion regarding the science YouTuber’s performance. Video 2 is also interesting for another reason because it illustrates a rather untypical behaviour of the science YouTuber regarding the channel’s history. This might challenge the audience's concepts and expectations of how science communication should be done and how flexible those concepts are. The comparison of the two videos allowed me to identify the characteristics on which these negotiations are based and whether authenticity is more likely to be attributed regarding the video theme or the performance of the YouTuber. At this point I would like to mention that although the example chosen is a science YouTuber who is present in front of the camera, the observations gained may also be transferred to channels where the producers are not visible. The performance of the science YouTuber not only refers to the personality in front of the camera but seems to be rather related to the brand of the channel. This brand can also represent a channel that displays animations and whose production is supported by a team of designers.

Although the two videos display different communication patterns, the commentary analysis revealed that comments regarding the authenticity of the content, the production mechanisms and the channel's brand seem to share similar characteristics. However, the comments include less direct statements such as "this is authentic or credible". Rather, it becomes apparent that comparisons are used for evaluative statements on the video and channel brand. In other words, this means that even if the viewers attribute authenticity to the science YouTuber directly, they use comparisons to do so instead of just addressing the producer's performance as being authentic, real or trustworthy. For example, comments refer to the logic of the channel established in the past. This means that a video is judged according to whether it matches previous videos and that, for example, the behaviour of the science YouTuber is judged according to how he has behaved in the past. This can also be observed in the comments on video 2.

> Really, I knew right from the start that this couldn't be clickbaiting because I knew you never would do something like this. Luckily, I was right. Congrats. [86]

As can be seen in the statement above, these comparisons are drawn, for example, to refer to the history of the channel. Although the science YouTuber in video 2 makes use of clickbaiting, some of the followers trust that this is only educational. Based on their previous experience with the science YouTuber, they believe that the video uses clickbaiting, but only to educate about the method. Based on this, the video is judged according to whether it matches the brand that has been built up or whether it differs too much from previous videos and thus reveals the brand as no longer coherent. Correspondingly, authenticity is attributed if science YouTubers behave coherently to their brand created and presented in the past. So, if science YouTubers upload a video that differs significantly from previous videos in terms of content or format, they run the risk of being perceived as less coherent and therefore less authentic. The channel's brand and related motives and values seem to be under special observation. As illustrated in the example above, comparisons are, for example, used in relation to the channel's brand and formerly uploaded videos on this channel in order to make a judgement.

[86] Comment on video 2, 12.09.2012, 15:59, transl.

In addition, comparisons are drawn in regard to other communities on YouTube. This includes other channel communities as well as genre communities. Here, expectations of one genre community are compared with expectations of another. These expectations seem to be based on individual experiences with different communities as well as in exchange with those experiences of other viewers and producers. Regarding my comment analysis, comparisons are often made in reference to beauty tutorials or gaming videos.

> I think this is one of the first videos to which I could give multiple thumbs up. I like how sophisticated you create your videos. Your lottery, for example, most YouTubers would have raffled their own signed products or an iPad or something like this (...).[87]

Here, the viewer compares the producer's idea of giving away vouchers for books to lotteries of other YouTubers who use this concept for product placement. With the producer giving away books, the channel still seems to fit the viewer's expectation of a science YouTuber – even when it promotes a similar behaviour as the channel creators of other genres. So, in principle, science YouTubers do not seem to be expected to draw products, but when it comes to books that are raffled off, it seems to fit the expectations of the viewers again. Therefore, it appears that higher expectations are placed on science YouTubers than on other genres. Yet they are certainly expected to earn money. However, it seems important that behind deviant – not coherent – behaviour, viewers can still recognise the values ascribed to science communication. These in turn seem to be composed of general expectations of science communication itself and expectations of the channel's brand. Authenticity in those cases seems to be attributed if the science YouTubers' performances differ from other communities:

> This video is SO good. YouTube needs more of those factually kept and very informed contents. But in contrast to all the pranks, etc., which have various MILLIONS of clicks, this video unfortunately has only 50,000 clicks (date: 10.02.2017). However, very good video! Thank you for it and keep it up. This can only be praised. [88]

This comment highlights that the producer presents the content by using facts, which makes it look informed and well prepared, and that this is valued by the viewer who wrote this comment. For this viewer, videos of pranks are not as informative and therefore do not

[87] Comment on video 2, 12.09.2016, 20:02, transl.
[88] Comment on video 1, 10.20.2017, 20:59, transl.

deserve a high number of clicks. Again, it becomes obvious that viewers seem to have specific expectations towards science YouTubers, especially in relation to other YouTube genres. As already mentioned above, these expectations appear to be based on experiences with traditional media, on the one hand, and on expectations of social media platforms like YouTube, on the other. This is also displayed in the following comment where the producer is praised because the video is not too emotional. This again seems to be in line with the viewers' expectations towards the traditional idea of objective journalism where knowledge should not be presented as too emotionally but rather neutral[89]. This is also highlighted in the following comment which was posted in response to video 1.

> Aside from the good video, I really appreciate that you didn't use sad music to emphasise the pictures, this does make the whole thing way more serious. (...).[90]

Viewers also seem to have expectations based on YouTube's platform politics, meaning the concept of video creators giving insights into their personal life. Together with the production of videos directly in the living rooms, insights into private life are supposed to help build a relationship between YouTubers and viewers. In addition, behind-the-scenes glimpses or even the appearance of such glimpses underline YouTube's concept of a transparent and democratic public communication medium. The following comment, on the one hand, praises exactly that in congratulating the YouTuber to the new child. On the other hand, the viewer emphasises that giving too many insights into the producer's private life would again be against the concept of good and credible science communication on YouTube.

> Congratulations you two and lots of health and a good life for your little one! I just posted a comment with one of [name of the partner] videos, telling (…) that I really like to watch the two of you and that I love that you don't tell too much private stuff. (...).[91]

Accordingly, not only the producers but also the viewers must constantly balance these two worlds of expectations when creating and valuing videos. Moreover, there does not seem to be a fixed rule as to how science communication must look like on YouTube. Rather, science

[89] See, for example, Ward (1998) or Bakir and McStay (2018) regarding the discussion of emotions and objectivity in journalism.
[90] Comment on video 1, 08.02.2017, 17:47, transl.
[91] Comment on video 2, 16.09.2016, 22:35, transl.

YouTubers need to adapt to a fluid understanding of authentic science communication among their constantly changing community. To do so, viewers as well as producers use comparisons to permanently adjust to each other's expectations. For the producers, this means to perform as coherent as possible to be attributed with authenticity. If video producers can create coherent content and present themselves or their brand as coherent and therefore in line with the channel's history as well as with the genre community, they are able to build a relationship with their audience.

Drawing from my empirical material, they do so in sticking to their brand, on the one hand, and in constantly distancing themselves from non-science related YouTube communities, on the other. In the chosen example, the producer presents himself as someone who is interested in teaching especially young people about history and politics and sticks to that image in publishing a funny book about history. The science YouTuber also maintains the style in video production and content presentation. In using clickbaiting to present his first book, the YouTuber, on the one hand, adapts to the platform by allowing the viewers some insights into his private life. On the other hand, the producer educates the viewers about the concept of clickbaiting and organises a book lottery which meets the viewers' expectations regarding the brand and personality of the science YouTuber. Although the video creator uses a common method to get attention and money, by raffling books and educating people about clickbaiting, the channel also differentiates itself from other genre channels such as beauty tutorials or gaming videos.

Both, sticking to a brand over time and differentiating from other communities not only depend on the producer's behaviour but also on the communicative process between the producer and the channel's community. In this constant process, creating coherence seems to be the key for the co-construction of authenticity. Therefore, to be attributed with authenticity, and thus with expertise, it appears to be necessary to perform in a coherent manner. In doing so, science YouTubers create their channel community and become more successful in collecting more subscribers. The goal of reaching the largest possible channel community is one of the tips that YouTubers receive in order to become successful.

