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Potentials and Limitations of Educational Videos on YouTube for Science Communication

Sarah Kohler[1]* *and Tabea Clara Dietrich*[2]

[1]Department of Science Communication, Karlsruhe Institute of Technology, Karlsruhe, Germany, [2]Institute of Communication and Media Studies, Leipzig University, Leipzig, Germany

YouTube has become a complement learning platform which fosters learning on demand with educational videos. Educational videos are understood as a fruitful strategy to enhance the user's knowledge and are applied in schools, as well as in science communication, e.g., to inform about climate change. This paper discusses two perspectives which become visible in the current research literature on educational videos on YouTube. First, studies assume that watching educational videos changes the attitude or behavior of the recipients. Second, studies question whether educational videos have a higher impact than other information materials such as texts. We frame both perspectives with regard to theories from media effect studies and learning concepts from education science and discuss their conclusions for educational videos on YouTube. We will first focus on students as a target group for educational videos, but in the further course, we will discuss the results for the public as targeted group of science communication as well. In the final section we will summarize which potentials and limitations educational videos have for educational purposes in science communication.

Keywords: science communication, educational videos, online videos, youtube, knowledge gap, learning styles

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***Correspondence:**
Sarah Kohler
sarah.kohler@kit.edu

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INTRODUCTION

Educational videos and educational television have a long tradition in explaining complex information in kindergartens, schools, and higher education (Choat, 1982; Choat, 1983; Forsslund, 1991; Kearney and Levine, 2019). Nowadays, online videos are also a tool for science communication. Many educational videos on a wide range of topics are uploaded on video platforms to inform not only students but also the public. One of the most prominent platforms is YouTube, which states to have two billion assigned users and one third of all users in the Internet (YouTube, 2020a). YouTube has become very popular for educational videos and has been established among students as a complement learning platform which fosters learning on demand (Rat für Kulturelle Bildung, 2019). Moreover, many people use YouTube as a source of information about issues concerning science, technology, and medicine (Allgaier, 2019). The advantage of online videos lies in their versatility: "Science online video has adopted many different styles, formats and genres, creating a variety of categories that are difficult to classify and that have virtually no creative limits" (León and Bourk, 2018, 1). Therefore, educational videos can be understood as a powerful tool to enhance people's knowledge. Especially YouTube with its accessibility and low barriers functions as transmitter of scientific knowledge.

In the following, we use the terms science communication and educational videos to describe online videos with scientific content from any subject which aim to describe complex issues and

information for the target group of students. We define any video which focuses on any scientific topic as science communication independent of whether the video is produced professionally or is based on user-generated content. In contrast to Welbourne and Grant (2016, 710), the videos do not necessarily have to be considered as a form of science journalism or be understood "as the activities of professional communicators (journalists, public information officers, scientists themselves)" (Treise and Weigold, 2002, 311). Instead, science communication can also be conducted by lay people and passionate amateurs (Welbourne and Grant, 2016, 707; Nisbet and Scheufele, 2009). Further, science communication includes all forms of communication focused on scientific knowledge or scientific work, both within and outside institutional science, including its production, content, use, and effects (Schäfer et al., 2015, 13). If science videos on YouTube are overtly didactic or instructional and explain single aspects from any educational context, we define these as educational videos. Likewise, educational videos can be understood as a type of science communication which transfers scientific knowledge in layman terms.

Metag (2017, 256) stated that there are hardly any theories which formulate assumptions for science communication only. Usually, other media effect theories which have already been proven or which are popular in media effect studies are applied to science communication as examples of use. Therefore, we suggest that studies on educational videos often tackle the effect from two perspectives and frame both perspectives with theories from media effect studies and education science.

