Geonews: Timely Geoscience Educational YouTube Videos about Recent Geologic Events

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Abstract. Geologic events like volcanic eruptions, earthquakes, and tsunamis hurt nearby people and stimulate the curiosity of people farther away, thus providing opportunities to engage the public to be more interested to learn about Earth processes. Geoscientists are increasingly using social media such as Twitter to explain to the public what caused these events and videos provide an especially vivid way to reach this audience. However, it is still unclear how to create, evaluate and disseminate videos on timely natural events to communicate geosciences. To address this challenge and opportunity, we analyzed the impact of 33 short geoscience educational (GeoEd) videos that we created and posted on YouTube between 2018 and 2020. These include 12 videos on timely geologic events (Geonews videos) and 21 videos that are not specially about timely geologic topics (General GeoEd videos), all of which were similarly advertised and have similar lengths. By comparing the performance of the Geonews and General GeoEd videos, we conclude: 1) The YouTube audience is consistently interested in Geonews videos but some General GeoEd videos are more popular; 2) Geonews videos may trigger more meaningful dialogues than General GeoEd videos, especially for local audiences; ~~and~~ 3) The 'golden period' of Geonews videos engaging YouTube audiences is within 3 weeks after posting; ~~.~~ 4) The Geonews audience tends to be younger and more diverse than the General GeoEd video audience; ~~.~~ 5) Creating Geonews videos can be a promising strategy for geoscientists to engage public audiences on YouTube-like social media.

1. Introduction

Effectively communicating science to the public is challenging (Allum et al., 2008; Dyer, 2018; Bartel and Bohon, 2019; Greussing et al., 2020) but news about natural hazard events like earthquakes, tsunamis, and volcanic eruptions attracts people's attention and create opportunities for two-way~~s~~ dialogues about geosciences (Falk and Dierking, 2010; Tong, 2014; Barrett et al., 2014; Illingworth et al., 2018). Some research suggests that discussing the science behind such events soon after they occur on message-based social media, such as Twitter, can engage the public who want to learn more (e.g. Rosenbaum and Culshaw, 2003; Veil et al., 2011; Drake et al., 2013; Shiffman, 2017; Takahashi et al., 2015; Lacassin et al., 2020; Wibisono et al., 2020). However, few studies have tested if the same strategy can also be successfully applied to videos posted on YouTube (Schäfer, 2012; NAS, 2017). This work ~~explores~~ ~~2~~addresses two questions: First, would videos posted on YouTube about Earth events and processes also stimulate the public to be more interested in these? Second, are YouTube users more interested in timely

events-based geoscience educational videos (herein referred as to 'GeoEd videos') relative to videos that are unrelated to recent events in the news?

Social science provides the fundamental theories of how to effectively communicate geoscience to the public (Nisbet et al., 2010; Illingworth et al., 2015). With more and more evidence against the early one-way expert-to-public knowledge-transfer model (known as 'information deficit model'), researchers increasingly suggest that it is important to value 'lay local' knowledge to stimulate dialogues and better communicate science to the public (Irwin and Michael, 2003; Allum et al., 2008; Siersdorfer et al., 2010; Illingworth et al., 2015; Stewart and Lewis, 2017; Illingworth, 2017). Also, although meta-analysis on overall public knowledge and attitude about science shows a weak positive relationship, results varied for different subjects (Allum et al., 2008). Geoscience has three unique features regarding communicating with public. First, understanding how complex Earth systems operate is complicated because many Earth processes cannot be directly observed: They occur deep in the Earth and/or over unimaginably long timescales (Singer et al., 2012; Willis et al., 2021; Mosher and Keane, 2021). Dealing with geoscientific information can easily cause a high cognitive load (Arthur, 2018). Therefore, communicating geoscience to the public should strive to reduce cognitive load. Secondly, different geoscience aspects are more relevant to some places than others (King, 2008), for example Californians are more interested in earthquakes than hurricanes and Floridians are more interested in hurricanes than earthquakes. Different places also have different communities sharing local cultures and beliefs (Michael, 2009), so that taking advantage of local context and geological events is especially important for public engagement (Takahashi et al., 2015; Semken et al., 2017). Thirdly, geoscience topics often concern dynamic and complex systems, involving much uncertainty and chaos (Manduca and Kastens, 2012; Stillings, 2012). This makes visual storytelling, multimedia and two-ways conversations (between the public and experts) even more important (Nisbet et al., 2010; Mosher et al., 2014; Urban and Falvo, 2016; Mosher and Keane, 2021). Lastly, explaining Earth science concepts also requires understanding different components of an Earth system and how these interact (Forster and Freeborough, 2006; Bobek and Tversky, 2016; Lacchia et al, 2020). The challenge of explaining this complexity encourages more geoscientists to explore using social media for communicating geosciences to the public. We need to learn more about how to best use different types of social media to communicate geoscience issues to them (Schäfer, 2012; Dunn, 2013; Illingworth et al., 2018).

Videos have special advantages for communicating geoscience to the public and beginning students compared to words alone or words and static figures combined (Nisbet et al., 2010; Wiggen and McDonnell, 2017; Littrell et al., 2020). Most difficulties of communicating geoscience mentioned above can be overcome with videos and animations (Wijnker et al., 2019; Ploetzner et al., 2020) and by integrating psychological designs into repeatable educational units (Goldberg et al., 2019; Greussing et al., 2020; Mayer, 2021). Moreover, research has shown that YouTube videos can involve large numbers of people to be more interested in important geoscience issues such as climate change (Zavestoski et al., 2006; Askanius and Uldam, 2011; Krauss et al., 2012; Stewart and Nield, 2013; Van Loon et al., 2020). Videos

also have the advantage of being organizable into YouTube channels where they are more easily found to be used for teaching and learning in diverse environments (Welbourne and Grant, 2016; Maynard, 2021). Furthermore, YouTube provides a 'comments' function which makes dialogue possible. Therefore, it is valuable to understand if and how timely, short videos about geologic events in the news posted on YouTube can reach the public and trigger meaningful dialogue.

In this study, we analyzed the performance of 33 GeoEd videos (all less than 6 mins with elaborated editing) that we posted on YouTube in 2018 and 2020, paying attention to who was interested in these and for how long as well as what dialogue occurred in the comments. These include 12 timely videos about natural events in the news ('Geonews videos') and 21 GeoEd videos about processes that are not time-sensitive because they are not about something that just happened ('General GeoEd videos'). Geonews videos are mostly published about 2 weeks after the event occurred. General GeoEd videos aims to explain some geological concepts or phenomenon and do not utilize timely events to engage the audiences; These are created with less urgency and take longer to make. By comparing the performance of Geonews and General GeoEd videos, we explore the advantages and limitations of the Geonews format. Using data from YouTube Analytics and Comments, we can evaluate audience engagement with these two types of videos that we made and posted in 2018 and 2020 (2019 was excluded because no Geonews videos were posted in 2019).

This study (1) introduces how we design Geonews videos; (2) compares the performance and audience features of Geonews and General GeoEd videos on YouTube; and (3) explores how and why Geonews videos engages a different group of viewers. Our results indicate that using Geonews-like videos to explain what, where, and why geologic events happen is a useful strategy for engaging diverse YouTube users.

2. Geologic Events and Geoscientific Outreach

Using geologic events to interest and teach people has been long discussed (Vitek and Berta, 1982). Most research about communicating natural hazards to the public focuses on preparing for potential disasters, emphasizing what people should do during a geologic disaster and how to be resilient afterwards (Rosenbaum and Culshaw, 2003; Forster and Freeborough, 2006; Ickert and Stewart, 2016; Kelly and Ronan, 2018). With the development of the internet, computers and smartphones, social media is increasingly acknowledged as a key tool for the communication and education activities of emergency agencies. More and more geoscientists highlight the importance and effectiveness of using these new tools to reach and teach the public and beginning students after a natural hazard event happens (Bartel and Bohon, 2019; Barton et al., 2020; Lacassin, et al., 2020). Most studies document effective and ineffective uses of social media in crises, focusing on topics such as fast communication, accuracy, credibility, uncertainty, and communicating broadly (Freberg et al., 2013). Using social media as disaster resilience communication tools in addition to traditional engagement and education activities is well studied (Dufty, 2011; Veil et al., 2011; Freberg and Palenchar, 2013; Lundgren and McMakin, 2013).

The need to enhance public perception of geology and natural hazards, educate them about the Earth, and recruit geoscience students continues to increase (Rosenbaum and Culshaw, 2003). As a result, geoscientists increasingly apply an event-based method in a cultural context to discuss geologic events and natural hazards on social media (Illingworth, 2018; Fallou and Bossu, 2019). There are several popular social media platforms that are available but probably the most studied and used is Twitter. Considering the need to respond as fast as possible to disasters, this is understandable. Twitter messages are short and very interactive. Twitter allows geoscientists to provide useful information almost immediately after an event (Hicks, 2019). Writing text and posting "point-and-click" photos and camera-recordings of an event is easier and faster than creating GeoEd videos which must provide context, consider educational effects, and require more time.

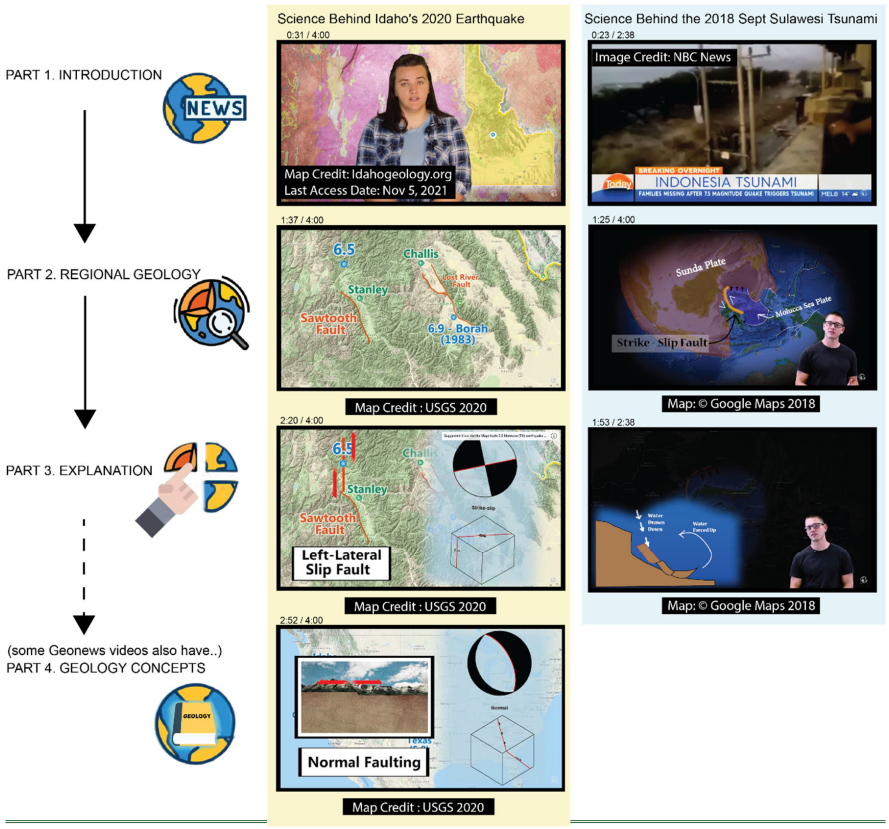
Researchers have used a case-based and descriptive way to study the effects of using Twitter to communicate to the public about geologic events, showing that Twitter can gain the attention and inform the public quickly (Rosenbaum and Culshaw, 2003; Lomax et al., 2015). These studies find that such events allow geoscientists to communicate pertinent scientific information to the public but many aspects are not well explained by Twitter and similar social media (Mossoux et al., 2016; Lacassin et al., 2020). The need for jargon-free explanation with coordinated graphical elements is not met with these social media platforms. These shortcomings can be overcome by making short videos that provide context and visual clues with embedded educational designs and input from more than one person (including experts). Such videos, if available soon after the event, can powerfully complement "on the spot" Twitter and similar social media posts. Well-crafted, short videos about a newsworthy event can be engaging and can possibly better manage cognitive load of the public than can texts, pictures, or unedited videos without educational considerations. In addition, videos can be embedded into websites and other social media like Facebook and Twitter (Moloney and Unger, 2014).