Figure 12: How to build your community.
Screenshot of a course of the YouTube Creator Academy displaying the importance of community-building for YouTubers in finding authentic ways to connect to their viewers.

Figure 12 displays a screenshot from a YouTube Creator Academy course, which emphasises the importance of a channel community and points out that an authentic appearance is necessary to achieve this. Thus, when authenticity is negotiated over coherent behaviour, the expertise of science YouTubers can be traced back to whether video producers are able to act coherently or not. Therefore, when coherence is important for creating a community and gaining more followers, we must look more closely at the term coherence and in which ways science YouTubers specifically perform coherence. In the following, the term will therefore be unpacked further.

What has become clear so far is that first, coherence seems to be performed over time, comparing earlier and recent videos and brands of a science channel. Second, this coherent performance should differ from non-science related communities. The first one can be described as a positive coherence over time. The second one can be described as a negative coherence because science channels must perform in such a way that they are distinguishable from channels in other communities, like channels presenting beauty advice or gaming experiences. Therefore, when creating a channel with the goal of becoming a successful science YouTuber, producers must display coherent performance for both of these characteristics. This process, which I call coherence management, needs to be done

actively when starting a science YouTube channel and is closely related to the creation of a specific brand of the channel. In publishing the first videos, this brand is still rather fluid and becomes more concrete over time. Science YouTubers achieve coherence when the presented brand is based on expectations on online science communication and differs from characteristic markers of other YouTube genres. At the same time, however, they must also meet expectations as members of the YouTube community and, for example, provide entertainment, speak the community's language or offer insights into their private lives. On the other hand, coherence is achieved when sticking to the channel's brand which is created in the videos published over time.

I argue however, that neither the video producers' brands nor the rules and values for the science genre are completely fixed. Science YouTubers rather orient themselves in, what I call, the corridor of coherence (see figure 13), where they can move freely, and which is defined by movable boundaries. This new approach, which I introduce here, illustrates how coherence is negotiated between producers and viewers. The boundaries of this corridor limit the possibilities of the science YouTuber to change content, production or performance. However, these walls are not fixed but movable.

Developments over time (e.g. enhancing the production process, adding new topics) and therefore a forward movement are possible as well as shifting the walls as such in reference to changes in how the genre community values the performance of the science YouTubers as part of the science communication or educational community. The walls of the corridor can become narrower or wider and thus describe the scope of the science YouTuber to either follow the rules of the platform or the expectations towards science YouTubers. In constantly negotiating the rules and values of science communication on YouTube between the producers and the viewers, the borders can even float to one side or the other. This happens, for example, when expectations of science communication on YouTube or the behaviour of YouTubers change. In addition, this might be rather important as given rules for good science online videos change over time, as do the social media platforms and their communicative interactions.

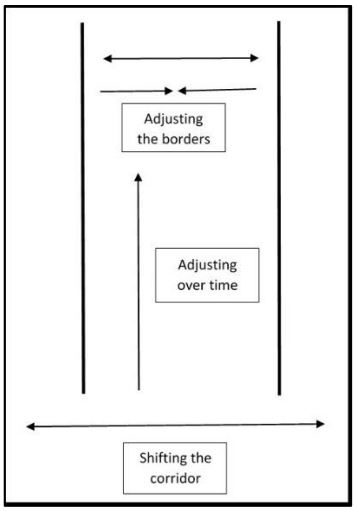


Figure 13: The corridor of coherence.
Co-constructing coherence is a constant process. The channel's brand needs to be coherent over time with some scope in between the borders of the corridor. Over time, the borders of the corridor can widen or narrow. The differentiation to other communities is symbolised by the movement of the entire corridor to the left or the right.

This corridor of coherence may even broaden. In my document analysis, I observed that the more successful science YouTubers become the more can they add new topics, collaborate with YouTubers of different communities or even change their brand. One example is the successful science YouTube channel "AsapSCIENCE", which did not belong to my sample. However, the two producers gave a lot of interviews, and many articles have been published about the channel's history and development over time, which I examined in a document analysis. The channel has existed since 2012 and was created by Mitchell Moffit and Gregory Brown who both studied biology. They produce videos about various topics of science and have 9.4 million subscribers.[92] With a growing channel community and rising success, the two producers added videos differing in style and presenting new content. While they started with videos using voice-over drawing, they later added a vlog and uploaded music videos. Especially in the vlog they presented themselves in front of the camera with more personal views and behind-the-scenes insights. In doing so, they expanded their offerings, changed video formats and the way they communicated with their community without losing users. Their brand was so solidified that they could experiment with new channels or special playlists. Instead of being perceived as incoherent, they managed to reach new viewers and expand their channel community.

[92] https://www.youtube.com/user/AsapSCIENCE/featured (accessed: 14.08.2020).

While displaying coherence over time and contrasting other communities fosters the co-construction of authenticity and therefore leads to successful science communication on YouTube, the question arises how this is done exactly. Is coherent performance based on the producers' personality, on the content presented or on how they communicate with the audience? In video 1 of my analysis the producer presents himself as someone who wants to make history entertaining and who tries to foster political discussions. In the comments, I could observe that many young people watch the videos to get better grades and, therefore, for educational purposes:

> (...) my final exam is partly also your merit. :)[93]

The video producer also introduces himself as someone who presents well-researched content and who can connect with users by making jokes and giving some insights into his private life. The channel's community at the same time compares its videos with other communities on YouTube, such as the beauty or the gaming community. In this context, they implicitly display their ideas of how science YouTubers should or should not act. When comparing the science YouTuber's attempt to sell a new book with strategies of the gamers or the beauty channels, the comments show that selling products is something which users do not expect when watching science communication. During the discussion, however, followers point out that selling a book is something that still fits in the image of a science YouTuber because it is something that educates young people.

> (...) Finally a YouTuber publishing something interesting and surely something worth knowing :D. [94]

Both examples of coherence, one co-constructed based on the presentation of the channel's brand and the other based on the demarcation to other YouTube communities, illustrate forms of narratives. Accordingly, science YouTubers build their brand on narratives that illustrate their passion for science, their video style, their favourite topics and other things. In the presented case, the producer uses the narrative of a young science YouTuber with a passion for history and journalism who spends his free time producing educational videos directly from the living room about German history, thus aiming to foster discussions on

[93] Comment on video 2, 12.09.2016, 22:35, transl.
[94] Comment on video 2, 12.09.2016, 14:41, transl.

daily political topics. As described above, the producer moves in a corridor of coherence starting from this narrative. Depending on the distance between the walls, the narrative can be considered extended or changed. At first it seems obvious that a narrative – one might think of the use of storytelling in science communication – refers centrally to the content of the video. For example, when a coherent narrative is created to convey a scientific topic. However, as I have already demonstrated in the comment analysis, the requirement for a coherent narrative refers not only to the content but also to the brand of the channel and, in a broader sense, to the shaping of the channel and genre community (namely, when the walls of the corridor shift to the right or left).

In his work on the narrative paradigm, Fisher (1984, 1985, 1997) outlined that humans have to narrate and are therefore essentially storytellers (Fisher, 1997). Narration, or storytelling, in this sense is a necessity of communication in general but also for the constitution of communities (Baker, 2006; Fisher, 1997) as well as for the human being to have access to itself and the world (Ricoeur, 1980). In the process of communication, people relate to factors of reliability or authenticity that are based on the decision whether they believe a narrative or not. In the following, I will use the narrative paradigm to explain how coherence co-constructs authenticity and to answer the question of how this process is based on the channel's brand, the content presented as well as the forming of a specific community.

According to Fisher (1997), coherence is one of the two features for narrative rationality and therefore for evaluating a story's quality, while fidelity is the other. Only if a story is valued with coherence and fidelity is it considered to be reliable. Fisher (1997) introduces three aspects of coherence which I could also observe within the results of the video and comment analysis. The first aspect is the structural or argumentative coherence which determines whether a message is consistent. Second, material coherence relates to the comparison with other stories and third, characterological coherence depends on the reliability and trustworthiness of characters.