The first perspective emphasizes quality aspects within the videos. Studies have e.g., analyzed the quality of educational videos especially on scientific (e.g., Coates et al., 2018) or medical topics (e.g., Azer 2012; Yavuz and Genc, 2019; Abrar et al., 2020) or whether videos on YouTube reached their target groups for a specific content (Daun, 2018). Another assumption linked to this type of research is that if the quality is enhanced, it will improve recipients' understanding, or liking, of the video, or even change their attitude or behavior (e.g., Shoufan 2019a; Shoufan 2019b) pointed out that the explanation quality and factors such as presentation, content, efficiency, voice, and interestingness are relevant to rating educational videos. This kind of research asks how to reach the audience and whether the exposure of the stimulus might have an impact. Speaking of the impact of the stimulus, we see parallels from research on educational videos to the knowledge gap hypothesis (Tichenor et al., 1970). Both assume that the stimulus has an impact on a broader target group and can overcome differences in people's knowledge. The knowledge gap hypothesis has shown that the gap increases between people with higher and lower socioeconomic status and education (Tichenor et al., 1970, 159f.). Therefore, we question which implications we already know from this perspective for educational videos.

The second perspective investigates the comprehensibility of videos compared to other media such as texts or subtitles (e.g., Tarchi et al., 2021). The assumption is that specific media fit better in terms of comprehension and understanding for different recipients. Such effect studies analyze which individual predisposition might influence the effects on individuals. In this case, we see parallels to research on media and education and apply another classical approach of this research, namely the learning style model VARK (visual, aural, read/write, kinesthetic) (Fleming and Mills, 1992; Fleming, 2001). VARK is used to analyze students' success and effort in class (Prithishkumar and Michael, 2014). Therefore, we question whether learning styles can provide insights on the success of educational videos.

In this contribution, we will discuss potentials and limitations of educational videos based on the implications of the mentioned theories. Our research questions are: What do we already know about the impact of educational videos from both perspectives, and, based on this, which potentials and limitations do educational videos have for science communication with educational purposes? We will first focus on students as the target group of educational videos. In the final section, we will discuss our theoretical considerations for other users as well and summarize the implications of educational videos for science communication with educational purposes.

EDUCATIONAL VIDEOS AND YOUTUBE

In this section, we will describe the development of educational videos and the specifics of YouTube as a video sharing platform. Further, we will explain how research on educational videos often discusses the effect from two perspectives.

Teachers have introduced educational videos and television in their classes more than forty years ago, which means that research on educational videos and television hits the same age (Choat, 1982; Choat, 1983; Forsslund 1991). This research already pointed out that educational television cannot replace real-life experience, but it can function as an aid for teachers and as a component of the school curriculum (Choat, 1982, 186). Kittelberger and Freisleben (1994, 7) have shown that audio-visual media are more important than other teaching media in terms of their role as a leading medium, arguing that they can be regarded as a tool for the efficient communication of teaching content. They predicted accurately more than 25 years ago that audiovisual media will play a more important role in further education in the future, because creative, process-oriented, and active forms of learning will gain in importance. If student commitment, active learning, and cognitive load are considered, videos are indeed an effective educational tool (Brame, 2016, 1).

Since social media platforms like YouTube offer the possibility of easily sharing information with other users, online videos are also considered accessible tools for distributing scientific information to the general public (Young, 2008; Thelwall et al., 2012; Sugimoto and Thelwall, 2013). The characteristics of YouTube foster educational videos, as it is easy to upload and share new content (Chintalapati and Daruri, 2017, 853). Non-institutional educational videos on YouTube have become substantial in students' learning processes. Annual media usage studies conducted in Germany have shown that the use of educational videos among 12–19 year-olds has increased in the past years: In 2016, 10 percent (n = 1179) stated to be using

YouTube, which increased to 18 percent (n = 1200) in the year 2019 (mpfs [Medienpädagogischer Forschungsverbund Südwest], 2016; mpfs [Medienpädagogischer Forschungsverbund Südwest], 2019). These numbers illustrate not only the demand for educational videos but also the provided range of educational videos on online platforms like YouTube.

In this context, it is noteworthy that the producers of videos have shifted from professionals to users generating content (Welbourne and Grant, 2016, 707) including even lay people in a spirit of a "Do It Yourself" ideology (Jenkins, 2006): "We live in a time of change . . .where citizens are adopting a more active role in all areas of social action, including science" (León and Bourk, 2018, 2). In this case, lay people function as self-declared experts in educational videos which means that not all videos might meet high didactic standards or are even based on school curricula (Wolf, 2015, 30; Kim, 2012). This might also affect the quality of content (Akgun et al., 2014, 116).