Edited videos play an increasingly important role in informal education and are popular worldwide (Thomson et al., 2014; Welbourne and Grant, 2015; Wijnker et al., 2019; Vega and Robb, 2019). YouTube is the main platform for these and has about two billion users every month (Welbourne and Grant, 2015; YouTube, 2021). This audience uses YouTube videos for much more than entertainment; about half of YouTube adult use is for learning (Smith et al. 2018; Allgaier, 2020). YouTube videos can help communicate Earth science to the public because this is not easy (Dyer, 2018). Earth science concepts have many elements that are unfamiliar: They occur in strange lands or under the sea, and involve words and concepts that are abstract, complex, and confusing (Greussing et al., 2020; Stern et al., 2020). Well-crafted GeoEd videos are especially effective for revealing the meaning of unfamiliar words to the public and explaining abstract and complex geoscience concepts to them (e.g. Banchero et al., 2021; Schmidt-McCormack et al., 2017; Akinbadewa and Sofowora, 2020; Stern et al., 2017 and 2020; Tayne et al, 2021; Wang et al., submitted). However, despite evidence of the power of this approach, there is little known about the advantages and disadvantages of utilizing YouTube videos about recent geologic events to reach

and teach (Nisbet et al., 2010; ~~Binder, 2012;~~ Schäfer, 2012; Ta~~A~~kahashi et al., 2015). Few have studied the potential of using videos on the internet to explain recent geological events and natural hazards as a way to engage the much larger group of people who do not directly suffer from the event. Also, it is unclear if those who are impacted by an event or know someone directly impacted are better engaged by Geonews-like videos about it.

3. Geonews Videos

All UTD Geonews videos are about 3 to 5 mins long and created by geoscience students in the Geoscience Studio at the University of Texas at Dallas (UTD GSS). The GSS team is supervised by Professor Stern and creates all types of short GeoEd videos. A subset of these are assessed in the classroom, especially ones intended for undergraduate classes (Stern et al., 2017; Willis et al., 2021; Wang et al. submitted). Geoscience Studios began in 2016 and we began making Geonews videos in 2018. All Geonews videos have a similar format (Figure 1): 1) Start with a simple introduction of the event, including location and date; 2) Explain pertinent background; and 3) Provide a simple scientific explanation for the event, along with scientific evidence. In some cases, we introduce some relevant basic geoscientific concepts such as normal faults, plate tectonics, or earthquake magnitude. In some cases, we reach out to experts and get their input. All Geonews videos conclude with references and web links where interested viewers can learn more.



~~**Figure 1. Design framework of Geonews videos and two examples. Details and links of the two Geonews video examples can be found in Table 1. (Map: © Google Maps 2018; U.S. Geological Survey, earthquake.usgs.gov, 2020; © OpenStreetMap contributors; NBC News Today, 2018, last access: 9 Nov, 2021; Idaho Geological Survey, 2020)**~~

The workflow of making a Geonews video begins with: (1) Someone proposes an ongoing or recent event as a topic for a new video to the UTD GSS video production team. (2) Once the UTD GSS team agrees, a production leader volunteers and works with Prof. Stern to collect information, images and videos on the topic. (3) A 360-600 words narrative is written by the production leader and Prof. Stern, setting the length and pace for a 3-5 minute video. (4) The narrative is recorded (the narrator is also a UTD student) and graphics and background music added. (5) Once the video is finalized, it is posted on the UTD GSS YouTube channel and closed captions would be added and corrected. Once this is done, it is advertised to various on-line scientific communities such as the Geological Society of America, the American Geophysical Union, Sigma Xi, and the American Association for the Advancement of Science. These are

also advertised on Facebook on our personal accounts and in a Facebook public group "Geoscience Animations and Videos" (279 members as of Oct. 2021). In addition, the growing subscriber base for the UTD GSS YouTube channel (~2270 as of Oct. 2021) is also notified. This procedure allows us to release a Geonews video within about 2 weeks after we begin work.

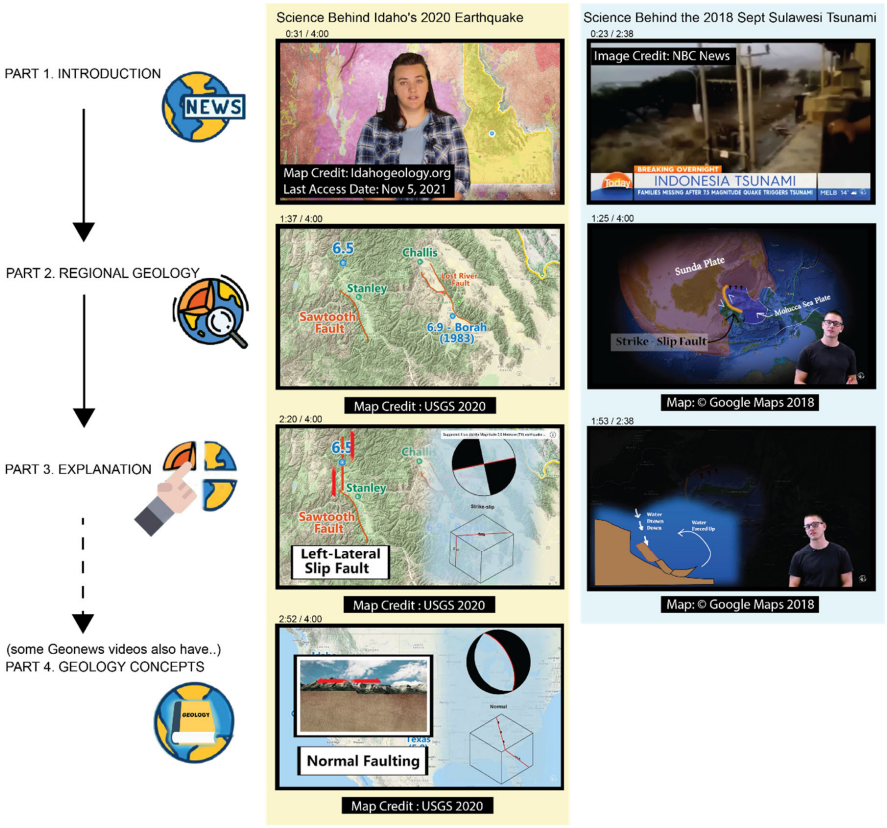


Figure 1. Design framework of Geonews videos and two examples. Details and links of the two Geonews video examples can be found in Table 1. (Map: © Google Maps 2018; U.S. Geological Survey, earthquake.usgs.gov, 2020; © OpenStreetMap contributors; NBC News Today, 2018, last access: 9 Nov, 2021; Idaho Geological Survey, 2020)

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From our experience, Geonews videos are easier to make than General GeoEd videos for three reasons: (1) The design is more standardized.

(2) Because the event just happened, a lot of relevant information (especially visual materials) is easy to find. It is easier to find relevant materials by keyword search, and easier to find experts to consult.

(3) Because the video concerns a single event, it is easier to pull together a story and write the narrative.

Table 1. List of 12 Geonews videos (2018 - 2020)

#	Title	Short Description (Location, ~~Magnitude,~~ TYPE*)	Link	Total Length
1	The Sinabung Volcano Eruption!	Indonesia, VE	https://youtu.be/t0xwiS2mW5k	2min35sec
2	Science Behind the Earth Suswa Fissure (Kenya)	Kenya, East Africa, FI	https://youtu.be/sOB7O3yvC4Q	3min14sec
3	Science Behind Hawaii Eruption 2018	Hawaii, US, VE	https://youtu.be/f-Z5d2ZBIro	4min50secs
4	Science Behind the 2018 Sept Sulawesi Tsunami	Indonesia, TS	https://youtu.be/1oaI4Mo7V_s	2min39sec
5	Taal Volcano Eruption 2020	Philippines, VE	https://youtu.be/z-iKOBjIiYc	2min43sec
6	Science of the Magnitude 5.7 Magna, Utah earthquake	Utah, US, ~~M5.7~~EQ	https://youtu.be/d6R6FTQnR3U	2min48sec
7	Science of the Magnitude 5.0 Mentone (TX) earthquake	Texas, US, ~~M5.0~~ EQ	https://youtu.be/MfxmvXsIpBI	3min23sec
8	Science Behind Idaho's 2020 Earthquake	Idaho, US, ~~M6.5~~ EQ	https://youtu.be/s_5YKFR5AMU	4min1sec
9	Science Behind Nevada's 2020 Earthquake	Nevada, US, ~~M6.5~~ EQ	https://youtu.be/GizueyqNwYQ	5min
10	Science Behind Mexico's 2020 Earthquake	Mexico, ~~M7.4~~ EQ	https://youtu.be/mIlQqfj8MQY	4min15sec
11	Science Behind the 2020 Sparta, North Carolina Earthquake	North Carolina, US, ~~M5.1~~ EQ	https://youtu.be/JDz5UDbVGb8	3min40sec
12	Science Behind the 2020 Aegean Sea Earthquake	Turkey and Greek Islands, ~~M6.6~~ ~~7.0~~ EQ	https://youtu.be/MMBFY-LahNc	5min1sec

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#	Title	Short Description (Location, Magnitude, TYPE*)	Link	
1	Science Behind the 2020 Aegean Sea Earthquake	Turkey and Greek Islands M6.6-7.0 EQ	https://youtu.be/MMBFY_LahNc	
2	Science Behind the 2020 Sparta, North Carolina Earthquake	North Carolina, US M5.1 EQ	https://youtu.be/JDz5UDbVGb8	
3	Science Behind Mexico's 2020 Earthquake	Mexico M7.4 EQ	https://youtu.be/mllQqfj8MQY	
4	Science Behind Nevada's 2020 Earthquake	Nevada, US M6.5 EQ	https://youtu.be/GizueyqNwYQ	
5	Science Behind Idaho's 2020 Earthquake	Idaho, US M6.5 EQ	https://youtu.be/s_5YKFR5AMU	
6	Science of the Magnitude 5.0 Mentone (TX) earthquake	Texas, US M5.0 EQ	https://youtu.be/MfxmvXslpBI	
7	Science of the Magnitude 5.7 Magna, Utah earthquake	Utah, US M5.7EQ	https://youtu.be/d6R6FTQnR3U	
8	Taal Volcano Eruption 2020	Philippines VE	https://youtu.be/z-iKOBjIiYc	
9	Science Behind the 2018 Sept Sulawesi Tsunami	Indonesia TS	https://youtu.be/1oal4Mo7V_s	
10	Science Behind Hawaii Eruption 2018	Hawaii, US VE	https://youtu.be/f-Z5d2ZBIro	
11	Science Behind the Earth Suswa Fissure (Kenya)	Kenya, East Africa, FI	https://youtu.be/sOB7O3yvC4Q	
12	The Sinabung Volcano Eruption!	Indonesia VE	https://youtu.be/t0xwiS2mW5k	