In my example, coherence which is co-constructed based on a demarcation to other communities on YouTube resembles material coherence. Viewers compare in their comments the story of the science YouTube video with their own expectations and thus their own story of science communication on YouTube and distinguish those from non-

science related communities on YouTube. This means that the audience compares the producer's marketing for a new book with the idea that science YouTubers educate their viewers. Marketing at first glance might not be in line with the expectation of how science communication should be done. The marketing of a book on historical facts does, on the other hand, fit those very expectations and contrasts with other videos where YouTubers promote non-educational products, such as smartphones or beauty products. With regard to the corridor of coherence, material coherence thus describes whether both walls tend to shift to the right or left – and thus, for example, closer to stricter criteria for science channels or closer to looser criteria for other genre channels.

The concept of characterological coherence seems to illustrate the process of co-constructing coherence over time, relying on the channel's brand. Trustworthiness and reliability of the science YouTubers are in this case based on what viewers expect regarding the presented brand so far and whether their actual presentation in the uploaded video fulfils these expectations and is therefore coherent. In my analysis, the viewers seem to expect that science YouTubers display the perfect balance between presenting well researched content, on the one hand, and giving insights into their private lives, on the other. This seems to be fulfilled by the producer in talking about becoming a parent. But instead of presenting the child, he introduces an educational book. This is in line with the brand the science YouTuber has built since the channel is online.

Over the years, the producer has built a brand that stands for presenting good educational content which helps students pass history exams while still shooting videos from the living room and occasionally giving insights into his private life. For Fisher (1997), characterological coherence is an important key aspect for his concept because once a person is seen as a trustworthy and reliable character, "one is willing to overlook or forgive many things" (p. 316). For example, in video 2, the video producer used clickbaiting to promote a new book and while this was inconsistent regarding the channel's brand as well as the YouTuber's image, most of the comments were forgiving. In video 1, the science YouTuber presented facts that users contested and sometimes subjectively evaluated as errors. However, some of these comments were still positive regarding the producer's reliable character:

> (...) I like your videos… I just beg to differ that the poison gas attack by Assad against his own people which you describe is very unlikely to have happened in the way it was propagated. (...) A good format, which I will keep on supporting in the future. [95]

With regard to the corridor of coherence, characterological coherence describes the path through the corridor. The walls to the right and left offer sometimes more and sometimes less space to further develop the narrative of one's own brand. For this, science YouTubers need a solid core narrative. Once viewers have gained confidence in this brand, the walls may expand, and the science YouTuber has more room to change the narrative or even add more deviating narrative strands.

Surprisingly, I have not found any comments from viewers that illustrate structural or argumentative coherence. This means that comments that deal with a coherent narrative in relation to the topic presented were rarely made. Although comments, especially on video 1, did indeed concern the content of the video (e.g. by criticising the facts presented), they did not lead to a discussion of coherent storytelling. Of course, this could also be due to the fact that my analysis only refers to two videos of one channel and therefore serves as an exemplary basis for my theoretical analysis. For me, however, it seems logical that hardly any comments regarding a structural or argumentative coherence can be found because there is no illustration of it in the corridor of coherence either. This is because, on YouTube, the brand of the channel seems to count more than the content of a single video - at least if you have reached a certain number of followers.

As explained in the previous chapter, even if a channel becomes established, every uploaded video has an impact on the success of a channel. Success is not constant but can already be noticeably minimised with just one video. I argue that this refers mainly to the content. The coherence corridor accordingly illustrates the negotiation of coherence in relation to a channel and less in relation to a video. The video could therefore simply be described as a too small unit to discuss a coherent storytelling of the content in detail. However, this doesn’t mean that coherent storytelling doesn’t count at all in science YouTube videos.

It would be conceivable to apply the corridor of coherence to one video only. Then the narrated story, and thus the coherent storyline, could move within the same boundaries as

[95] Comment on video 1, 11.02.2017, 17:58, transl.

the characterological coherence - or perhaps even within a corridor existing in parallel to the one of characterological coherence. What seems much more interesting to me at this point, however, is that due to the great importance of a coherent brand in relation to a coherent channel and genre community, the content of individual videos no longer seems to be as important as it is supposed to be. Instead, especially the material as well as the characterological coherence seem to be crucial for the attribution of expertise to science YouTubers.

The second aspect of narrative rationality is fidelity, which describes the considerations of reasons and values (Fisher, 1985). Both considerations could be observed in comments in video 1, to check facts or to discuss different values:

> A great video! I just want to correct something; in 2005 Aleppo had approx. 2.1 million citizens, however, in 2011 before the war there were around 4 million people living in Aleppo. (...).[96]

The point here, therefore, is to compare facts based on individual motives and values. With regard to science YouTube videos, this means that viewers review the facts presented in the videos and compare them with their own motives and values - but also with their own knowledge. At this point, therefore, the content becomes more important. It is then mainly about the evaluation of the facts in comparison to other sources, one's own knowledge and values. However, comments for checking fidelity mostly led to a discussion between viewers (see figure 11). Directly addressing the producer, commentators remarkably still valued the science YouTuber's reliability and trustworthiness when criticising the presented facts and therefore addressed the characterological coherence instead of fidelity (see examples above). Since the central issue here is the respective motives and values of the viewers together with a fact checking, it is also understandable that comments in this direction lead primarily to discussions within the audience. However, it can also be assumed here that in more narrowly defined channels and genre communities, viewers who pursue similar motives and values are more likely to talk to each other. In the present example, however, this is disrupted because the topic presented is highly controversial. To what extent there

[96] Comment on video 1, 11.02.2017, 18:50, transl.

might exist similarities in terms of motives and values within certain communities would need to be a subject of further research.

In summary, I argue that the concept of coherent narration provides valuable insights for explaining how authenticity is co-constructed between the producer and his or her community. Coherent narration therefore seems to be one key to successful science communication on YouTube and co-constructs the specific platform expertise of science YouTubers. However, coherent narration in science YouTube channels extends not only to the presented content such as storytelling in general but also contains the audience and the brand of the storyteller. Interestingly, what I could observe is that coherent narration indeed concerns all three aspects: the channel's brand, the presented content, as well as the coherent narrative of the channel community. According to the analysis, producers and viewers co-construct characterological as well as material coherence in an interactive process of comparison and demarcation. Only argumentative coherence was not discussed when evaluating the quality of the presented story. Nevertheless, the content is also evaluated, but this is done via the aspect of fidelity. While, on the one hand, it does not seem surprising that the creation of a coherent narrative is a characteristic of expertise of science YouTubers, it, on the other hand, appears to be rather striking that these negotiations of coherence are not so much about a coherent storytelling of content but rather about a coherent storytelling of one's own brand and a coherent story of the respective community.

For science communication, this naturally raises the question of what role the presented content actually plays. Is a review of the facts based on one's own motives and values sufficient to trust that it is also a matter of communicating scientific content accurately? And what significance does this have for science communication in general? In the Outro I will go into this question in more detail and try to give answers based on my research. Before I do so, however, I will first combine the two concepts presented so far to explain the platform expertise of science YouTubers in one overarching concept.

How science YouTubers become experts

In the previous two chapters, I have elaborated based on my empirical material how the platform expertise of science YouTubers can be described. Starting with the question of

what makes science YouTubers successful, I first looked at how channels and videos become visible on the platform and what form of expertise is required for achieving this. Expertise to become visible arises from experiences reflected in negotiations between users, producers and algorithms and attributed through the membership in these networks by human and non-human actors. Subsequently, I addressed the question of how expertise is attributed once videos and channels are visible. Expertise arises when the video becomes visible through the exchange between producers and viewers in negotiating coherence. Central to this are coherent narratives of the channel brand, the channel community and the presented content. In this chapter, I will integrate both concepts and present a comprehensive model for how the platform expertise of science YouTubers emerges.