The success of non-institutional YouTube channels and videos underlines the necessity of complement learning platforms. To give an example, one of the most successful German YouTube channels of educational videos with more than 350 million views in total is "simpleclub" (TheSimpleClub, 2019). These videos offer a wide range of subjects including mathematics, chemistry, history, and many more. The founders of simpleclub had the idea to create educational videos when they were in 11th grade and were looking for educational videos for themselves. In their opinion, the content and presentation of the uploaded videos were boring and bland, therefore, they started to make their own to help others (Girgla, 2019). They stated that they were trying to explain things as if they explained them to a friend (Becker, 2016). Likewise, there are other successful YouTube channels with educational videos for different school subjects from other countries, e.g., the United States-American YouTube channel "CrashCourse" has a total of 11.6 million subscribers (YouTube, 2020b). In general, YouTube among students is associated with fun (Davis et al., 2020). Further, the barriers to use YouTube are merely low: The language can be adapted, sometimes there are even subtitles. Independent of time and space, it is easy to watch educational videos whenever and wherever. Moreover, educational videos support the autodidactic skills of the users because these can watch the videos whenever they want, as often as they want, and get further information on the chosen topic in the form of other suggested videos. Educational videos are usually just a few minutes long and can only tackle single and simple aspects which can be explained within a few minutes (Kulgemeyer, 2018). The producers of the channels rather tend to make a series of short movies than one video which lasts as long as a lecture at school. This means that, most likely, entire curricula from school will never be displayed on YouTube completely.

YouTube has become a source of information about issues concerning science, technology, and medicine (Allgaier, 2019). Amongst others, studies on educational videos on YouTube have investigated whether watching a specific video might enhance the users' knowledge, attitude, or even behavior. Daun (2018) assert that educational videos on YouTube reached their target groups for specific content such as nutrition and food. Godwin et al. (2017) pointed out the "educational" potential of YouTube videos. They analyzed comments on a video on schizophrenia and summarized that a video "can be widely viewed as a unique educational tool that virally spreads knowledge" (Godwin et al., 2017, 825). They also emphasized that users wanted to educate themselves voluntarily *via* the video. Other studies investigated whether the quality of educational videos on YouTube fits to high standards especially on scientific (e.g., Coates et al., 2018) or medical topics (e.g., Azer, 2012; Azer et al., 2013; Azer, 2020). Yavuz and Genc (2019) figured out that over 50 percent of the educational videos on orthodontics have an excellent general information content and significantly higher interactions with recipients than others. Abrar et al. (2020) developed and evaluated educational videos on diabetic foot care and also found significant improvement in people's knowledge. The mentioned research is just an example of many studies which follow a surprisingly simple linear and causal assumption: Increasing information will lead to increasing knowledge.

On the other hand, research on educational videos has also investigated differences between videos, textbooks, or other learning resources such as online learning platforms (e.g., Kim et al., 2020) and discussed the content and the usefulness of the materials for the learners. Although textbooks seem to be students' primary choice for learning (Baudains et al., 2013), educational videos seem to have more advantages. Azer (2014) evaluated the clarity, quality, and percentage of content committed to cardiovascular mechanisms of medical textbooks, eMedicine, and YouTube videos. He emphasized the usefulness of YouTube videos especially for students in self-regulated learning programs. Malhotra and Verma (2020) and Golchai et al. (2012) found that multimedia presentations or E-Learning tools improve the learning outcome of students compared to traditional teaching methods. Flores et al. (2013) compared textbooks and digital animation in a video. In their study, students assessed the quality of both information materials and evaluated videos to be superior to textbooks. All these studies have in common that they show an overall effect of videos being superior to other learning resources.

TWO PERSPECTIVES ON EDUCATIONAL VIDEOS

We suggest that research on educational videos on YouTube tends to question the impact of the videos from two perspectives. In the following, we will discuss both and the parallels with classical theoretical approaches which have shed light on the potentials and limitations of videos.