(*EQ - Earthquake, VE - Volcano Eruption, TS - Tsunami, FI – Fissure)

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4. Methods and Materials

To better understand how focusing on timely natural hazard elements affects audience engagement with short videos, we compared Geonews videos with other short GeoEd videos we made that have a different focus (General GeoEd videos). We use General GeoEd videos as a control to study the effects of Geonews videos. By comparing the performance of Geonews and General GeoEd videos that we created and posted on YouTube in 2018 and 2020, we isolate the effects of timely reporting on natural hazards in engaging the audience. We exclude 2019 GeoEd videos because no Geonews videos were made that year (UTD GSS

activities depend heavily on UTD student interest and availability). The two types of videos were posted in the same years, eliminating engagement differences caused by continuously growing numbers of subscribers to the UTD GSS channel and our improving video-making skills. In 2018 and 2020, a total of 33 short GeoEd videos were posted on YouTube, including 12 Geonews videos (Table 2A) and 21 General GeoEd videos (Table 2B). In 2018, we posted 4 Geonews and 6 General GeoEd videos, increasing to 8 Geonews and 14 General GeoEd videos in 2020. The topics were chosen based on educational need, event impact, and UTD GSS team interest and availability. Some General GeoEd videos were made as undergraduate class projects. All the videos were reviewed and directed by Prof. Stern and other content experts to ensure accuracy.

All videos followed a similar video-making philosophy and workflow to ensure quality, artistic skills, project duration and dissemination strategies. The average length of the 12 Geonews videos is 3min 41sec (std. dev. = 1min 18sec) and that of the 21 General GeoEd videos is 3min 55sec (std. dev. = 1min 13sec). The range of lengths of Geonews and General GeoEd videos are also similar (from ~2min 30secs to ~5min). Both Geonews and General GeoEd videos were disseminated similarly. These similarities ensure the differences in audience response mostly reflect differences in timeliness: for Geonews videos, a focus on something that just happened, whereas for General GeoEd videos, there was no such focus.

We examined six factors available from YouTube statistics and comments to assess the nature of the audience and its engagement for the two groups of videos (Table 2). For engagement, we examined the number of views, average percentage of video watched (herein referred as to 'average percentage viewed'), like/dislike ratio, as well as analyzing all comments (Azer et al., 2013; Allgaier, 2019; Ozdede and Peker, 2020). Number of views reflect how interested the audience is in the topic: More views indicate more interest. We also compared the two groups over different time periods (15 weeks after video release as well as lifetime performance) to see how important timeliness was. Data was collected from YouTube Analysis. To assess how successfully the video retained audience interest, we also compared the two groups' average percentage viewed. This reflects video quality: higher percentage watched indicates a more engaging video (Guo et al., 2014). In addition, analysis of comments is useful for exploring in greater depth YouTube users' attitudes towards the information presented (Chatzopoulou et al., 2010; Hussain et al., 2018; Dubovi and Tabak, 2020). We analyzed 222 comments as of 10/03/2021 to understand how many meaningful dialogues were triggered. Like/dislike ratio indicates the users' attitudes about each video (Ozdede and Peker, 2020). Lastly, in order to understand audience demographics for the two GeoEd video groups, we also compared their ages and genders in an effort to understand if Geonews and General GeoEd videos engaged different audiences.

Two metrics that could be relevant to engagement are not considered: watching time and average view length. These are related to engagement but since the two groups of videos have very similar average lengths, these two metrics can be approximately represented by views and average percentage viewed.

Table 2. Details of 12 Geonews videos and General GeoEd videos created in 2018 and 2020* ~~* as of 10/03/21~~

. (* as of Oct 03, 21; -us- indicates US related events)

(A) Geonews Videos:

#	Video Example	Event Date	Release Date	Intensity (Mw/VEI/TIS)	Interval (Days)	Views *	Average View Percentage	Con
1	The Feb 2018 Sinabung Volcano Eruption	Feb. 19 2018	Feb. 27 2018	VEI 4 Little Damage And Largely Observed~~VEI 4~~	18	2,397	68%	
2	Science Behind the Earth Suswa Fissure (Kenya)	Mar. 27 2018	Apr. 14 2018	Little Damage And Largely Observed	18	2,309	67%	
3	Science Behind Hawaii Eruption 2018 -us-	May 06 2018	May 18 2018	VEI 0~3 Very Destructive	12	5,001	61%	
4	Science Behind the 2018 Sept Sulawesi Tsunami	Sep. 28 2018	Oct. 14 2018	TIS X~XII Very Destructive	16	5,407	66%	
5	Taal Volcano Eruption 2020	Jan. 12 2020	Jan. 16 2020	VEI 4 Little Damage And Largely Observed	4	2,417	59%	
6	Science of the Magnitude 5.7 Magna, Utah earthquake -us-	Mar. 18 2020	Mar. 29 2020	Mw 5.7 Frightened All Damage Negligible	11	4,893	67%	
7	Science of the Magnitude 5.0 Mentone (TX) earthquake -us-	Mar. 26 2020	Apr. 06 2020	Mw 4.7~5.0 Damage Negligible, Felt by Most	11	1,986	61%	
8	Science Behind Idaho's 2020 Earthquake -us-	Mar. 31 2020	Apr. 16 2020	Mw 6.5 Fright General, Damage Slight	16	7,135	59%	

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9	Science Behind Nevada's 2020 Earthquake -us-	May 15 2020	May 29 2020	Mw 6.5 Frightened All Damage Negligible	14	4,252	57%	
10	Science Behind Mexico's 2020 Earthquake	Jun. 23 2020	Jul. 05 2020	Mw 7.4 Fright General, Considerable Damage	12	1,420	60%	
11	Science Behind the 2020 Sparta, North Carolina Earthquake -us-	Aug. 09 2020	Aug. 25 2020	Mw 5.2 Frightened All Considerable Damage	16	4,147	65%	
12	Science Behind the 2020 Aegean Sea Earthquake	Oct. 30 2020	Nov. 16 2020	Mw 7.0 Cracked Ground, Damage Serious	17	2,732	57%	
~~#~~	~~Video Example~~	~~Event Time~~	~~Release Time~~		~~Interval (Days)~~	~~Views *~~	~~Average View Percentage~~	
~~1~~	~~Science Behind the 2020 Aegean Sea Earthquake~~	~~10 30 2020~~	~~11 16 2020~~		~~17~~	~~2,732~~	~~56.9%~~	
~~2~~	~~Science Behind the 2020 Sparta, North Carolina Earthquake~~	~~08 09 2020~~	~~08 25 2020~~		~~16~~	~~4,147~~	~~64.8%~~	
~~3~~	~~Science Behind Mexico's 2020 Earthquake~~	~~06 23 2020~~	~~07 05 2020~~		~~12~~	~~1,420~~	~~60.2%~~	
~~4~~	~~Science Behind Nevada's 2020 Earthquake~~	~~05 15 2020~~	~~05 29 2020~~		~~14~~	~~4,252~~	~~56.9%~~	
~~5~~	~~Science Behind Idaho's 2020 Earthquake~~	~~03 31 2020~~	~~04 16 2020~~		~~16~~	~~7,135~~	~~59.1%~~	
~~6~~	~~Science of the Magnitude 5.0 Mentone (TX) earthquake~~	~~03 26 2020~~	~~04 06 2020~~		~~11~~	~~1,986~~	~~60.9%~~	
~~7~~	~~Science of the Magnitude 5.7 Magna, Utah earthquake~~	~~03 18 2020~~	~~03 29 2020~~		~~11~~	~~4,893~~	~~66.8%~~	
~~8~~	~~Taal Volcano Eruption 2020~~	~~01 12 2020~~	~~01 16 2020~~		~~4~~	~~2,417~~	~~58.5%~~	

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9	Science Behind the 2018 Sept Sulawesi Tsunami	09 28 2018	10 14 2018		16	5,407	66.2%	7mi
10	Science Behind Hawaii Eruption 2018	05 06 2018	05 18 2018		12	5,001	61.2%	4mi
11	Science Behind the Earth Suswa Fissure (Kenya)	03 27 2018	04 14 2018		18	2,309	66.7%	3mi
12	The Feb 2018 Sinabung Volcano Eruption	02 19 2018	02 27 2018		18	2,397	68.2%	2mi

VEI: Volcanic Eruptive Index (Global Volcanism Project, 2013).

Mw: Moment Magnitude Scale (Kanamori, 1977), the damage of the earthquake is described by the Modified Mercalli Intensity (Wood and Neumann, 1931, Stover and Coffman, 1993).

TIS: Tsunami Intensity Scale (Papadopoulos, 2007).

(* as of Oct 03, 21; -us- indicates US related events)

(B) General GeoEd Videos:

#	Year	Video Type	Video Example	Views *	Average View Percentage	Total Length	Com
1	2018	Topical	Permian Basin Intro	15,681	59%	56min19sec	1
2	2018	Topical	What's happened inside Siberia's Mysterious Craters?	1,958	51%	4min24sec	
3	2018	Topical	Nuclear Bomb and Radioactive Dating - Dating .. Wrong??	807	65%	3min27sec	
4	2018	Topical	Three Types of Igneous Rocks at Wichita Mountains	1,329	54%	5min2sec	
5	2018	Topical	Why is the Moon white?	7,425	48%	3min54sec	6
6	2018	Topical	Evolution of the Permian Basin	658	48.1%	5min19sec	
67	2018	Topical	Drilling to the Mantle	1,905	64%	3min21sec	
78	2020	Topical	Are there volcanoes in Texas?	23,191	60%	5min33sec	4
89	2020	Simulation	Formation of a new subduction zone	451	55%	3min3sec	1
910	2020	Topical	What Happens When a Plane Flies into Volcanic Ash?	1,984	67%	2min33sec	
101	2020	Basic Concept	The Four Types of Volcanoes	23,617	52%	2min45sec	1
112	2020	Topical	Induced Seismicity - The Oklahoma Story	826	69%	3min45sec	