The starting point for this model is the question of how science YouTubers become successful. To reach this goal, video producers need to develop strategies to become visible as well as coherent narratives to attract followers. Whether content becomes visible is determined by YouTube's platform politics (Gillespie, 2010), more precisely by the platform's recommendation algorithms (Bucher, 2012). Science YouTubers need to master these algorithms and know how to handle them accordingly. In addition, they need to create coherent narratives for their channel brand as well as for the channel’s community. They become, as the YouTube Creator Academy describes it, optimisation wizards in the production of the videos, in how they adapt the metadata of the videos so that they are discoverable and how they present coherent narratives so that they become successful as soon as the videos are watched. The expertise they gain is based on normative markers such as jargon and experience-based knowledge but is also attributed by human and non-human actors. A central aspect of it are the negotiations between producers, users and algorithms, in the context of which the knowledge gained is reflected continuously.

For the platform expertise model of science YouTubers, I first draw a line of visibility as a border between the two expertise aspects before and after videos and channels become visible. This demarcation, however, is a measure that is exclusively related to the analysis in order to allow the exploration of individual elements of the platform expertise of science YouTubers. Accordingly, I consider this demarcation as not fixed. In fact, the two sides – with invisible videos on one and visible ones on the other side – cannot be strictly differentiated

from each other. Neither can the expertise concepts behind the two sides. On the contrary, the transitions between the two sides are fluid and developments on one side influence developments on the other side and vice versa. Nevertheless, in the following, I will use this simplified dichotomy of visibility to explain my approach of describing the platform expertise of science YouTubers (see figure 14).

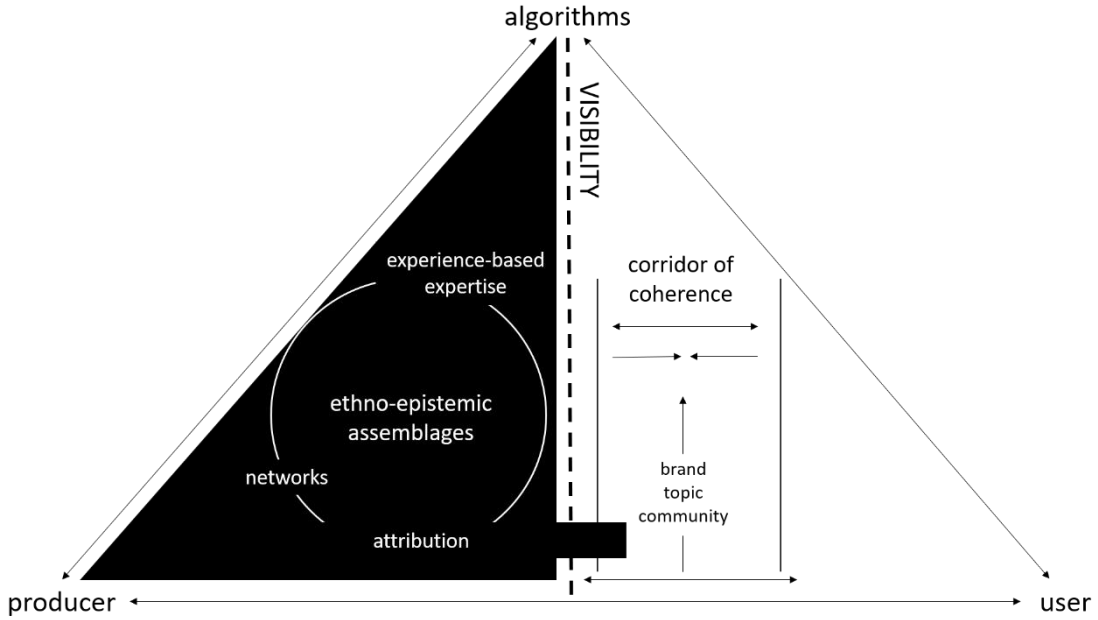


Figure 14: The platform expertise of science YouTubers.
The figure depicts the analytical dichotomy of visibility on YouTube within a process of recurring negotiations between producers, algorithms and users. Expertise on the left side can be described as ethno-epistemic assemblage of individual experience-based expertise, reflected expertise emerging in networks and the attribution of expertise by human and non-human actors. Especially the attribution reveals that this dichotomy is not fixed. Expertise is attributed via other producers, the algorithms, but also via the users after videos become visible. Here the attribution of expertise occurs in the co-creation of coherence regarding the channel community, the channel brand and the content displayed.

Before I will describe the specific parts of the model in more detail, I want to emphasise the importance of the triangle surrounding the graphic. It illustrates the negotiations between producers, users and algorithms which shape the platform expertise of science YouTubers. These negotiations describe an interactive communication process that is multidirectional and based on a comparison of changes on the platform as well as ongoing reflections of the actors' experiences and expectations. Users and producers adapt to the behaviour of the algorithms and vice versa, and the expectations of users and producers influence how expertise in the production of science online videos develops. The triangle as a frame around the model thus illustrates the importance of this interaction process and the fact that the platform expertise is not fixed but rather subject to process-related changes.

The left side of the model displayed in figure 14 illustrates how expertise unfolds with the intention of the science YouTubers to become visible on the platform. This part of the platform expertise of science YouTubers is based on different theoretical approaches of expertise; from anthropology (Carr, 2010), communication sciences (Rifkin & Martin, 1997) and Science and Technology Studies (Collins & Evans, 2002; Collins & Evans, 2009; Irwin & Michael, 2003). The theoretical approaches often deal with the question of who is allowed to participate in technical decision-making and who is not. When looking at science communication on YouTube, however, we have to take a step back and ask first of all who can actually participate in the public discourse of technology and science in a digitised world.

This question is important because social media platforms such as YouTube now offer non-scientists and non-journalists a stage for science communication. Professional training for science YouTubers is difficult because the conditions on the platform change with the behaviour of the users, producers and algorithms. Accordingly, a central element is an experience-based knowledge, which is created in the interaction between users, producers and algorithms. Science YouTubers compare their experiences with the experiences of other science YouTubers and the interactions with the platform algorithms and reflect their knowledge. Expertise thus arises from the experience gained and the exchange of experiences in networks and is also attributed by the actors of the platform, e.g. through the process of becoming visible.

The platform expertise on the left side of figure 14 can therefore centrally be described with the concept of ethno-epistemic assemblages by Irwin and Michael (2003). The blurred boundaries between experts and laypersons described by them enable the emergence of expertise in a relational exchange between human and non-human actors. Although this relational theory of expertise already includes concepts of a network-based expertise as well as the attribution of expertise, I highlight both concepts separately. The implementation of the concept of ethno-epistemic assemblages emphasises that expertise is generated through negotiations between human actors with different levels of knowledge about the platform (users, successful and less successful producers, software developers, advertisers, etc.) but also non-human actors such as the recommendation algorithms.

For the science YouTubers, this means that expertise is established and reflected in the exchange with other science YouTubers (in formal and informal networks), as well as with other video producers, via the access to platform services (e.g. the YouTube Creator Academy), the reception of articles about YouTube-specific topics and trial-and-error-based negotiations with platform-specific algorithms. However, network-based expertise is not only evident in the formal and informal networks already mentioned, such as the Facebook group of science YouTubers presented in this work. It is also demonstrated in the importance of collaborations, which means not only an exchange of knowledge about platform politics but also a collaboration to reach new target groups or to use the popularity of a partner to make one's own content visible.