What We Have Learned From Knowledge Gap Hypothesis

Knowledge gap hypothesis fits quite well into research on educational videos. The American educational children's television series Sesame Street is an example that is often used to explain the hypothesis. Sesame Street was developed to overcome differences between children with a lower and a

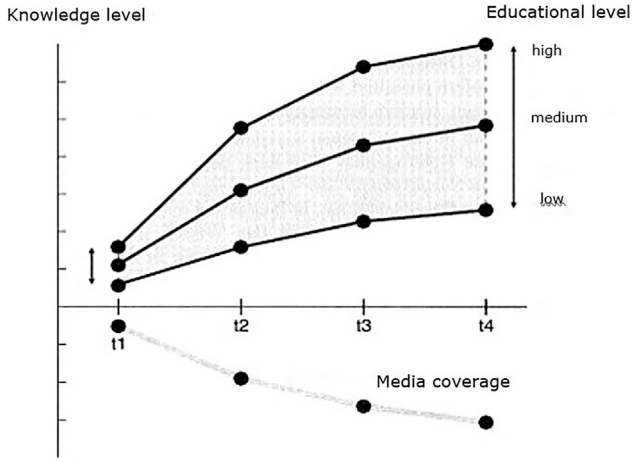

FIGURE 1 | Growth of knowledge gap (adapted from Bonfadelli and Friemel (2017), 242).

higher knowledge (Kearney and Levine, 2019, 318). Sesame Street has tried to catch the attention of children through the use of formal creative means in order to impart knowledge in a playful way (Ball and Ann Bogatz, 1972). Thus, Sesame Street can be considered one of the first audiovisual mediations on educational topics that are not of school nature. The first assumption resulting from knowledge gap hypothesis was similar to that resulting from the current research on educational videos: More information will increase knowledge.

Knowledge gap hypothesis has shown that the growth of knowledge varies. The heterogeneous distribution of knowledge results from the heterogeneous socioeconomic status of the recipients. The status includes the factors formal education level, occupation, and income, or a combination of all three (Bonfadelli, 1994, 95). The population segments with a lower socioeconomic status do not remain completely uninformed. Yet, compared to those with a higher socioeconomic status, their knowledge growth is significantly lower (Tichenor et al., 1970; Bonfadelli 1994, 92): "As the infusion of mass media information into a social system increases, segments of the population with higher socioeconomic status tend to acquire this information at a faster rate than the lower status segments, so that the gap in knowledge between these segments tends to increase rather than decrease." (Tichenor et al., 1970, 159f.). **Figure 1** shows the growing knowledge gap. The gaps are small at the beginning, yet there are large gaps between high, medium, and low educational levels at the end.

The knowledge gap occurs in heterogeneous population groups, whereas in homogeneous population groups, there are rarely any knowledge gaps (Wirth, 1995, 5). Research which aims to analyze the differences between groups has taken into account the knowledge gap hypothesis. Hwang and Jeong (2009) stressed the negative effects, e.g., a perpetual knowledge gap in the health sector might lead to health inequalities which can affect necessary preventive measures like cancer screening. They found that neither time nor varying levels of media publicity changed the gap. Tran (2013) examined how socioeconomic status influences individual news usage (traditional and online) and knowledge about public affairs. Boukes and Vliegenthart (2019) investigated the influence of different modalities of e.g., television news, newspapers, and news websites on the knowledge gap by means of a panel survey with repeated measurements of current affairs. The reception of news has a positive effect on knowledge acquisition, yet does not necessarily depend on the level of education.

What We Have Learned From Learning Styles Models

In this section, we would like to add another perspective. Educational videos on scientific topics try to explain complex information understandably for their users. In this context, learning processes and learning preferences play a crucial role. According to this, research has to discuss users' preferences and predispositions.