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123	2020	Topical	Creatures of the Burgess Shale	5,164	52%	3min38sec
134	2020	Topical	Big Bend National Park	1,095	77%	3min1sec
145	2020	Topical	The Ogallala Aquifer	8,563	55%	4min20sec
156	2020	Basic Concept	Geodes: How Nature Creates Beautiful Mineral Formations	3,300	60%	3min16sec
167	2020	Video Abstract	Formation of a New Subduction Zone by Lithospheric Collapse around the Margins of a Large Plume Head	423	54%	3min15sec
178	2020	Basic Concept	How do Fossils Form?	7,671	52%	4min34sec
189	2020	Video Abstract	How Far South Might Himalayan Earthquakes Occur?	2,345	52%	4min26sec
1920	2020	Basic Concept	Emergence: A chaotic system pushed into organization	753	68%	2min36sec
210	2020	Basic Concept	CO2 Drawdown - Where Should the Water Go?	1,042	62%	5min38sec
#	Year	Video Type	Video Example	Views *	Average View Percentage	Total Length
1	2020	Basic Concept	CO2 Drawdown - Where Should the Water Go?	1,042	61.6%	5min38sec
2	2020	Basic Concept	Emergence: A chaotic system pushed into organization	753	67.7%	2min36sec
3	2020	Video Abstract	How Far South Might Himalayan Earthquakes Occur?	2,345	52.4%	4min26sec
4	2020	Basic Concept	How do Fossils Form?	7,671	52.2%	4min34sec
5	2020	Video Abstract	Formation of a New Subduction Zone by Lithospheric Collapse around the Margins of a Large Plume Head	423	54.2%	3min15sec
6	2020	Basic Concept	Geodes: How Nature Creates Beautiful Mineral Formations	3,300	59.8%	3min16sec
7	2020	Topical	The Ogallala Aquifer	8,563	54.7%	4min20sec
8	2020	Topical	Big Bend National Park	1,095	76.5%	3min1sec
9	2020	Topical	Creatures of the Burgess Shale	5,164	51.8%	3min38sec
10	2020	Topical	Induced Seismicity - The Oklahoma Story	826	68.5%	3min45sec
11	2020	Basic Concept	The Four Types of Volcanoes	23,617	52.3%	2min45sec
12	2020	Topical	What Happens When a Plane Flies into Volcanic Ash?	1,984	67.2%	2min33sec
13	2020	Simulation	Formation of a new subduction zone	451	55.1%	3min3sec
14	2020	Topical	Are there volcanoes in Texas?	23,191	59.2%	5min33sec
16	2018	Topical	Drilling to the Mantle	1,905	64%	3min21sec

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17	2018	Topical	Why is the Moon white?	7,425	48.1%	3min54sec
18	2018	Topical	Three Types of Igneous Rocks at Wichita Mountains	1,329	54.1%	5min2sec
19	2018	Topical	Nuclear Bomb and Radioactive Dating - Dating .. Wrong??	807	64.9%	3min27sec
20	2018	Topical	What's happened inside Siberia's Mysterious Craters?	1,958	50.8%	4min24sec
21	2018	Topical	Permian Basin Intro	15,681	59.1%	5min19sec

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* as of 10/03/21

5. Results

To analyze the six selected metrics, we first summarized the number of views of individual Geonews and General GeoEd videos (Table 2; Fig. 2A), as well as their performance after 1 year and 3 years performance. Second, we compared the average views of both groups in the first 15 weeks after their release (Fig. 2B). Next, we compared the average viewed percentage of Geonews videos and General GeoEd videos over their lifetimes (Fig. 2C). Third, we summarized the differences of viewer age and gender for each group (Fig. 3 A and B). The ratio of like/dislike is reported in the text below. Lastly, we compared comments for both groups of videos (Fig. 4). These metrics are as of Oct. 3, 2021.

There are totally about 50,000 views of 12 Geonews video and ~110,000 views of 21 General GeoEd videos by Oct 3, 2021. The average number of views per video in 2018 and 2020 of General GeoEd videos (N=21) is 5,202 and that of Geonews (N=12) is 3,669. The standard deviation for General GeoEd group (SD=6,862) is much larger than that for the Geonews group (SD=1,650). The median views of Geonews videos is ~3,426, more than that of General GeoEd videos (1,958 views). The maximum views of General GeoEd and Geonews groups are 23,035 and 7,117 respectively, and the minimum views are 335 and 1,287 respectively. There are three General GeoEd videos with 15,000 to 25,000 views respectively, which strongly influences the group mean and standard deviation (Table 2 and Fig. 2A).

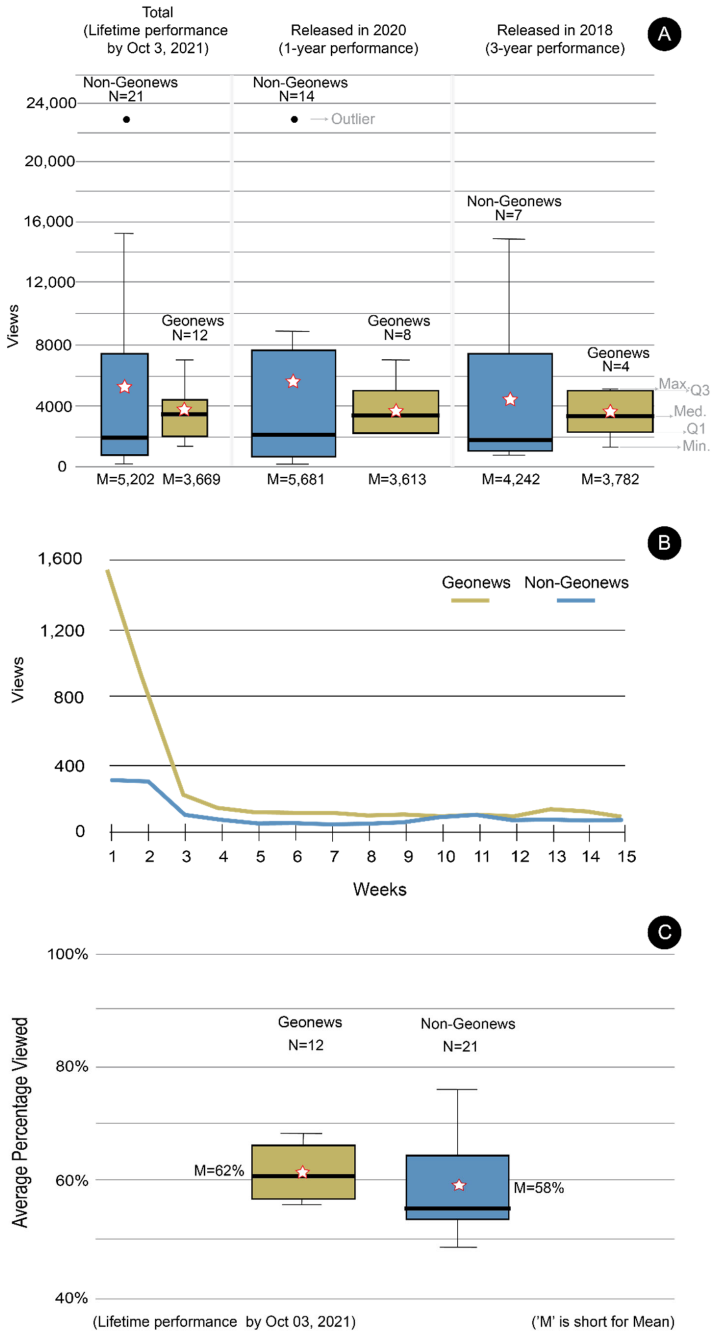
Fig. 2A summarizes the number of views of videos released in 2018 (3-year lifetime) and 2020 (1-year lifetime) separately; data for each video is in Table 2. The mean of views for General GeoEd videos released in 2018 (~4,243) is greater than that of 2018 Geonews videos (~3,782). The standard deviation of 2018 General GeoEd videos is 5,126 while that of Geonews videos is 1,438. Moreover, for General GeoEd videos released in 2020, the average number of views is 5,681 (SD = 7,537). Geonews videos released in 2020, on the other hand, have a slightly smaller mean (3,613 views) and a much smaller standard deviation (1,744).

Second, to understand how the timeliness of Geonews videos affects viewer interest and how this differs from General GeoEd videos, we compared the weekly views of the two groups over the first 15 weeks after their release on YouTube (Fig. 2B). The results show that, on average, about 42% of total views of Geonews videos occurred in the first week after release (1,563 of 3,669). About 72% of views occurred in the first two weeks (2,646 of 3,669) and approximately 78% in the first three weeks (2,880 of 3,669). Geonews group views in the first 15 weeks averages about 82% of the total (3,011 of 3,669). In comparison, General GeoEd videos average only 272 views in the first week of their release, only 5% of their total views. The number of first three-week views on average is 609 views, about 12% of the average total. In the first 15 weeks, General GeoEd group get 26% of the total views over their 1-3 year "lifetimes". This difference is remarkable!

In addition to analyzing views, we compared the average length of views of both groups on YouTube (Fig. 2C). The average percentage viewed of Geonews video is 62±4%, which is slightly longer and more stable than that of General GeoEd videos (mean=58±8%). The maximum average percentage viewed of individual Geonews and General GeoEd videos is 68% and 76.5% respectively, and the minima are 57% and 48%. The median average percentage viewed of Geonews videos is 61%, slightly higher than that of General GeoEd videos (55%).

Furthermore, to better understand the features of YouTube audiences of Geonews and General GeoEd videos, we studied viewer age and gender metrics (Fig. 3A and 3B). Most Geonews and General GeoEd viewers are above 65 years old (41.6% and 47.8%, respectively) but this may be partly skewed by the demographics of the scientific societies where we advertise our videos (GSA, AGU, Sigma Xi, and AAAS). However, the second most important age group for the two video groups differ. Geonews videos got significantly more views from younger YouTube users. Young adults (25 to 44 years old) provide 36% of all viewers of Geonews videos, whereas the second biggest viewer group of General GeoEd videos are 45 to 64 years old. Both video groups got little interest from viewers younger than 25 years old (Geonews: 3.8% and General GeoEd: 4.3%). In terms of gender, most viewers of both video groups are male, but Geonews video viewers include more females. For Geonews videos, almost 20% of viewers are female compared to 10% for General GeoEd videos. It is not possible to extract ethnicity information from YouTube data.

In addition, the ratio of like/dislike for Geonews videos is 98% (total like = 998, N=12) while that for General GeoEd videos is 95% (total like =1968, N=21) by Oct 3, 2021. The small difference may not be significant.


A
Total
(Lifetime performance
by Oct 3, 2021)
Released in 2020
(1-year performance)
Released in 2018
(3-year performance)
Non-Geonews
N=21
Non-Geonews
N=14
Outlier
Non-Geonews
N=7
Geonews
N=12
Geonews
N=8
Geonews
N=4
Views
24,000
20,000
16,000
12,000
8000
4000
0
Max.
Q3
Med.
Q1
Min.
M=5,202
M=3,669
M=5,681
M=3,613
M=4,242
M=3,782
B
Geonews
Non-Geonews
Views
1,600
1,200
800
400
0
1
2
3
4
5
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7
8
9
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11
12
13
14
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Weeks
C
Average Percentage Viewed
100%
80%
60%
40%
Geonews
N=12
Non-Geonews
N=21
M=62%
M=58%
(Lifetime performance by Oct 03, 2021)
('M' is short for Mean)

Figure 2. Comparison of views and average percentage viewed of Geonews and General GeoEd videos. (A) Views of Geonews and General GeoEd videos in lifetime, 1 year and 3 years. (B) Average views of Geonews videos and General GeoEd videos over first 15 weeks following posting on YouTube. (C) Average view percentage of Geonews videos and General GeoEd videos.