Although I decided to use the relational theory of ethno-epistemic assemblages as my central concept, I also apply the normative framework of Collins and Evans' (2002) experience-based expertise. Here, the emergence of expertise is described by means of different levels of experience of acquired knowledge and the resulting possibilities for interaction with research processes. Regarding science communication on YouTube, I use this concept to describe how science YouTubers gain experience in interacting with the platform. I refer to this interactional process with the term of an individual experience-based expertise, in distinction from experiences shared in networks. With increasing experience, science YouTubers acquire, for example, specific jargon, learn how to handle statistics provided by YouTube, and improve the management of metadata. Often these experiences allow them to become a member of (in) formal networks, where individual experiences are shared, compared and reflected. As already mentioned, the importance of experience-based expertise also illustrates the fact that the behaviour of the algorithms, users and producers on the platform changes and that knowledge about this is correspondingly process-based and not fixed.

Finally, when looking at the left side of figure 14, it is apparent that the attribution of expertise also plays an important role. Attribution as such can also be assigned to a relational framework of expertise. Like the experience-based expertise described above, what we could observe on YouTube is a fluid form of attribution in contrast to a generalised attribution based on the membership in a particular group, such as the group of scientists. At this point I would like to highlight two aspects of attributed expertise as displayed in the

platform expertise of science YouTubers. In line with the concept of ethno-epistemic assemblages (Irwin & Michael, 2003), I argue that expertise on social media platforms like YouTube can not only be attributed by users and producers but also by algorithms. This attribution of expertise by algorithms can be observed, for example, when a video or channel becomes visible, i.e. when a video is displayed on the landing page or in the recommendation bar on the video page. This form of agency of platform's algorithms is also mentioned by YouTubers when talking about being punished by the algorithm or feeling that they are at its mercy. At the same time, the attribution of expertise connects the two sides of the model displayed in figure 14, namely, in the process of becoming visible. In the moment when the video becomes visible, the uploaded content is evaluated by the viewers. Now it is no longer just a question of optimising the metadata but also of optimising the content, its presentation as well as the production quality and branding of the channel and the video producer. This part of the model is displayed on the right side of figure 14.

Participation as key element of social media platforms provides real-time feedback on the uploaded content through likes and dislikes as well as through comments. As shown in my data, the users' comments in response to videos are one of the most important aspects for science YouTubers to gain feedback to improve their video production, to gain more subscribers and therefore become more successful. In comments, viewers can place criticism as well as compliments and suggestions for topics. In addition, the comment section often functions as a collective corrective for the presented content. Accordingly, users expect comments to be noticed, e.g. by implementing topic requests. YouTube also paints a picture of itself as a democratic video platform which enables amateurs to become visible. In the development of the platform, the concept of the amateur has increasingly been equated with one of authenticity.

These developments have led to platform success stories often based on the description of particularly authentic content or YouTubers. A closer look at the negotiations between video producers and viewers in the comment section reveals, however, that authenticity per se is not actually what is negotiated here. This may be due to the fact that the concept of authenticity formerly associated with the amateur is no longer easily detectable since YouTubers have become more professional. But it may also be because the term has become

so charged with meaning that it can no longer be used in collective negotiation processes. This means that there are so many notions of authenticity that it has become difficult to use just one concept as marker for success and thus for expertise. Instead, the attribution of expertise is performed through the collaborative negotiation of coherences. This is displayed in figure 14 on the right side with the corridor of coherence.

As described in the previous subchapter, I use Fisher's (1984, 1985, 1997) narrative paradigm to describe the negotiation of coherences regarding science YouTube videos. This paradigm describes the meaning of coherence in storytelling. Storytelling is a central element in science communication (see, for example, Dahlstrom, 2014), and it is not surprising that storytelling also plays a role in successful science communication on YouTube. According to Fisher (1984, 1985, 1997), narrative rationality is necessary to positively evaluate a story's quality. Resembling the three aspects of coherence – argumentative, material and characterological coherence – a story is qualified as good when coherence not only applies to the content but also to the channel's brand and to the characteristics of the channel's community in reference to other channel or genre communities. However, characterological coherence and material coherence seem to be more important for establishing trust in a story and therefore in a YouTube channel as the co-construction of argumentative coherence. The content presented is thus still evaluated with regard to fidelity, another aspect of narrative rationality.

While the content is evaluated, a coherent storytelling of the content seems less relevant in assessing the quality of the story. However, viewers also perceive the content as coherent if they can identify with it, i.e. if the content relates to their everyday life or addresses current topics, which reveals parallels to the importance of agenda setting in traditional media. Of greater importance is, however, the presentation of a coherent channel brand (characterological coherence). This also includes the appearance as a science YouTuber and the associated expectations of the audience as to how science YouTubers should behave. As described above, this can mean, for example, that science YouTubers are expected to not use product placements to gain money. This is also where the special nature of the genre of science YouTubers becomes apparent.

They often face a mix of expectations viewers draw from their experiences with science journalists and scientists as they appear in traditional media in combination with expectations regarding YouTubers who entertain, reveal personal information and build an emotional bond with their subscribers. The same applies to the negotiation of coherences with regard to the channel community. In the context of YouTube science channels, this material coherence describes the co-construction of coherence regarding the narrative of the channel or the genre community. In this process, the creation of a coherent feeling of membership ensures that new viewers feel connected to the science YouTuber and the channel's followers.

Closely linked to a coherent community narrative is the co-construction of a coherent channel brand. Cunningham and Craig (2017) describe negotiation processes as a necessary step to develop a brand. For this purpose, these negotiations must be repeated in an ongoing process. They emphasise that this form of brand-building is specific to YouTube, whereas, traditionally, brands are first defined before they are being launched. Similar processes can be observed with regard to science YouTubers. I use the concept of the corridor of coherence to illustrate this process. If science YouTubers create a new channel and upload the first videos, they are at the beginning of this corridor. Accordingly, further developments of the channel, i.e. the production of more videos, can be described as moving through this corridor. With its two walls, the corridor describes the scope the video producer has regarding the selection of topics, the development of the channel’s brand and a channel community – or in other words the scope of the narrative. The special thing about this corridor of coherence is that the walls can move.

The distance between the two walls illustrates the scope in which the science video producers can adapt or change their narrative, based on the viewers’ expectations. In the space between these walls, the brand of the science channel develops accordingly. Especially when a channel is new, the positions of the walls fluctuate and can be very narrow or very wide apart. For example, when the producer has yet to decide which topics to pursue on the channel, the walls are further apart. Much more often, however, it is the case that the genre is already fixed. This means that with the first uploaded scientific content, the science video producers, whether consciously or unconsciously, already assign themselves to the category

of science and thus expose their channels to certain expectations. These expectations are initially narrowly defined and thus the corridor is also rather narrow. However, the better the audience and video producer get to know each other, the more flexible the creative freedom becomes. So, it is not surprising that it can often be observed that with increasing success science YouTubers try to include new formats or topics, e.g. by publishing more news-related content or presenting other scientific topics. The more successful channels become and the more established the channel community is the more can science YouTubers experiment.

Not only can the corridor become wider and narrower, the walls themselves can also move. This element is important because it illustrates that the genre of science communication on YouTube is not conclusively defined. This means that there are no universal characteristics with regard to the format but especially with regard to video content and the expectations and requirements for science communication on YouTube. I already pointed out in Chapter 1 how difficult it is to provide a common definition of science communication in general and the particular challenge of clearly distinguishing science communication on YouTube from other content, like education, edutainment and news. This is also related to the fact that different topics on channels are often mixed and that the decision which topic to display is more based on user demand than on common definitions of science communication. Therefore, the genre of science communication on YouTube has no clear boundaries. Should more personal and entertaining content be presented, or is an accurate presentation of science content more important to users? These and similar questions arise in this negotiation process in contrast to well-known science formats of film and television and other genres on YouTube.

In summary, the platform expertise of science YouTubers as displayed in the model I introduced in figure 14 can be described as an ongoing reflective process of negotiations between producers, users and algorithms. This platform expertise is composed of individual and networked experiences as well as an attributed expertise through algorithms and viewers in ethno-epistemic assemblages. The attribution of expertise by the audience can be described by negotiating coherent storytelling with regard to the presented video content, the channel's brand and the channel community based on the user's and producer's expectations. A closer look at my model of the platform expertise of science YouTubers

reveals that there are similarities to other approaches, such as the two-step gatekeeping process introduced by Singer (2014) or the concept of staging science introduced by Hilgartner (2000). In the following, I will briefly describe both concepts and compare them with my approach by pointing out similarities and differences.