The assumption that each student learns differently has become a prominent pedagogical issue in the past decades (Hawk and Shah, 2007, 1), which is why many learning style models have been developed (Truong, 2016, 1187; Dağ and Geçer, 2009). Learning style can be conceptualized as part of a broad concept of personality (Hawk and Shah, 2007, 2) or even as an individual's characteristics (Fleming, 2001, 1). According to Ocepek et al. (2013, 346), learning styles reflect "an application of cognitive, epistemic, and thinking styles in the process of learning". This means that learning styles as part of the personality and cognitive processes could be quite stable predispositions. Indeed, theories differ as to whether learning preferences might change over time (Truong, 2016, 1186) or might be affected in cause of developmental disabilities (e.g., Orban et al., 2018). Othman and Amiruddin (2010, 653) indicate learning styles as a technique which also interacts with its environment. Fleming (2001; Fleming and Mills, 1992) has developed the learning style model VARK which is based on sensory perceptual modes. VARK focuses on instructional preferences as the "preferred ways of gathering, organizing, and thinking about information" (Fleming, 2001, 1). The acronym VARK stands for Visual (V), Aural (A), Read/Write (R), and Kinesthetic (K): Visual learners prefer any visual information such as maps, graphs, different colors, and pictures. Aural learners like to listen and to explain, to discuss topics with others. Read/Write learners prefer texts and lists, and taking notes. Kinesthetic learners like to try things they do not understand, laboratories, recipes, and solutions to problems, and hands-on approaches (Hawk and Shah, 2007, 7). Learners can have preferences for more than just one way (Ocepek et al., 2013, 348), yet the dominant learning style is the learning mode (visual, aural, read/write, kinesthetic) which is selected more frequently (Ocepek et al., 2013, 346). VARK has become quite popular in educational research and was applied in many studies (Othman, 2010). VARK is used to analyze students' success

and effort in class (Prithishkumar and Michael, 2014) or the effect of learning styles in mobile learning (Li and Yang, 2016). Klement (2014) examined whether the preferred learning styles might shift depending on the school subject. Although some subjects had clear preferences (e.g., kinesthetic and sports education or informatics), the other subjects always had components for visual and aural learners. Huang (2019) investigated whether learning styles might affect problem solving creativity, and found that visual learners performed better on both text- and image-based questions.

Since the Internet provides users and students the possibility to learn flexibly and autonomously (Boer et al., 2011, 727), studies also concentrate on the relationship between learning styles and online environment. Numerous studies have demonstrated that videos can be a highly effective educational instrument (e.g., Allen Moore and Russell Smith, 2012; Kay, 2012; Lloyd and Robertson, 2012; Rackaway, 2012; Hsin and Cigas, 2013; Stockwell et al., 2015). Yang and Tsai (2008) investigated how learning preferences differ if students have to learn with videos. Kurilovas and Juskeviciene (2015) analyzed in a study how virtual learning environments such as Moodle work in favor for the different learning styles and established interconnections between learning activities (e.g., view photo, view picture, record and listen to lectures. . .) and applications which are provided by Moodle (e.g., video viewing tools such as YouTube and Live-Streaming, picture repositories, audio recorders, . . .). They linked YouTube on Moodle with the learning activity of viewing videos (visual learning style) but also with the learning activity of viewing the demonstration of a procedure. The latter was combined with the kinesthetic learning style (Kurilovas and Juskeviciene, 2015, 1383). This approach is quite similar to the approach by Ocepek et al. (2013). The authors examined students' preferences for multimedia types (e.g., animations and video material, audio learning material, . . .) and different learning styles. The results showed that students commonly use videos, but if they have a dominant visual mode, they use animations and video lectures more frequently than others (Ocepek et al., 2013, 348).

VARK simply asks for learning preferences and implies neither skills of the students nor their intelligence. It rather is a method that is part of the individual's personality. Therefore, VARK does not refer to types of people but to a stable set of learning preferences. Although it might be obvious that especially individuals with a dominant visual learning style benefit from educational videos, even kinesthetic learners could consider videos as useful as long as procedures (e.g., experiments) are shown. Azer (2012) stated that studies are needed which investigate whether students are able to differentiate between reliable and unreliable online resources. This fits into concepts of media literacy and information literacy. Kingsley et al. (2011) also emphasized the importance of information literacy. Their results showed that students have "neither the skills nor the training to locate, evaluate, and retrieve evidence-based information" (Kingsley et al., 2011, 6). Therefore, information-seeking behavior and learning might affect each other (Borgatti and Cross, 2003).

In the further course, the theoretical background serves as reference to determine the relevance of the chosen perspectives for the acquisition of knowledge through educational videos.