~~Furthermore, to better understand the features of YouTube audiences of Geonews and General GeoEd videos, we studied viewer age and gender metrics (Fig. 3A and 3B). Most Geonews and General GeoEd viewers are above 65 years old (41.6% and 47.8%, respectively) but this may be partly skewed by the demographics of the scientific societies where we advertise our videos (GSA, AGU, Sigma Xi, and AAAS). However, the second most important age group for the two video groups differ. Geonews videos got significantly more views from younger YouTube users. Young adults (25 to 44 years old) provide 36% of all viewers of Geonews videos, whereas the second biggest viewer group of General GeoEd videos are 45 to 64 years old. Both video groups got little interest from viewers younger than 25 years old (Geonews: 3.8% and General GeoEd: 4.3%). In terms of gender, most viewers of both video groups are male, but Geonews video viewers include more females. For Geonews videos, almost 20% of viewers are female compared to 10% for General GeoEd videos. It is not possible to extract ethnicity information from YouTube data.~~

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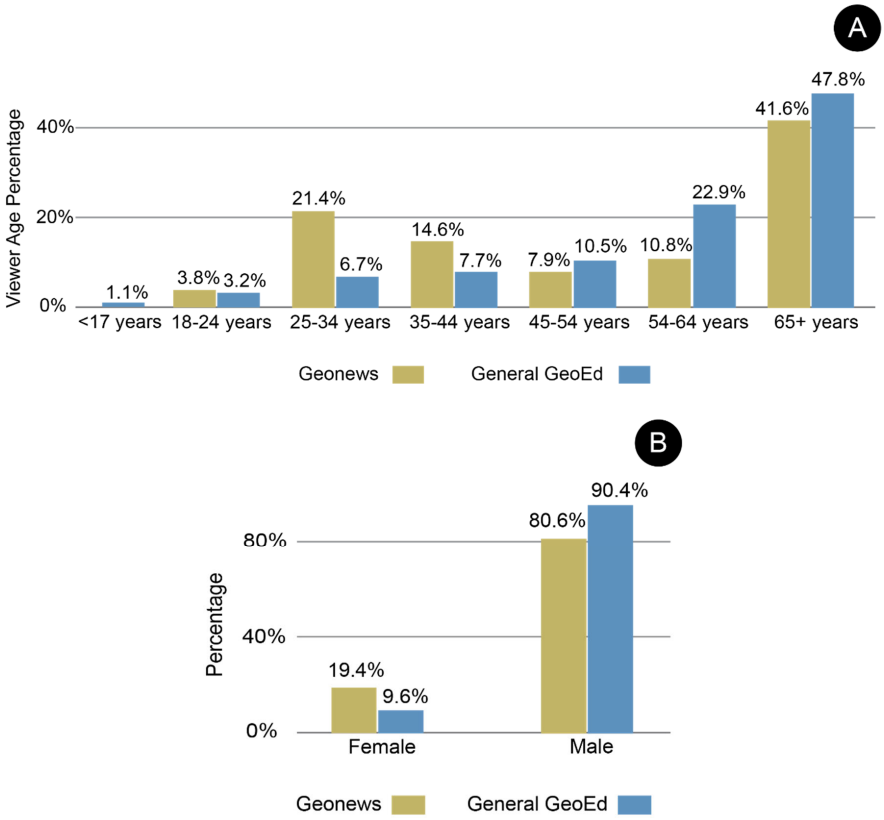

Figure 3. Histogram of viewer ages (A) and gender (B) of Geonews and General GeoEd videos. The data is from 167,000 views of 33 YouTube videos by 10/03/2021 (~50,000 views of 12 Geonews video, ~110,000 views of 21 General GeoEd videos).

Lastly, we summarized the comments (N=222) of Geonews and General GeoEd videos into 5 classes (Fig. 4): Meaningful dialogue, positive feedback, negative emotions, distrust, and other comments. From the past research of public understanding of science as well as learning engagement (Irwin and Michael, 2003; Michael, 2009; Dunn, 2013; Welbourne and Grant, 2016; Carmichael et al., 2018; Dubovi and Tabak, 2020), meaningful dialogue can involve personal experiences and observations (e.g. I live here and see.., I felt three quakes at home now I know why.., etc.), actively sharing relevant information, requesting more information (e.g. references or more videos on relevant topics), giving advice for improvement (e.g. comments on video or audio quality; correcting pronunciations or clarify some terms), arguing about science, requesting to reuse videos for educational purposes. Positive feedback includes gratitude and applause for the video design. (Allum et al, 2008; Dubovi and Tabak, 2020). Negative comments show

fear, anger or confusion (Allum et al, 2008). The distrust category expresses their distrust about news sources or biased conclusions due to funding sources. Other comments include advertisements, harassment, or irrelevant comments, etc. As of early October, 2021, there were 73 comments for Geonews videos (~6.1 comments/video on average, SD=~4.4) and 149 comments for General GeoEd videos (, ~7.1 comments/video on average, SD=~8.4). The number of comments for Geonews videos are more evenly distributed while General GeoEd videos have some with many comments (e.g. the General GeoEd video 'Are there volcanoes in Texas?' has 37 comments.). We found that more meaningful dialogue~~s~~ happened in response to Geonews videos than to General GeoEd videos (Fig. 4). Also, people who leave their comments under Geonews videos tend to share more about their personal experience and feelings, share more details, write longer comments (can be several paragraphs), and share their knowledge (such as the pronunciation of local names, what they know about the event, or time of the event, etc.).

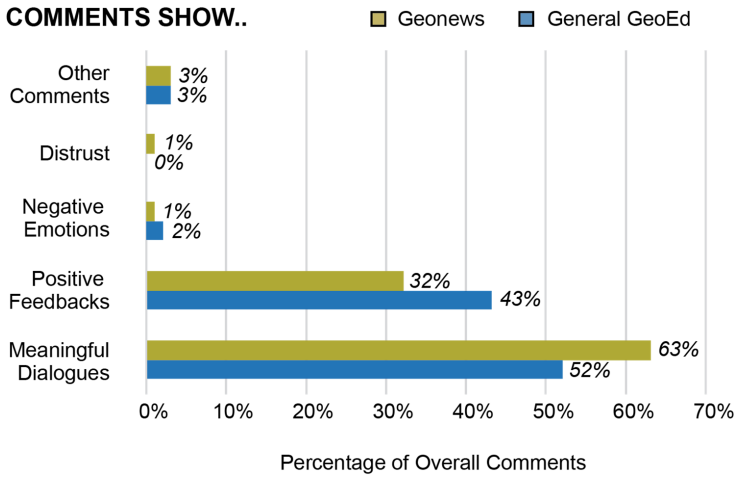

Figure 4. Comparison of comments about Geonews videos (N=73) and General GeoEd videos (N=149). Datum as of 10/03/2021. All the values are rounded to the nearest ~~one~~integer. See text for detailed explanation.

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6. Discussion

To understand if and how timely natural hazard videos are useful for engaging YouTube viewers to learn more about Earth processes and communicate with geoscientists, we analyzed and compared six metrics of Geonews and General GeoEd videos that we made and posted in 2018 and 2020. The results show that Geonews videos more consistently gain views compared to General GeoEd videos, which are much more variably attractive to the YouTube audience (Fig 2 and 3). In addition, Geonews videos have a slightly higher ratio of like/dislike than General GeoEd videos. These results indicate that the YouTube audience is

interested in Geonews and the way it explains Earth processes. Geonews videos attracted audience more steadily than General GeoEd videos, but some General GeoEd topics can be much more popular than Geonews videos. These data also indicate that Geonews videos may be useful in engaging younger and more diverse YouTube audiences than General GeoEd video, however, the potential of growth of views of the popular General GeoEd videos in the long-term is much higher than the Geonews videos (Fig 3).

One result that is very clear is that most views of Geonews videos happen in the first few weeks after the event (Figure 2B). About 82% of total views of Geonews videos occur within the first 3 weeks after release on YouTube, remarkably different from General GeoEd videos (12% of "lifetime" views in first 3 weeks). There is a big drop of views in Geonews videos after the initial 3 weeks; viewers are less likely to watch them after the 'golden period'. This may be related to audience interest but also can be influenced by the design of search engine or recommendation algorithm of YouTube. This needs further work to confirm. Regardless of the reasons, our data shows that Geonews videos engage the YouTube audiences less after the first three weeks. Also, ~~At present, our team needs about 2 weeks (4-18 days; mean = 13.5 days) to create a Geonews video (Table 2A). No significant relationship between release speed and views is found ($R = 0.12$, with $R^2=0.015$), indicating release speed is not the most important factor for Geonews video popularity. In spite of this, considering the timely nature of Geonews videos, faster release is recommended. This will be difficult to accomplish in an academic institution because of other obligations and little funding but could be accomplished with additional funding or at a government agency, scientific society, or private news organization.~~

~~T~~the 12 Geonews videos occurred in regions that include the USA, Mexico, Indonesia and Turkey-Greek areas.~~-~~ Viewers in these regions may be more interested in these videos than people living outside these regions.

Moreover, t~~T~~he data shows that Geonews videos reach younger and more diverse audiences, at least in terms of gender, than do General GeoEd videos (Fig. 3). An important demographic group that Geonews engaged better are YouTube users in the 25 to 44 years age old range. The more balanced gender and age distribution that Geonews videos attract reflects its potential to reach a younger and more diverse audience. It is hard to determine why higher percentage of younger and female users were reached by Geonews videos than the General GeoEd videos. We suspect it may be relevant to how different ages of people access to news. Younger generations may use YouTube as their major source to watch news. ~~The regions of the 12 Geonews videos includes US, Mexico, Indonesia and Turkey-Greek area.~~ The Pew statistics (2021) shows that 95% of US young adults (18 to 29 years old ~~year old~~) ~~make~~ routinely use ~~of~~ YouTube (Statista, 2020). The time that young adults spend on YouTube has increased continuously over the past few years (Kaul et al., 2020). Survey results from Wissenschaft (2018) for~~in~~ Germany shows that 42% of 14- to 29-year-olds use YouTube frequently or very frequently to inform themselves about science. This~~ese~~ evidence shows that YouTube plays an increasingly important role in the learning habits of today's young people (Boy et al., 2020). Kaul et al. (2020) argued that if environmental science communicators are

serious in their efforts to reach young people, new strategies based on YouTube need to be devised. The results of this study support these conclusions. Nearly half of the audience for Geonews YouTube videos viewers are young to mid-life adults (ages 19-44 account for about 48% of total viewers).