I already introduced and discussed the two-step gatekeeping process by Singer (2014) above. In her publication, she redefines gatekeeping in the scope of digital media. While in traditional media, such as newspapers, editors and journalists act as gatekeepers and decide which content is published, viewers also influence this selection process on social media platforms. Accordingly, the concept describes two steps of gatekeeping, one by the editors and journalists and a second step by the users deciding which content becomes more visible and which less. As introduced above, my concept of expertise with the central element of mutual negotiations between producers, users and algorithms also stresses the importance of users in the selection of topics displayed on the science YouTube channel. However, with regard to the importance of algorithms, in my model I would suggest to add another step to this approach. This would mean that between the first step in the gatekeeping process by journalists and editors and the third step of gatekeeping by the users there is a second step in the gatekeeping process, namely, by algorithms.

However, in my model of platform expertise, I describe how science YouTubers become visible and thus become experts, not how content is selected and presented to the public. Even if the concept of gatekeeping can be adapted to social media platforms, further aspects are missing in the consideration. The most obvious difference is that the process of gatekeeping takes place in successive steps. However, the model I have described illustrates that the platform expertise of science YouTubers does not emerge linearly, but instead that different processes overlap and influence each other. Furthermore, the multi-stage gatekeeping process, which describes the selection of journalistic content in digital mass media, cannot be easily transferred to social media platforms. Here, other characteristics come into play that determine which content becomes visible and which does not. Sometimes, content from traditional media is reproduced on platforms such as YouTube possibly resulting in a secondary gatekeeping process on different platforms. To better understand how gatekeeping on YouTube works, more research is needed in the future.

The second concept which can be related to my model of platform expertise of science YouTubers is the one by Hilgartner (2000) on the staging of science. Hilgartner (2000) illustrates how science becomes visible by using a theatre stage[97]. On the backstage he describes preparations that are necessary to successfully present science on the front stage. Successful in this context could mean that what is shown on the front stage is perceived as credible and possibly also leads to a legitimisation of the research projects. On the backstage, for example, research topics are selected or data is prepared accordingly. This may also include which research projects will be funded, based on the question of which projects will receive the biggest applause on the front stage. Science is then presented or staged on the front stage. Hilgartner (2000) emphasises that stage management should not be visible on the front stage, i.e. the audience should not be able to see which decisions have been made behind the scenes. There are obvious similarities between Hilgartner's (2000) concept and mine because entering the front stage is also about becoming visible to the audience.

What our two approaches have in common is in a sense the dichotomy of visibility. While Hilgartner (2000) uses the image of the stage to emphasise the performance of science, I use the dichotomy to point out the importance of algorithmic control of visibility on social media platforms. Here too, precautions are taken on the backstage in order to present oneself optimally on the front stage. However, a central element on YouTube is the look behind the scenes and thus on the backstage. Of course, one may argue whether this is a real look behind the scenes or whether it is also staged. Nevertheless, my concept differs from Hilgartner's on this point, after all, a look behind the scenes is not forbidden in principle but explicitly desired. One could assume, however, that there are several front and back stages on social media platforms like YouTube. But even here a clear demarcation of these stages seems difficult. The dichotomy of visibility, which I drew for analytical reasons, is also a constructed demarcation. In reality, the transition from a video that is not found to one that is found is most comparable to a process along a continuum rather than the step in front of the curtain.

[97] Hilgartner (2000) transfers Goffman 's (2017) concept of the front and back stage to science communication.

Now that I have presented my model of the platform expertise of science YouTubers and described it in contrast to other concepts, I would like to draw a bigger picture in the final chapter of this thesis. This raises various questions based on how this platform expertise emerges with regard to possible effects on science communication on and outside YouTube and the role of recipients in the communication of science on social media platforms. To what extent is the platform expertise I describe specific to science communication on YouTube and what are the implications of this concept for science communication in general? For example, how much influence has the fact that coherent narratives of brand and community seem to have more meaning than the content displayed in the video?

III. OUTRO

> *In social media, whatever makes you stand out from the rest works. Many people succeed with exaggeration and outrage - we succeed with scientific depth.*
> *(Mai Thi Nguyen-Kim)*[98]

Throughout this thesis I have introduced my model of the platform expertise of science YouTubers. I explained how the term platform is misleading (Gillespie, 2010) because it suggests a neutral and democratic communication process which negates the impact of algorithmic curation. Instead, YouTube displays rules that Gillespie (2010) describes as platform politics and which producers have to master to become successful on the platform. I furthermore discussed the development of YouTube towards more professional content and a stronger focus on advertisers (Allocca, 2018; Burgess & Green, 2018; Kim, 2012). Through the professionalisation of the platform, especially advertisers have more influence on which content is recommended and which is not. I also took a closer look at science communication studies and pointed out that science communication has undergone many changes in the course of its history (Bucchi, 2014; Trench & Bucchi, 2010; Weingart, 2005).

I have demonstrated that the development from the deficit model to more participatory models of science communication can also be observed on social media platforms such as YouTube (Peters et al., 2014). I also showed that despite the growing importance of social media platforms for science communication, there is little research on this topic. This is particularly true for YouTube. Based on this, I presented my research questions which attempt to combine the perspective of platform studies with that of the science of science communication. I asked the question of how science YouTubers become experts to get more insights into how YouTube's platform politics influence science communication. Using a mixed-methods approach, with interviews, ethnography as well as a document, platform, network, video and comment analysis, I examined the platform and the production of

[98] Translated quotation. Original: "In den sozialen Medien funktioniert alles, was einen von anderen abhebt. Viele schaffen das mit Zuspitzung und Empörung – wir mit wissenschaftlicher Tiefe". https://www.brandeins.de/themen/youtube-mailab-je-laenger-wir-fuer-die-recherche-gebraucht-haben-desto-besser-kommt-es-an (accessed: 29.08.2020).

science videos from different perspectives to draw a holistic picture of science communication on YouTube.

With regard to the analysis of the collected empirical material, I introduced a model to describe the platform expertise of science YouTubers which originates in repeated negotiations between producers, users and algorithms. Expertise is thereby, on the one hand, created through the goal of becoming visible on the platform and, on the other hand, through being evaluated as authentic by the users. In order to become visible, expertise is constructed in negotiations between users, producers and algorithms based on individual experience-based expertise and on ethno-epistemic assemblages, with knowledge exchange in networks and an attribution of expertise both via algorithms and users. The attribution of expertise by users gains importance at the moment the video becomes visible. Here, the attribution of expertise and thus, authenticity, takes place via coherent storytelling. Users reward a coherent story of the channel brand as well as of the channel community. The fidelity of the displayed content also plays a role in this process of attribution. Interestingly, a coherent storyline of the video topic seems less relevant. In order to be successful, video producers need to gain expertise in the interaction with the platform and its elements, which are constantly renewed, and at the same time actively manage coherence in order to be perceived as experts by users.

I therefore conclude that what we can observe on social media platforms, like YouTube, is a new class of experts in science communication who do not have to be journalists or scientists. Even without certified expertise in communication or science, they can reach a large number of people and inform users about science. These new science communication experts must, on the one hand, have specific expertise in dealing with the platform and, on the other hand, meet the expectations of the platform users. Since the platform politics of YouTube, like the ones of other social media platforms, change regularly, this expertise can only be gained through individual experience and in exchange with other producers, users and the algorithms. Thus, the platform-specific knowledge is constantly reflected, as is the expertise about how to handle the platform. At the same time, users have expectations of science YouTubers which are based on expectations of YouTubers as well as of science communication in general. Science YouTubers have to develop their own brand in this

tension between insights into their private lives and objective and neutral science communication and build up their own community alongside a coherent narrative which is subject to negotiations between users and producers.

