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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 (denoted Geonews videos) and 21 videos that are not specially about timely geologic topics (denoted 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 the following points: (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; (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 creates opportunities for two-way dialogues about geosciences (Falk and Dierking, 2010; Tong, 2013; 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). 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 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 event-based geoscience educational videos (herein referred to as "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 earlier, 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 dialogue 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 (National Research Council, 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 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-way 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 beginner 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 related to 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 who are 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 min 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 aim 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 attract 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 as well as beginner 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 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 2 billion users every month (Welbourne and Grant, 2015; YouTube, 2021). This audience uses YouTube videos for much more than entertainment; about half of YouTube adults 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, 2020; Tayne et al., 2021; Wang et al., 2022b). 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; Schäfer, 2012; Takahashi 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 University of Texas at Dallas (UTD) Geonews videos are about 3 to 5 min long and were created by geoscience students in the Geoscience Studio at the University of Texas at Dallas (UTD GSS). The GSS team is supervised by Robert 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., 2022b). Geoscience Studios began in 2016, and we began making Geonews videos in 2018. All Geonews videos have a similar format (Fig. 1): they (1) start with a simple introduction of the event, including location and date; (2) explain the 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.

The workflow of making a Geonews video begins with (1) someone proposing 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 Robert Stern to collect information, images, and videos on the topic. (3) A 360–600-word narrative is written by the production leader and Robert Stern, setting the length and pace for a 3–5 min video. (4) The narrative is recorded (the narrator is also a UTD student), and graphics and background music are 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 online scientific communities such as the Geological Society of America (GSA), the American Geophysical Union (AGU), Sigma Xi, and the Amer-