~~To find the answer, further research is required.~~

In addition, our analysis of comments shows that meaningful dialogue occurred more often with Geonews videos (63%) than with General GeoEd videos (52%) (Fig. 4). Although the data in this work is limited (222 comments from 160k views) and the commenting audience members may not be representative of their communities (see Sec. 7 Limitations), we see users living near the event leaving comments on about half of the Geonews videos in this study (even Geonews videos with fewer views, e.g. Mentone, TX earthquake and Aegean Sea Earthquake). These comments involve feelings, thoughts, experiences and lay knowledge about the events. From analyzing these comments, we tentatively conclude that people living in the region affected by the event are more likely to leave comments on Geonews videos. A possible explain for this may be related to the difference between the "Publics-in-General" and "Publics-in-Particular" (Michael, 2009) as well as the high level of the 'lay local' knowledge of viewers who live in the affected region (Allum et al., 2008). Research shows that when the public tries to understand science, they also regard themselves as one of these "publics" (Irwin and Michael, 2003; Lacchia et al., 2020). Local people may think that a nearby event differentiates them from others because they know more about it as well as being more affected by it. Such 'lay local' knowledge may increase their willingness, confidence and motivation to share and communicate on YouTube (Dunn, 2013; Welbourne and Grant, 2016; Carmichael et al., 2018; Dubovi and Tabak, 2020). This may be responsible for the higher possibility of having longer and more detailed descriptions of their personal experiences under Geonews videos. Additional evidence supporting this hypothesis is that most comments on Geonews videos concern the event rather than about video design which comprise a larger proportion of comments on General GeoEd videos. This tendency of people in the affected region to want to share personal thoughts and experiences about a timely event has been observed for Twitter and Facebook (e.g. Lacassin et al., 2020; Hugelius et al., 2017). We discuss the differences of comments among YouTube, Twitter and Facebook in later sections.

~~In addition, our analysis of comments shows that meaningful dialogue occurred more often with Geonews videos (63%) than with General GeoEd videos (52%) (Fig. 4). Although the data in this work is limited (222 comments from to 160k views) and the commentinged audience members may not beprobably cannot representative of for their communitiesy population (see Limitations section), we see users living at the events area leaving comments on about half of the Geonews videos in this study (even the Geonews videos with not so many views, e.g. Mentone, TX earthquake and Aegean Sea Earthquake). These comments involve feelings, thoughts, experience and lay knowledge about the events. More comments on Geonews videos explore feelings, thoughts and knowledge about the event, indicating deeper engagement (Dunn, 2013; Welbourne and Grant, 2016; Carmichael et al., 2018; Dubovi and Tabak, 2020; Dubovi and Tabak, 2020). From analyzing thesethe analysis of comments, we tentatively conclude that people living in the~~

region affected by the event are more likelyhave some tendency to leave some comments on Geonews videosare most engaged. A possible explain for this may be related to the difference between the "Publics-in-General" and "Publics-in-Particular" (Michael, 2009) as well as the high level of the ir 'lay local' knowledge of viewers who live in the region affected by the event (Allum et al., 2008). Research has found that when the public tries to understand science, they also regard themselves as one of these "publics" (Irwin and Michael, 2003; Lacchia et al., 2020). Local people may think that a nearby event differentiates them from others because they know more about it as well as being more affected by it. Such 'lay local' knowledge may increases their willingness, confidence and motivation to share and communicate with the video makers (Dunn, 2013; Welbourne and Grant, 2016; Carmichael et al., 2018; Dubovi and Tabak, 2020)communicate with experts and learn from the video. This may be responsible for the higher possibility of having longer and more detailed description comments of their personal experiences under Geonews videos. Additional evidence supporting this hypothesis is that most comments on Geonews videos are related to the event rather than about video design which comprise a larger proportion of comments about General GeoEd videos. This difference may reflect the greater 'lay local' knowledge about the event. SuchThis tendency of people in the affected region to want to share(discussing personal thoughts and experiences about a timely event) has been largely observed forseen in Twitter and Facebook. We , and we will discuss the differences of comments among YouTube, Twitter and Facebook in at the later sections.

More discussion about geographic distribution (data) and topic differences. Most viewed are local people and among Geonews videos, US events got more views.

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A major limitation of our method is the number of assessed videos is limited to those posted on the UTD GSS YouTube channel (with about 2,200 subscribers by Oct 2021). The effect of channel popularity is not tested in this research. The bigger and more popular channels (such as NASA) and smaller and less popular channels (such as new channels with very few subscribers) may have different results if they undertook a similar experiment. However, we are unaware of any other YouTube channel that makes a range of GeoEd videos that are comparable to those of UTD Geoscience Studios and also makes something like Geonews videos (IRIS recently started a new channel and released some Geonews-like videos, named 'IRIS Teachable Moments', but it is separate from their major channel. We have no access to the data for individual videos, therefore, we did not incorporate this in our analysis). In addition, although the General GeoEd videos have various designs and topics, the number of General GeoEd videos as a control group may not adequately capture YouTube audience interest. However, with a combined method of quantitative and qualitative ways to assess YouTube video design elements, the results provide useful insights into the engagement potential of natural hazard events in the news as an important element of GeoEd videos. Furthermore, we know that both Geonews and General GeoEd videos are used in some classrooms from anecdotal feedback from K-12 teachers in STAT-CAST and mini-CAST meetings as well as from YouTube comments and comments from colleagues. We did not conduct a formal survey to explore the reasons why

~~they used the videos in their classrooms but it may be because the videos provide supplementary and timely information for especially undergraduate geoscience classes. We are unable to distinguish views in formal education from public views. This creates an uncertainty, that is, the extent to which both groups of videos are viewed in the classroom by geoscience classes and at home by geoscientists vs. by the general public. Furthermore, many General GeoEd videos are designed for students and teaching purposes, whereas Geonews videos are designed with non-geoscientists in mind (mostly for science outreach and improving public understanding of geosciences). We do not know how to resolve this uncertainty via YouTube analysis, surveying in comments rarely gave good responses.~~

~~Another limitation concerns the emotional impact of Geonews videos. Timely information about hazards may trigger fear, anger, distrust and other negative attitudes and feelings. This is seen in about 2% of the YouTube comments. Video makers may need to use more time to reply to comments and share more information in an effort to respond to negative comments (Takahashi et al., 2015; Jones, 2020; Lacassin et al., 2020). It may be useful to share some resilience knowledge (Van Loon et al., 2020) or hazard simulation games (e.g. Kerlow et al., 2020; Hawthorn et al., 2021) that can better prepare them in a casual environment.~~

~~We are very encouraged by these results. Geonews videos are easier to create than General GeoEd videos. Greater ease of creation reflects more standardized video design that takes advantage of plentiful visual materials and scientific information available online and digests these for the public and beginning students. The scope of Geonews videos is easily defined and restricted, therefore, the narrative is easier to create and review. The richness of freely available online visual materials about the events also ease the production process. In contrast, because General GeoEd videos are about a very broad range of topics, creating these follows no standardized design and there is no incentive for keeping them short and posting them quickly, these narratives take longer to research and write with more discussion items that need to be considered. As a result, the production time for General GeoEd videos is invariably longer than for Geonews videos (typically not in days or weeks).~~

~~7. Implications about Universal Video Design~~

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6.1. How reliable are the YouTube Analytics data and is it ethical to use the data?

The reliability of YouTube metrics data is largely determined by how YouTube (and its parent company Google) gets the data. The video watching and channel metrics, such as the number of views, are collected via the YouTube platform. The data is relatively accurate, especially considering the magnitude of the data and partially reflects YouTube efforts to correct these (Talreja, 2021). Some concern is given to the reliability of gender and age data. When users register a Google account, they are asked for basic demographic information such as name, age, and gender. Since there is no way to verify the accuracy of this information, users could provide false information. User information is available via YouTube Analytics to those logged into Google services including Google Chrome Browser and YouTube. Google

will also predict users' age and gender utilizing advertisement clicking behaviors and cookies. Google does not publish the accuracy of their age or gender data, so we can only discuss its accuracy from indirect evidence. First, some studies used demographic data from YouTube to train models predict the users' demographic features, with good results (e.g. Ulges et al, 2013). Second, Tschantz et al (2018) did a survey-based research on the accuracy of Google age and gender data inferences and concluded that Google accurately estimates the data. Therefore, considering the magnitude and period of the data collection, the population nature of the dataset (not samples), we suggest that the results we got from the YouTube Analytics data in this study are reasonably reliable.

Based on past discussions of social media research ethics (Association of Internet Researchers, 2012; Townsend and Wallace, 2016; Woodfield, 2017; Golder et al, 2017; Legewie and Nassauer, 2018), the ethics of Geonews project using YouTube Analytics data and comments content analysis are considered in three parts: (1) Informed consent; (2) If the data are public or private; and (3) Is there any potential risk? Informed consents were collected from users when they register for their Google accounts. Although many argue that the consent is just a box to tick in the terms and conditions (e.g. Nature Editorial, 2019), we argue that this consent is adequate for our study since it is a minimal risk project. We use data that are either completely anonymized and aggregated or are voluntarily posted by YouTube users as comments for public view. The risk of harm for using and reporting these data is minor. For these reasons we think that using this data in this study, although without specifically informed consent for our study, is ethical.

6.2. How do comments differ between Twitter, Facebook and YouTube?

Social media platforms encourage participation, sharing, interaction and collaboration using online technologies, but have different styles and foci (Pavelle and Wikinson, 2020). Common types of social media include blogs and microblogs (e.g. Twitter), content communities (e.g. YouTube), and social networking (e.g. Facebook). Some argue that because YouTube is limited to video content (Zuckerberg et al., 2012), most of the comment threads and discussions can be ignored by other users who are interested in the videos. It is true that most discussion threads on YouTube are not as detailed as those on Twitter or Facebook and that posting rates are also relatively low (Moran et al., 2011). Users who leave comments on YouTube videos may not expect feedback from other YouTube viewers but they may ask questions to the video uploaders. This is seen in our study too. Therefore, scientists posting YouTube videos are encouraged to pay more attention to answering YouTube comments because it is possibly to establish emotional and mental connections in this way (Pavelle and Wikinson, 2020; Smith, 2020).

6.3. How are videos and Geonews videos found on YouTube?

We advertise our videos via on-line communities of three scientific societies: The Geological Society of America, the American Geophysical Union, and Sigma Xi. These audiences are older and more knowledgeable about Earth processes than the general public. We advertise our videos to the general public using what YouTube offers. In general, YouTube videos can be found by two ways, search and recommendations (Landrum et al., 2021). Search results are largely determined by videos' relevance,

historical views and likes (Zhou et al., 2010). On the other hand, the YouTube recommendation system adopts machine learning models (Covington et al., 2016; Beautemps and Bresges, 2021). There are several special features of machine learning models that relevant. First, the models consider the upload time and time-dependant popularity; Geonews videos benefit from this feature. Second, the models try to match user language and video language. This may explain why Geonews videos outside US get fewer views, even though some events are important (e.g. Mexico earthquake 2020 or Aegean Sea earthquake 2020). Third, the watching time and percentage of views are important factors reflecting engagement in the YouTube recommendation models. Therefore, the higher average percentage of views Geonews videos may also make them more recommended than general GeoEd videos.

Aside from YouTube's video searching and recommendation system, the popularity of a video also depends on its content and content-agnostic factors (Borghol et al., 2012; Figueiredo et al., 2014; Velho and Barata, 2020). Content factors include the stylistic and informational characteristics of a video (e.g. thumbnail, topic, design). Content-agnostic factors reflect the popularity of the creator or partner's social network or video upload date and time (Khan and Vong, 2014). One content-agnostic strategy is to join with YouTube influencers to help promote videos (Geipel, 2018; Nafees et al., 2021) but the results for individual projects may vary (Donhauser and Beck, 2021). Research also shows that, compared to the YouTube algorithm and content-agnostic factors, content factors are most influential for the popularity of a science video (Figueiredo et al., 2014).