At the end of this text, I will now discuss the influence of my model of platform expertise of science YouTubers on how credible and trustworthy science is perceived on social media platforms. I will also address the potential implications of these developments for science communication before considering further research questions.

Via social media platforms, anyone seems to be able to communicate research results and other scientific knowledge in real time and unfiltered. Bucchi (2013, 2017) therefore observes a “crisis of mediators” in the course of these developments, which may also lead to a loss of quality of the information communicated. He attributes this to the fact that the central element on social media platforms is entertainment instead of information (Bucchi, 2017). However, while it is true that content on YouTube is determined by entertainment and marketing strategies, in recent years the platform has shown increasing characteristics that are otherwise attributed to mass media, carrying those characteristics to the extreme (Burgess & Green, 2018; Haridakis & Hanson, 2009). YouTube’s C.E.O., Susan Wojcicki underlines this change of strategy in an interview she gave the New York Times in 2020 (Roose, 2020), stating that while in the beginning the platform was a “more entertainment-based company”, YouTube now feels responsible to also inform its users, by using recommendation algorithms to show users more quality content.

Accordingly, during the Covid-19 pandemic, YouTube used the platform's recommendation algorithms to highlight content communicated by “an authority”, such as the World Health Organisation (Roose, 2020), because “we [YouTube] want to deliver accurate, useful information” (Susan Wojcicki in Roose, 2020). YouTube is not the only social media platform that has recently started to curate content according to its accuracy. Other platforms have also introduced measures, mostly in response to criticism from society and politics, to mark or even remove false facts. Twitter, for example, introduced a fact-checking system that marks questionable tweets and presents links where to find further information to fact check the respective tweets (Culliford & Paul, 2020). These changes are still new, and the question arises as to what influence they really have on the reception of the content

displayed and whether the curating measures work. This should be the subject of future research.

However, with the approach to openly curate content, YouTube enters a conflict between the original image of an open, democratic platform that is explicitly appreciated by users and the requirements of politics and society to judge and curate content according to its informational quality. In this context, a further question that arises is what influence algorithmic curation has on the reception of knowledge and information and on what criteria this curation is based. Although I cannot go into detail in this thesis, I would like to point out the extensive research in the field of algorithmic curation, e.g. in the context of algorithmic bias[99] and how this might affect curational strategies on social media platforms. Curating information on YouTube, however, may add another level of gatekeeping, one that is difficult to monitor and, unlike in public media institutions, is not driven by common values. This gatekeeping process would then be determined by the characteristics inscribed in the curating algorithms and would thus influence the dissemination of information on a globally operating social media platform.

It can therefore be observed that social media platforms are becoming increasingly relevant in the context of information but also in the context of science communication. While, on the one hand, YouTube postulates that the communication of information is gaining in importance alongside the entertainment factor, on the other hand, an influence of precisely that entertainment aspect on science communication can be observed. In the course of these developments, science communication activities are more often mixed with entertaining content and formats, such as music videos or comedy shows. In addition, the social ties science YouTubers establish with their viewers may also have an impact on the perception and attribution of trust in science. This may, for example, result in a reduced communication of the scientific content, e.g. because the presentation format must adapt to the attention-oriented conditions of the platform. In addition, the easy upload of content to the platform simplifies the dissemination of conspiracy theories (Allgaier, 2019) and misinformation.

[99] Algorithmic bias means, for example, that prejudices are re-enacted by algorithms. For more detail, see, for example, Hajian et al. (2016), Kirkpatrick (2016), Friedman and Nissenbaum (1993), Bozdag (2013).

However, this does not necessarily mean that the quality of the information conveyed is reduced overall. Instead, the fluidity of social media platforms and thus the fluidity of science communication creates new opportunities for science as well as for scientists to become visible and allow input from non-scientists and non-journalists (Bucchi, 2017). Where otherwise normative markers, such as a high scientific reputation, create trust in science, on social video platforms the feeling of being well entertained and emotionally connected can also create this trust (Reif et al., 2020). Therefore, new actors as well as new formats in science communication on social media platforms not only confront us with challenges but also open up new ways for scientists to interact with society. And at the same time, through direct exchange, it enables viewers to take responsibility and possibly check, discuss and correct presented content.

In this respect, the question of whether science communication by new actors on social media platforms is good or not is no longer relevant because such communication is already taking place. Moreover, the question of whether science communication via social media platforms generally leads to a loss of trust in science seems to be redundant (Dickel, 2016; Weingart & Guenther, 2016). Instead, the question should be how this new class of experts influences science communication and its reception, and how this results in new characteristics for the attribution of trust and credibility. Bucchi (2017) therefore rightly asks to what extent terms such as accuracy or quality change in digital science communication and what new responsibilities arise when research results can be communicated, discussed and received in real time. While the field of science communication has long been dominated by normative impulses (Bucchi, 2013), these normative impulses seem no longer applicable on platforms like YouTube.

What we observe instead is a relational form of expertise, which, aligned with the conditions of the platform, is renewed in multidirectional negotiations. The use of algorithms for successful communication and the reflective exchange of experiences with human and non-human actors as well as the establishment of relationships between communicators and their viewers are becoming increasingly important - while content-specific expertise seems to take a back seat. YouTube can certainly be described as a new medium, whose handling communicators must learn at first. Just as journalists have to learn how to deal with the rules of communication in mass media. The special thing about the platform, however, is its

fluid character, which makes it necessary to constantly reflect and possibly renew the knowledge gained through networked experiences.

Of particular importance to me seems to be the attribution of expertise through co-constructed coherences. This may provide a first approach to answering the question, based on which characteristics credibility and trust are attributed on social media platforms. Even if classical characteristics, such as a high scientific reputation measured by publications, still seem to play a role in attributing expertise and trust, social markers are increasingly coming to the fore in the process of evaluation. At the centre is the co-constructed social relationship between a coherently presented channel brand and a coherently negotiated channel community. At the same time, the importance of correctly communicated content is becoming less important, and errors made by science YouTubers are quickly forgiven if the coherence of the relationship is not compromised. Especially the fast and easy access to knowledge via the internet enables viewers to check facts at least superficially in real time and thus represents a collective corrective - similar to the collective gathering and writing of knowledge on Wikipedia. Storytelling itself has long been considered important for science communication (Dahlstrom, 2014; Martinez-Conde & Macknik, 2017; Phillips, 2012), yet always with a focus on content-related storytelling. In view of my observations and the theories derived from them, it seems necessary to take a closer look at branding and relationship-building on social media platforms based on a more broadly defined storytelling, taking into account not only the content but also the actors.

This co-construction of coherence is based on the possibility of continuous interactive communication in the comment section of social media platforms. In commenting on science videos, producers and their viewers are able to deepen discussions on the presented content, to connect and exchange experiences and track their influence on the video production (e.g. in checking whether given advice or criticism is answered by the producer or even appears in following video productions). The importance of relationship-building for science communication has already been discussed, either referring directly to the term relationship-building (Kearns, 2012), or when fostering the skills to connect to the audience in science communication courses (Bray et al., 2012). In addition, practitioners stress that building a relationship between science communicators and the audience might also be

crucial. Undoubtedly, content still matters, but telling connecting stories and complementing facts with emotions to build a relationship with the audience seem to be key to successful science communication and may also have an influence on the perceived trustworthiness of science (Davies, 2019; Orts-Gil, 2020; Reif et al., 2020).