POTENTIALS AND LIMITATIONS OF EDUCATIONAL VIDEOS

In the previous sections, we have discussed the effect of educational videos from two perspectives. The first one focused on the differences between groups and their different effects, the second one underlined differences between individuals.

Educational Videos and Their Impact on Groups

Knowledge gap hypothesis has shown that different knowledge acquisition processes occur in groups with heterogeneous socioeconomic status. Yet, when it comes to educational videos on YouTube, of course, neither occupation nor income might be appropriate to rate the socioeconomic status of students. Instead, we suggest taking other factors into account to define the social status of students: Communication skills, existing knowledge, and social contact. These factors might explain the effectiveness of media effects (Tichenor et al., 1970, 162). In the following, we utilize these factors to discuss the potentials and limitations of educational videos.

Communication skills refer to the ability to understand complex information more easily (Bonfadelli et al., 2008, 12) and can be based on e.g., the level of education (Tichenor et al., 1970). It can be assumed that reading and comprehension skills for students which are in the same school class are similar to each other (e.g., Kingsley et al., 2011). Therefore, a potential of educational videos on YouTube might derive from the similar knowledge of the students who are addressed equally with educational videos. The research on educational videos has also showed that, in general, educational videos are a well-perceived learning resource (e.g., Yavuz and Genc, 2019; Abrar et al., 2020). Aldallal et al. (2019) found that educational videos on YouTube function as learning resource for oral surgery by fourth and final year dental students. The success of the educational videos might derive from the similar communication skills of the students. In this case, educational videos are more effective if groups are homogeneous in terms of the educational level.

The factor *existing knowledge* refers to the amount of information people have already received on a certain topic (Tichenor et al., 1970, 162). It points into a similar direction as communication skills if we assume that the educational level is an equivalent to existing knowledge. Students with prior knowledge have developed advanced schemes that simplify the interpretation, storage, and retrieval of new information (Markus and Zajonc, 1985; Wicks, 1992) which increases the motivation in learning new information. If this is considered as an indicator

between groups, students with a higher prior knowledge will gain more insights than those without and will benefit more from educational videos. As educational videos tend to be rather short, YouTube channels like simpleclub or CrashCourse create video series on specific topics. Watching the next video deepens the students' understanding. Yet, compared to those who fail to understand the information, the gap of knowledge will increase. Knowledge gap hypothesis points into the same direction as it emphasizes that less educated people do not remain uninformed but simply need more time to build up knowledge (Tichenor et al., 1970, 160). We conclude that educational videos might have a greater impact on students who already have a prior knowledge on a specific topic and who deepen their knowledge with more videos. Just watching one video to gain permanent knowledge might not be sufficient.

The third factor *social contact* asks whether users have social contacts which reinforce the information. We differentiate between situations in which educational videos were included by teachers in classes and educational videos on YouTube. The main difference lies in the context situation and voluntariness. In the first case, videos are probably implemented by the teacher either as supplement or as a method (e.g., with so-called flipped classrooms). In such a situation, students have the possibility to discuss the given information with teachers and other students. Yet, if educational videos are watched by students on their own, the possibilities to talk immediately to others are limited. YouTube offers a section where users can comment on the video, e.g., with other users, or producers, and where they can send feedback or request other topics. Anyhow, the asynchronous communication cannot be compared to the communication in classrooms. We conclude that educational videos are more efficient if people can discuss them with others. We assume that the commentary function will not be sufficient for this experience. Therefore, educational videos might only work in favor for those who are able to discuss the content of the video with others.