Geonews videos are designed to catch the momentum of timely natural hazards to engage the public. Therefore, we expected that the views of Geonews videos would correlate with timeliness of video after the event. However, no significant relationship between release speed and views is found ($R = 0.12$, with $R^2=0.015$), which is unexpected. At present, our team needs about 2 weeks (4-18 days; mean = 13.5 days) to create a Geonews video (Table 2A). The most popular videos are posted within a week after the event. We suspect that our release speed is too slow to catch viewers' peak interest and that a faster release after the event would receive more views.

Also, the popularity of Geonews videos seems to be influenced by geography. YouTube provides some geographic data for videos but 50 - 95 % of the geographic data for where viewers are is missing or inaccessible. Thus, we do not have enough data to conduct a robust investigation of the geographic distribution of audiences for each Geonews video. However, our results (Table 2) show that 5 of the 6 most viewed Geonews videos (>4,000 views) are US events. Events of other Geonews videos occurred in Indonesia, Philippines, Turkey-Greece, and Mexico, with native languages that are not English. Thus, we suspect that a geographic feature of Geonews audiences may be at least partially related to the language feature of the search and recommendation algorithms used by YouTube as discussed in previous paragraphs. Also, although we add English closed-captions, non-English speakers probably have great difficulty to follow the Geonews videos. This reinforces the needs of having multiple language versions of

Geonews videos, and encourages local geoscience teams to create Geonews type videos to engage local audiences.

Lastly, we expect that the significance and type of the events will affect the popularity of Geonews videos. Although the significance of an event to the public is related to damage and casualties as well as the magnitude of the event, as well as the population affected by the event it is still hard to compare the significance in the public mind of different types of geohazard events. Thus, the results of this work are not enough to estimate the correlation between significance of an event and the popularity of the Geonews video about it. However, we conclude from Table 2 that more destructive and powerful events near US population centers will be most popular. Due to our limited videos for each type of geohazard, we cannot tell what types of geohazards are more popular for what audiences (e.g. previous experience of hazards or geographic distributions), but this can be an interesting future research direction.

7. Limitations

A major limitation of our method is that the number of assessed videos is restricted to those posted on the UTD GSS YouTube channel (with about 2,500 subscribers by Feb. 2022). The effect of channel popularity is not tested in this research. More popular channels (such as NASA) and smaller and less popular channels (such as new channels with very few subscribers) may have different results if they undertook a similar experiment. However, we are unaware of any other YouTube channel that makes a range of GeoEd videos comparable to those of UTD Geoscience Studios and also makes something like Geonews videos (IRIS recently started a new channel and released some Geonews-like videos, named 'IRIS Teachable Moments', but it is separate from their major channel. We have no access to the data for individual videos, therefore, we did not incorporate this in our analysis.) In addition, although the General GeoEd videos have various designs and topics, the number of General GeoEd videos as a control group may not adequately capture YouTube audience interest. However, with a combined method of quantitative and qualitative ways to assess YouTube video design elements, the results provide useful insights into the engagement potential of short, timely videos about natural hazard events in the news as an important element of GeoEd videos. Furthermore, the emotional impact of Geonews videos is another concern. Timely information about hazards may trigger fear, anger, distrust and other negative attitudes and feelings. This is seen in about 2% of the YouTube comments. Video makers may need to use more time to reply to comments and share more information in an effort to respond to negative comments (Takahashi et al., 2015; Jones, 2020; Lacassin et al., 2020). It may be useful to share some resilience knowledge (Van Loon et al., 2020) or hazard simulation games (e.g. Kerlow et al., 2020) to help these viewers.

Another limitation is that there are few comments considering the views (222 comments for 160k views, ~0.1% comment rate) and the numbers of comments for each video varies (0 to 37 comments). It is hard to argue that the comments on the videos are representative of the viewing audience. As discussed above, we suspect that the audience near the event may be especially motivated to leave comments about their

personal experiences or about the events. A more in-depth method (survey or interview of commented audiences) is needed to better understand audience motivations, which is an interesting future research topic.

8. Conclusions

Our study shows that timely videos about Earth events in the news are useful for engaging the public and show promise for reaching younger and more diverse audiences. Results of this research suggests that short, timely videos about natural hazards and events especially engage people who live near where it occurs, motivating them to learn and discuss the geoscience behind these events. Although Geonews videos might have fewer total views than some popular General GeoEd videos, Geonews videos are especially good at starting meaningful dialogue and engage YouTube audiences for several weeks after the event happens. The popularity of Geonews videos has a geographic aspect that can be enhanced by adding pertinent languages. We encourage others to add captions or voice-over to any of our posted videos. There are opportunities for geoscientists around the world to create Geonews videos focusing on regional events using local languages as well as translating Geonews videos. Moreover, considering the production efficiency compared to other GeoEd videos, engaging audiences with Geonews videos on YouTube is a very promising strategy. Geoscientists can create YouTube Geonews videos to partially fulfill their needs of delivering scientific information, but taking time to reply to YouTube comments (not only Geonews but all kinds of GeoEd videos) could also be important for meaningfully communicating topical geoscience to the public (just like some scientists do with Twitter, e.g. Lacassin et al., 2020; Pavelle and Wilkinson, 2020). Our findings about Geonews videos may encourage other types of timely event-based educational videos as well.

~~**6.1. HowHow reliablee are the YouTube data and is it how moralalto to usee it for research?**~~

~~(and its parent company Google) numberthe se Some is reliability dataare asked forway to y theaccuracy ofisformationcould provide false informationUviato those king~~

~~OGoogle doesdid not publish the quantitative data of the age or gender, such as error rate, so all the evidence is indirect. oSecond, thelyeecesarWhen you use our services, you're trusting us with your information. We understand this is a big responsibility and work hard to protect your information and put you in control. Some data are more reliable than others. However, we have already considered the not so reliable data.An interesting question is the optimum length of Geonews videos; It seems shorter Geonews videos have higher viewer percentage than longer ones. We tested for both video groups if there is any relationship between various parameters including gender, age, video length, lifetime views, and average percentage viewed. The results reveal a possible relationship between video length and average percentage viewed, with a strong negative relationship between video length and percentage viewed for Geonews videos (R = -.72 with R2= 0.5, N=12) (Figure 5). In contrast, the correlation coefficient of General GeoEd~~

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videos is also negative but much weaker (R = -.32 with R2= 0.1, N=21). Tao et al (2014) 's work shows that General GeoEd type videos (esp. lecture videos) also follows the rule that shorter videos (less than 6 minutes, especially less than 3 minutes) have a larger watch percentage. (However, the evidence for Geonews videos does match their suggestion: 'shorter videos are more engaging'. This mismatch can reflect the fact that our design of General GeoEd videos are never similar to traditional lecture-type. Although the reason is unclear, the evidence shows that, compared to General GeoEd videos, the view percentage of Geonews videos are more negatively correlated to video length.

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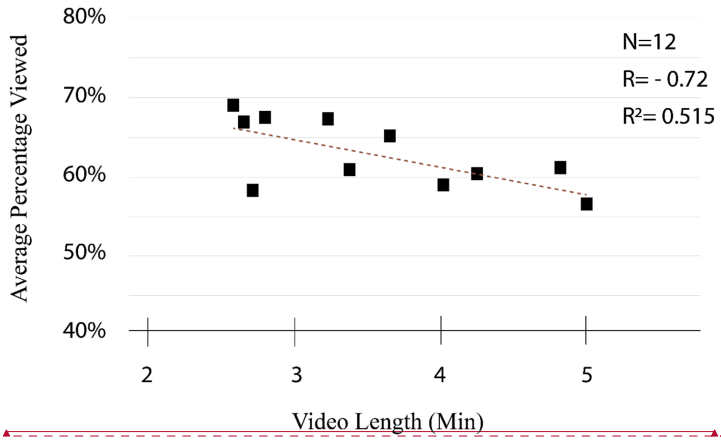

Figure 5. The plot of 'average percentage viewed vs. length' for Geonews videos.

6.2. How do comments are different amongbetween Twitter, Facebook and YouTube?

Social media platforms are mainly aboutencourage participation, sharing, interaction and collaboration using online technologies, but havestill has different styles and foci uses (Pavelle and Wikinson, 2020). Common types of social media include blogs and microblogs (e.g. Twitter), content communities (e.g. YouTube), and social networking (e.g. Facebook). Some of the social media focus on enhancing conversations: Twitter enables fast conversations among users while Facebook supports deep conversations among users with a variety of features. Some argue that, comparing to the other social media such as Facebook and Twitter, because YouTube is limited to video content (Zuckerberg et al., 2012). Also, unlike Facebook or Twitter, most of the comment threads and discussions can be easily ignored by other users since their focus is probablywho are interested in the videos. It is true that most threads on YouTube for particular discussion is commonlyare not as long as those on Twitter or Facebook and thate posting rates are relatively low (Moran et al., 2011). Users who leaveleft comments on YouTube videos are mostly just for sharing their personal ideas or experiences without expectation of feedback from other YouTube

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audiencesviewers but they may ask questions to the video uploaders of the video, but may want feedback from the video uploaders, especially educational videos. ourThis is support by our research results too, many of the comments under General GeoEd videos and Geonews videos are merely sharing their personal experiences and show their gratitude. As shown previously (figure 4), almost all the comments and questions are for us (the video producers), not for other YouTube audiences. Therefore, science communicators on YouTube shouldare encouraged to pay more attention to answeringreply the YouTube comments because , although not like Twitter or Facebook that more focuses on individuals, using comments YouTube communicators can also possibly to establish emotional and mental connections by reply commentsin this way (Pavelle and Wikinson, 2020) and this communication can even be done with YouTube videos (Smith, 2020).We adveriseadvertise our videos via on-line communities of three scientific societies: Tthe Geological Society of America, the American Geophysical Union, and Sigma Xi. These audiences are older and more knowledgeable about Earth processes than the general public. We have no way to advertise our videos to the general public using whatbeyond what YouTube offers. .: benefit fromisfewerimportantaresreflectingmake them (Beautemps and Bresges, 2021)from Khan OnesRedcar video afterunThe most posted after the eventWviewers' peak interest and that aafter the event would popularity- %where viewers arerobustof the Eother iny-cewiththat aedy and type an to the publicand casualties as well as e in the public mindpowerfulnear population centers be most popular.Due to our limited videos for each type of geohazards, it is hard to discuss, we cannot tell what types of geohazards are more popular for what audiences (e.g. previous experience of hazards or geographic distributions), but this can be an interesting future research direction to improve Geonews videos. at theM)short, timely videos about viewers

Another limitation is thatLastly, there are few comments are relatively few considering the views (222 comments for 160k views, ~0.1% comment rate) and the the numbers of comments for each video variesd largely (0 to 37 comments). ITherefore, it is hard to argue that the audiences left comments on the videos are representative for the whole populationof the viewing audience and the evidence is not enough for discussing if the pattern shown in this work (figure 4) will keep happen in the future Geonews or General GeoEd videos. If the pattern found in this work is consistent for the UTD Geoscience Studio channel and if it is meaningful for other channels need further research to confirm. We suspect that since Geonews will beare more event-based, the us especially the event-relevant audience near the event may be especially motivatedhave the tendency to leave comments about their personal experiences or about the events, whereas the General GeoEd videos will have more comments and questions about the teaching topics. AThis needs to a more in-depth method (survey or interview of commented audiences) is needed to better understand theiraudience motivations, which can beis an interesting future research topic.