With the introduction of my model for platform expertise of science YouTubers, I have demonstrated that the boundaries between experts and laypersons are not only blurred but rather result in new perspectives on the emergence of expertise. Accordingly, normative concepts can no longer be applied to these. This new class of experts, whose expertise arises from a constant exchange of experiences between human and non-human actors and is attributed in similar assemblages, can be observed in a corresponding way outside digital science communication, for example, in how digitisation processes are negotiated in cultural institutions and museums. Here, too, an intersection between digital offerings, society and knowledge is created and here, too, old (normative) concepts of expertise are broken up. Following the rapid development of new technologies makes it necessary to constantly adapt experience-based knowledge in negotiations with various other actors. Finally, here, too, the way in which knowledge is conveyed is changing from the approach of educating an uninformed audience to a more participatory, experience-oriented communication between the museum and its visitors. This is also reflected in the increasingly important multidisciplinary cooperation in teams dealing with digitisation issues and digital communication (see, for example, Hohmann et al., 2019).

Furthermore, my model of a platform expertise of science YouTubers may also provide information about epistemological processes within science. Here I refer to approaches like Citizen Science or Responsible Research and Innovation. Here, too, the boundaries between experts and laypersons are becoming blurred and negotiations between human and non-human actors, on the one hand, and negotiations along social relations between science and society, on the other, are gaining more importance (see, for example, Maasen & Dickel, 2019; Mahr & Dickel, 2019; Wenninger & Dickel, 2019). In the process of the participation of citizens in the production of knowledge, the building of relationships based on coherent narratives could be of particular importance. In addition, negotiation processes are necessary, e.g. on how the contribution to a research project is recognised, how research is

reviewed by citizens, and how knowledge and its management is negotiated in the case of the use of digital platforms.

Before I will outline concrete implications for science communication from my point of view and conclude by defining further research questions based on the limitations of this work, I would first like to return to my example from the beginning: the video "Die Zerstörung der CDU" posted by Rezo shortly before the European elections in 2019. The model of platform expertise that I have established in this thesis can also be applied to Rezo, both in terms of the expertise of becoming visible based on individual experiences and ethno-epistemic assemblages, and of attributed expertise based on a coherent storytelling which portrays the relationship between him and his followers. Precisely this more fluid relational concept of expertise challenges the normative concepts of traditional journalism. It was therefore not surprising that when Rezo was awarded the prestigious Grimme Prize (Grimme Online Award 2020, 2020) in 2020, the discussions were again about whether a YouTuber has enough expertise and whether YouTube as a pure entertainment medium should be taken seriously. However, as I have already shown, a quite complex form of new expertise can be observed on YouTube, and YouTube is no longer merely a pure entertainment medium but is also gaining in importance for the dissemination of information and knowledge. Instead, the question arises to what extent the perception and evaluation of media has changed through platforms such as YouTube.

In a new video, "Die Zerstörung der Presse" (The Destruction of the Press)[100], Rezo encounters criticism regarding his lack of expertise in talking about issues like climate change. On the other hand, he talks about the crisis of traditional media formats, such as the press, and explains why, in his view, they have lost the trust of their readers. For him, this loss of trust is manifested in the lack of transparency of traditional media providers, which is increasingly demanded by consumers. He illustrates this argument with a comparison between YouTube and the press. With the advent of the internet, information was suddenly available anytime, anywhere. In addition to mass media coverage, there was now also access to eyewitness reports and opinion leaders outside institutionalised media formats.

[100] Rezo: „Die Zerstörung der Presse"; https://www.youtube.com/watch?v=hkncijUZGKA (accessed: 16.08.2020)

Moreover, the increasing diversification of information was accompanied by a loss of confidence in media providers. It is therefore not surprising that it is precisely the view into the living rooms of video producers on YouTube that is so attractive for many users. Here they are offered the possibility of knowing the people who are communicating with them.

In videos about science, education and news, this means that motives and values are made transparent not only within the framework of a coherent brand history. Moreover, the sources used for videos are published within the video description and thus made comprehensible. Users of social media platforms have become accustomed to having the opportunity to check information presented to them. In traditional media, however, it is hardly common to publish sources. Here, collective trust in the institution of the media continues to be relied upon. According to Rezo, sooner or later media institutions will have to face the demands for more transparency. This also requires, similar to what Bucchi (2017) postulated for science communication, more openness to criticism and reflexivity regarding normative approaches in journalism. But Rezo also takes the users into account. Here he demands more responsibility for how information is received, checked and chosen.

For me, it is precisely at this point that it becomes clear what the tasks of science communication could be due to the emergence of these new science communication experts on YouTube. Besides the communication of research results, more space should be given to the communication of scientific work and the methods used. After all, researching sources, weighing and checking information are central tasks within the research process. Providing support for users of social media platforms could help to promote the responsible selection of information and at the same time create more transparency in science communication. In addition, platforms such as YouTube must be taken more seriously by science and science communication - as places of information and education as well as creative playgrounds for new science communication perspectives and a direct exchange with users. I am not saying that it is necessary for every scientist to become a science YouTuber. Rather, activities on social media platforms of research institutions must be pursued more thoroughly, for example, in the number of people who take care of the respective channels.

This also includes not consciously bypassing the participatory elements of the platform but rather actively engaging with them. At the same time, it seems to be advantageous not only to learn from science YouTubers but to actively involve them in science communication projects. One example of such a partnership is the collaboration between the University of Nottingham and the science YouTuber Brady Haran, who regularly produces videos with the participation of scientists from the university[101]. Probably, as with initial collaborations between scientists and science journalists, some negotiations will be needed to establish trust between science YouTubers and scientists. However, such cooperation can also be beneficial for the external image of science and science communication in general. However, further research is needed to better understand the extent to which expertise in digital science communication is changing and what influence this has on the communication and reception of science.

In the present dissertation, I have used a mixed-methods approach to develop theoretical considerations regarding a new concept of expertise for science YouTubers. In doing so, I have used the approaches of platform studies and science of science communication. By applying many different methodological approaches, I succeeded in taking a holistic view of the platform, on which I could develop my concept of a new expertise of science YouTubers. However, this methodological approach did not give me the opportunity to delve deeper into particular issues. It is therefore recommended to focus on specific elements and take a closer look at them in future research projects. Of particular importance in this context, in my opinion, is the detailed empirical and theoretical analysis of the communicative interaction processes between video producers and users, for example, in order to further refine my concept of the attribution of expertise based on co-constructed coherences. Especially the examination of these communication processes in the context of the expertise concept could be a promising approach to understand how social discussions about concepts like "fake news" and "post factual era" arise and what mechanisms underlie the trust in conspiracy theories.

With regard to the science of science communication, questions also arise in the reproduction of prejudices on social media platforms such as YouTube and their influence on

[101] See, for example, http://www.periodicvideos.com/ (accessed: 16.08.2020).

science communication. For example, there are clearly observable reproductions of classical gender roles on the platform. Studies in recent years indicate that women are underrepresented on YouTube (Döring & Mohseni, 2019; Molyneaux & O'Donnell, S. Gibson, K. Singer, J., 2008; Wotanis & McMillan, 2014). A similar imbalance can be observed on science YouTube channels (Amarasekara & Grant, 2019; Morcillo et al., 2019; Thelwall & Mas-Bleda, 2018). More research is needed to identify how these gender roles are reproduced and what influence the algorithmic curation that is increasingly taking place on social media platforms may have on this process. This is followed by other questions regarding the visibility of minorities on social media platforms as well as the influence of prejudices inscribed in algorithms. Finally, a similar question arises for the field of platform studies, namely, regarding the effects of algorithmic curation on social media platforms. In this context, it likewise seems to be useful to look at YouTube from the perspective of infrastructure studies and to investigate the effects of networking between different social media platforms, as well as the various offerings that are emerging around YouTube (such as the YouTube Creator Academy).

For me, these new science communication experts on YouTube represent the opportunity to gain new perspectives on established communication concepts, to have more direct access to possible target groups and to test new creative formats of digital science communication. At the end of the day, it is perhaps less important who has sufficient certified expertise than who is able to communicate science in an understandable and entertaining way without lecturing. In the end, I can only agree with one of the science YouTubers I interviewed who said that

"With everything I do in science communication I always think of it as inspiring curiosity" [102]

[102] I#3, 45:38:01

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