Educational Videos and Their Impact on Individuals

The VARK model has pointed out that individual differences have an influence on how information are processed. It can be used to explain why learning success might differ between individual students. In this case, the preferred learning style has an influence on how information in educational videos are processed. Although it seems obvious that individuals with a dominant visual learning style might benefit from educational videos and aural learners from spoken explanations in the videos, research has shown that also kinesthetic learners draw advantages from videos as long as procedures or experiments are shown. Since the majority of people have more than just one learning preference, online videos become a powerful instrument for scientific topics (Metten et al., 2016). Thus, in general, there seems to be a great potential for educational videos on YouTube as several learning preferences benefit from the audiovisual presentation. Yet, only those will be exposed to educational videos who know how to search for information and, therefore, they might be affected. Just applying web applications or tools like YouTube does not include an instant improvement of the learning process (Kurilovas and Juskeviciene, 2015, 1384). We assume that the impacts of educational videos differ depending on the individuals' media literacy and information seeking behavior (Borgatti and Cross, 2003). VARK shows that students who know their dominant learning style choose fitting learning techniques. Speaking of educational videos, e.g., visual learners would rather choose YouTube to receive information while read/write learners would consult Wikipedia. Research which analyzes which information stimulus might be more efficient to gain more knowledge, e.g., text or videos, does not take into account individual learning preferences. We assume that if students choose their preferred information stimulus voluntarily, the success of educational videos will be stronger for those who are more prone to use audiovisual information. In this case, the question is not whether enhancing the quality will enhance peoples' knowledge but whether the individual will fit to the visual presentation.

It is necessary to differentiate educational videos which are integrated in classes at school from educational videos on YouTube. Usually, the latter like videos from simpleclub do not belong to educational institutions and cover only some single aspects which might be part of the curriculum at school. This means that there is no obligation for students to watch educational videos on YouTube in contrast to educational videos which are implemented by the teacher in class. Even more, learning itself consists of an individual process and is the sole task of the individual (Kerres, 2018, 273). For this process, several requirements have to be met: Individuals must be able to reflect their own deficits, they need to know how they encounter this, and they have to be willing to do something about it. The first part might be the difficult one as it requires a lot of self-reflection by the student and of one's own learning process. Students need to know what they have to learn and which aspects are relevant to improve their own learning process. This describes information seeking as a result which derives from the discrepancy between the perceived level of information and the perceived need for information which means that the information is also rated on its usefulness (Bonfadelli, 2017, 92). Students need to know how to increase their knowledge, they must be aware that there are educational videos on YouTube, they must be able to search for them, decide for one and, finally, they must be willing and motivated to watch them.

DISCUSSION

In this final section, we will discuss our assumptions on the potentials and limitations of educational videos for science communication. If science communication uses science videos for educational purposes such as informing the public, our assumptions might also be transferred to the success of science communication.

Based on the definition by Schäfer et al. (2015, 13) in which science communication includes any form of communication focused on scientific knowledge or work, both within and outside

of institutional science, educational videos which explain single aspects of scientific topics are understood as science communication. Likewise, science videos can be understood as educational videos. Regarding to this, the aim of science videos is to inform, teach, or educate the public. This means that the producers of a video seem to assume that the potential users have deficits referring to scientific questions. Hence, educational videos are subject to the paradigm of public understanding of science (Weingart, 2003, 116). Users suffer from deficits but are able to enhance their knowledge with the usage of videos. The deficit model implies additional aspects which are also visible in educational videos. It is unidirectional and asymmetric (Bonfadelli, 2017, 85). Thus, if research questions how science videos enhance the knowledge of users or use textbook knowledge to measure the impact of scientific information (Priest, 2013), it surprisingly follows a quite old-fashioned understanding of a stimulus-response model. In this case, neither the accessibility of information nor the circumstances of the target group are considered although the characteristics of groups or individual preferences or predispositions lead to different outcomes, e.g., are more or less successful. Educational videos at school might not work for every student, the same is true for science videos on YouTube: 'one fits all' cannot be applied to science videos.