6.3 Limitations

~~Limitations, data reliability, how data comes, how moral it is, comments analysis representing the large group? Ethics of using the YouTube data (Townsend and Wallace, 2016).~~

~~A major limitation of our method is the number of assessed videos is limited to those posted on the UTD GSS YouTube channel (with about 2,200 subscribers by Oct 2021). The effect of channel popularity is not tested in this research. The bigger and more popular channels (such as NASA) and smaller and less popular channels (such as new channels with very few subscribers) may have different results if they undertook a similar experiment. However, we are unaware of any other YouTube channel that makes a range of GeoEd videos that are comparable to those of UTD Geoscience Studios and also makes something like Geonews videos (IRIS recently started a new channel and released some Geonews-like videos, named 'IRIS Teachable Moments', but it is separate from their major channel. We have no access to the data for individual videos, therefore, we did not incorporate this in our analysis). In addition, although the General GeoEd videos have various designs and topics, the number of General GeoEd videos as a control group may not adequately capture YouTube audience interest. However, with a combined method of quantitative and qualitative ways to assess YouTube video design elements, the results provide useful insights into the engagement potential of natural hazard events in the news as an important element of GeoEd videos. Furthermore, we know that both Geonews and General GeoEd videos are used in some classrooms from anecdotal feedback from K-12 teachers in STAT-CAST and mini-CAST meetings as well as from YouTube comments and comments from colleagues. We did not conduct a formal survey to explore the reasons why they used the videos in their classrooms but it may be because the videos provide supplementary and timely information for especially undergraduate geoscience classes. We are unable to distinguish views in formal education from public views. This creates an uncertainty, that is, the extent to which both groups of videos are viewed in the classroom by geoscience classes and at home by geoscientists vs. by the general public. Furthermore, many General GeoEd videos are designed for students and teaching purposes, whereas Geonews videos are designed with non-geoscientists in mind (mostly for science outreach and improving public understanding of geosciences). We do not know how to resolve this uncertainty via YouTube analysis, surveying in comments rarely gave good responses.~~

~~Another limitation concerns the emotional impact of Geonews videos. Timely information about hazards may trigger fear, anger, distrust and other negative attitudes and feelings. This is seen in about 2% of the YouTube comments. Video makers may need to use more time to reply to comments and share more information in an effort to respond to negative comments (Takahashi et al., 2015; Jones, 2020; Lacassin et al., 2020). It may be useful to share some resilience knowledge (Van Loon et al., 2020) or hazard simulation games (e.g. Kerlow et al., 2020; Hawthorn et al., 2021) that can better prepare them in a casual environment.~~

~~Lastly, ethics of using YouTube data for analyzing Geoscience videos in this study is not ideal. The order of magnitude of data, the communication nature, and the speed with which it is made available (approaching real time) make social media a potential tool to revolutionize science communication~~

research. Internet research is very different from traditional research and as such brings about many different ethical challenges. Therefore, debates exit for the ethical issues of social media research. As argued by the Association of Internet Researchers (2012) and Golder et al (2017), the guidelines for internet research cannot be static and each social media project needs an individual ethical assessment. A major ethics concerns of social media research suggested by Townsend and Wallace (2016) include: (1) If the social data is private or public; (2) if the audience give the informed consent; (3) If the data is anonymity; (4) the risk of harm to the users. Current framework to check the ethnics of a particular work mostly includes the procedure for checking individual project (Association of Internet Researchers, 2012; Townsend and Wallace, 2016; Woodfield, 2017). Based on the framework, studies should check terms, conditions and legalities of particular social media platform, privacy and risk of the data, re-use and re-publication. As an extension of the framework, Legewie and Nassauer (2018) examined the online video research (using video data on social media) from informed consent, analytic opportunities, privacy, transparency and the risk of harm. Referencing these two frameworks, the ethics of Geonews project using YouTube Analytics data and comments content analysis are considered in three parts: which has less concerns about identity risk and the regular consent form on YouTube user agreement are given by users when they sign up Google account. The YouTube Analytics data is completely anonymous and the comments data are falling in the domain of public data. The informed consents from users via a general consent of the data when they register the Google Account, which is used for login YouTube too. This consent is offered but for most users it is just a box to tick in the terms and conditions (YouTube,). This consent is not good enough for researchers since most of the users have very little idea about how their data are used (Nature Editorial, 2019), but for our purposes, the YouTube Video Analytics data, such as amount of views and statistics of gender, are completely anonymized and aggregated, and the risk of harm for individual users are very low. The comment data are voluntarily exposed by YouTube users for public and the analyze of the data is anonymized and aggregated too. Therefore, this study with general consent from YouTube users probably, though not ideal, is enough, the risk of harm for using and reporting these data is lower than normal life risks and the privacy is protected via anonymization of the data.

7. How are videos found on YouTube?

YouTube is a highly competitive environment, research on news sharing in social media needs to keep pace with and use the changing media landscape to reach and teach the public (Allum et al, 2008; Welbourne and Grant, 2016; NAS, 2017). Also, we need to better understand how science communicators can best be heard among many competing sources of information and misinformation (Siersdorfer et al., 2010; Illingworth, 2017 and 2018). Some scientists strive to improve their skills and techniques to produce more popular videos on YouTube (Velho and Barata, 2020). In general, YouTube videos can be found by two ways, search and recommendations (Landrum et al., 2021): Individuals who are searching for information, consciously or subconsciously, that aligns with their pre-existing views and likes will find it on the vast platform. YouTube's recommendation system both identifies what is popular to increase popularity and

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considers search and view history of individual users (Zhou et al., 2010). Apparently, words in hashtag, title and descriptions provide important information for the YouTube search engine, thus considerately compose them are important for YouTube users to find videos. On the other hand, YouTube employs an algorithm that determines what viewers see (Covington et al., 2016). This personalized recommendation system is composed of two neural networks, one that first winnows down the massive body of YouTube content to a few hundred videos (i.e., "candidate generation") and then one that ranks those videos based on predicted user engagement from each audience member's history of activity (i.e., "ranking"; Covington et al., 2016). Especially, the newly trained recommendation model adds a new feature considering the upload time and time-dependant popularity. Geonews videos may take more advantage of this new model with consideration of time-dependant popularity feature since it takes the momentum of the timely geohazards. Another recommendation feature is to consider user language and video language. This may explain why Geonews videos outside US (e.g. Mexico earthquake 2020 or Aegean Sea earthquake 2020), even though the events are significant and influential, get relatively less views. Most of the users in non-English native speaking nations may have limited access to current Geonews videos. Making multiple language versions of Geonews videos may be necessary for increase the influence of the video, especially when the topic of the Geonews videos are about events at non-English speaking countries. Furthermore, the watching time and percentage of views has been seen as an important factor for determine engagement in YouTube recommendation system. Therefore, the higher average percentage of views Geonews videos may also be better recommended than general GeoEd videos. General GeoEd videos may get more views from directly search since in long term they can be more functional comparing to Geonews videos.

Aside YouTube's video searching and recommendation system, the popularity of a video also largely depends on its content factors and content-agnostic factors (Borghol et al., 2012; Figueiredo et al., 2014). Content factors include the stylistic and informational characteristics of a video (e.g. topic, narration, animation, tone and length). Content-agnostic factors are external to the video and reflect the popularity of the creator or partner's social network or video upload date and time (Khan and Vong, 2014). YouTube's recommendation system both identifies what is popular to increase popularity and considers search and view history of individual users (Zhou et al., 2010). Among these three, content factors appear to be most informative for the popularity of a science video (Figueiredo et al., 2014). Surely, to ensure a video is searchable, there are three major factors affecting the exposure of videos on YouTube: YouTube Mechanism, features of natural events, and characteristics of audiences.

YouTube Mechanism: Hashtag, title and other factors.

Natural Events: At present, our team needs about 2 weeks (4-18 days; mean = 13.5 days) to create a Geonews video (Table 2A). No significant relationship between release speed and views is found ($R = 0.12$, with $R^2=0.015$), indicating release speed is not the most important factor for Geonews video popularity. In spite of this, considering the timely nature of Geonews videos, faster release is

recommended. This will be difficult to accomplish in an academic institution because of other obligations and little funding but could be accomplished with additional funding or at a government agency, scientific society, or private news organization.Our results show that 5 of 6 most viewed Geonews videos (>4000 views) are US events. The significance of the event (Earthquake Magnitude, Volcanic Explosivity Index, and Tsunami Intensity Scale), Geographic and momentum will affect the pattern, if there is no momentum or geographically feature (non-English speaker, culturally may not influenced by geohazards). Our results show that 5 of 6 most viewed Geonews videos (>4000 views) are US events. Why? It is not the group is not big, but maybe the language barrier and culture barrier. We cannot be sure, the comments are not so many too and not about the events, in comparison, US viewers are more likely to share their experiences about the events. According to Hootsuite and We Are Social, 88 percent of all Indonesian internet users—about 132 million people—actively use YouTube. Other research suggests that up to 47 percent of Indonesians access YouTube every day for about 30 minutes on average. 53 percent of Indonesians use YouTube to look up product information, and 86 percent of Indonesians use it to understand how to use products.

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Audiences: Audience distribution, Credibility, interests, culture (Mexico event are large and damaging but not so many views, four comments, two comments are mostly about risk preparation and one comment from a geological major).

88. Conclusions

Timely videos about Earth events in the news are especially useful for engaging the public and show promise for reaching younger and more diverse audiences. Although Geonews videos might have lessfewer total views than some popular General GeoEd videos, Geonews videos are especially good at starting meaningful dialogue and engage YouTube audiences for several weeks after the event happens. The popularity of the Geonews videos has a geographic aspectfeature and can be possibly enhanced by adding diversepertinent languages., This providesing opportunities for gGeoscientists with different backgrounds to create Geonews videos focusing on regional events usingwith local languages, or translating Geonews videos.

Moreover, considering the production efficiency compared to other GeoEd videos, engaging audiences with Geonews videos on YouTube is a very promising strategy. Geonews videos are easier to create than General GeoEd videos. Greater ease of creation reflects more standardized video design that takes advantage of plentiful visual materials and scientific information available online and digests these for the public and beginning students. The scope of Geonews videos is easily defined and restricted, therefore, the narrative is easier to create and review. The richness of freely available online visual materials about the events also ease the production process. In contrast, because General GeoEd videos are about a very broad

range of topics, creating these follows no standardized design and there is no incentive for keeping them short and posting them quickly, these narratives take longer to research and write with more discussion items that need to be considered. As a result, the production time for General GeoEd videos is invariably longer than for Geonews videos (typically not in days or weeks). Therefore, Geonews videos can be easier to be created by geoscientists without much video making experiences.

QLastly, our promising findings about Geonews videos may encourage other types of timely event-based educational videos as well. Results of this research suggests that short, timely videos about natural hazards and events especially engage people connected with the eventwho live near where it occurs, motivating them to learn and discuss about the geoscience behind these events. Geoscientists can create YouTube Geonews videos to partially fulfill their needs of delivering scientific information, but taking time to reply to YouTube comments (not only Geonews but all kinds of GeoEd videos) could also be important for meaningfully communicating topical geoscience to the public (just like some scientists do with Twitter, e.g. Lacassin et al., 2020; Pavelle and Wilkinson, 2020).

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