The concept of the public understanding of science also assumes that the communicating party has a superior knowledge which is to be transferred to the laypersons. This might be one major flaw as in the case of science videos, there is no guarantee of the communicating parties' expertize. In fact, the actors can be lay persons themselves and pretend to have knowledge. Or even worse, the communicating party seems to be an expert yet disseminates false information (ZDF [Zweites Deutsches Fernsehen], 2020). According to this, two aspects need to be discussed when research analyzes science videos: How users interpret the expertize of the actors and the content of the video. This is highly correlated with the situation of media usage. We suggest two scenarios. The first one describes a situation where others disseminate the video content, e.g., similar to teaching staff who include videos in classes, friends, or family, or other institutions disseminate the video. Here, others have selected and evaluated the video in terms of quality which might positively affect the users' perception of the quality as well. Other people function as an additional controlling authority since they choose educational videos to be suitable as learning aid and fitting element to everyday life. While teachers play a crucial role in the learning process (Othman, 2010) in general, peer groups influence their members, too. The social status of the peer group might become relevant, as we have discussed that differences in social status result in different knowledge acquisition processes. If research tackles such questions, it should discuss whether the users come from a homogeneous or heterogeneous group. The second scenario describes a situation in which users watch science videos alone. Again, we would like to emphasize that several prerequisites must be met for someone to watch a science video: The user has to be aware of his/her own deficits, must be willing to tackle the deficit, and has to know how to do this. In this case, the understanding of science communication shifts rather into a direction where concepts such as uses and gratification (e.g., Bonfadelli and Friemel, 2017, 79ff.) and information seeking (Atkin, 1973) work as approaches to explaining why and how users respond to a particular need for information. As we have explained, it is likely that users try to use the sources which are in favor with their own learning style preferences. Users with a read/write preference will probably search for text-based information (Wikipedia, books. . .) while users with a visual preference will more likely choose videos. Still, it is unclear how they will judge the quality and expertize of the content and the actors. We have summarized that previous research on science videos has examined esthetics, design, and content as indicators of quality and, therefore, of the success of a video. We suggest that other factors are important. YouTube statistics of each video might function for users as an indicator of quality: The more views, the more likes, the higher the quality. In this case and as we already pointed out, it is probably difficult for users to judge whether the actors in the videos are experts or not or whether the content itself has a high quality. YouTube metrics such as likes and views are no indicators of quality, rather they are indicators of the channel's popularity or likeability with the actors (Kulgemeyer, 2018, 11). Regarding this, the characteristics and environment of YouTube might lead to misconceptions. Although YouTube has become a complement platform for learning, it is first and foremost known as a platform for fun and entertainment. Yet, rating a music video with "likes" shows rather subjective enjoyment of the users than objective judgement of the quality. It seems to be crucial that users know how to select the "right" videos and to reflect and judge the content and source of information. These highly complex decisions can of course be addressed in learning environments such as schools (Kulgemeyer, 2018, 9).

Therefore, in the further course, concepts like digital divide and media literacy should be considered. Both question how users search for information and rate the source of information. This will clarify whether some users gain more knowledge than others which is in line with the rationale: Information technology, and the ability to use it and adapt it, is the critical factor in generating and accessing knowledge in our time (Castells, 2010, 93).

We have emphasized that the situation in which science videos were chosen and watched by users might be important. For this reason, we assume that research which focuses on single aspects of quality will not be sufficient if it is conducted as a study in an artificial environment like labs or experiments. It will be biased because the situation itself obliges one to watch the video. Indicators of how and why users have selected specific science videos will not be revealed. Research in science communication could address this issue with studies which examine the user groups and predispositions of the users e.g., whether they are mostly visual learners or are able to reflect their own learning process and potential deficits.

Finally, we would like to ask how to measure the success of videos if we only focus on circumstances but not on the

content or design of the science videos. Science communication tends to measure the effectiveness and outcome of videos based on textbook knowledge (Priest, 2013). In regard to the knowledge gap hypothesis, science communication research also has to reflect whether to choose cross-sectional or longitudinal studies. The first study design might rather reveal differences between individuals based on predispositions, the latter is able to clarify changes between groups over time.

The aim of this paper was to describe the potentials and limitations of educational videos on YouTube for science communication. We have shown that both social status and individual predispositions influence the outcome of educational videos. For future research in science communication, we suggest to take these considerations into account more strongly. Educational videos on YouTube might function as a tool to disseminate scientific information. Anyway, the platform itself, the users' situation in media usage, preferences and literacy, social status and peer groups are able to influence a potential outcome.

AUTHOR CONTRIBUTIONS

TD conceived of the presented idea. SK supervised the idea. Both authors SK and TD wrote the manuscript and contributed equally to the final manuscript. All authors contributed to the article and approved the submitted version.

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