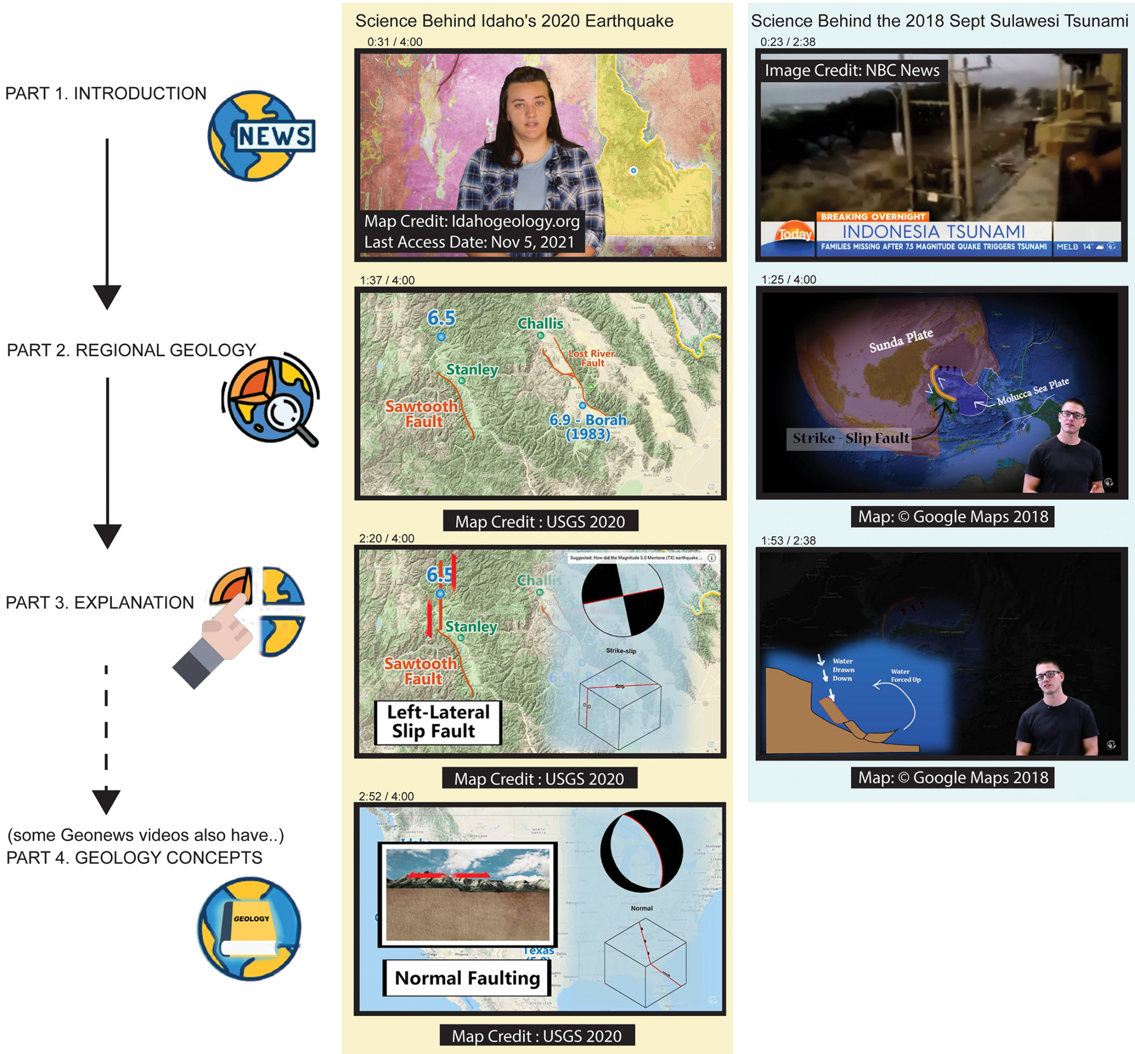

Figure 1. Design framework of Geonews videos and two examples. Details and links for the two Geonews video examples can be found in Table 1 (maps: © Google Maps 2018; U.S. Geological Survey, 2020, https://earthquake.usgs.gov/, last access: 29 April 2022; © OpenStreetMap contributors 2018. Distributed under the Open Data Commons Open Database License (ODbL) v1.0; NBC News Today, 2018; Idaho Geological Survey, 2020).

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

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 material) is easy to find. It is easier to find relevant material 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.

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

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

No.	Title	Short description (location, type*)	Link	Total length
1	The Feb 2018 Sinabung Volcano Eruption	Indonesia, VE	https://youtu.be/t0xwiS2mW5k (last access: 29 April 2022)	02:35 min
2	Science Behind the Earth Suswa fissure (Kenya)	Kenya, East Africa, FI	https://youtu.be/sOB7O3yvC4Q (last access: 29 April 2022)	03:14 min
3	Science Behind Hawaii Eruption 2018	Hawaii, USA, VE	https://youtu.be/f-Z5d2ZBIro (last access: 29 April 2022)	04:50 min
4	Science Behind the 2018 Sept Sulawesi Tsunami	Indonesia, TS	https://youtu.be/1oaI4Mo7V_s (last access: 29 April 2022)	02:39 min
5	Taal Volcano Eruption 2020	Philippines, VE	https://youtu.be/z-iKOBjIiYc (last access: 29 April 2022)	02:43 min
6	Science of the Magnitude 5.7 Magna, Utah earthquake	Utah, USA, EQ	https://youtu.be/d6R6FTQnR3U (last access: 29 April 2022)	02:48 min
7	Science of the Magnitude 5.0 Mentone (TX) earthquake	Texas, USA, EQ	https://youtu.be/MfxmvXsIpBI (last access: 29 April 2022)	03:23 min
8	Science Behind Idaho's 2020 Earthquake	Idaho, USA, EQ	https://youtu.be/s_5YKFR5AMU (last access: 29 April 2022)	04:01 min
9	Science Behind Nevada's 2020 Earthquake	Nevada, USA, EQ	https://youtu.be/GizueyqNwYQ (last access: 29 April 2022)	05:00 min
10	Science Behind Mexico's 2020 Earthquake	Mexico, EQ	https://youtu.be/mIlQqfj8MQY (last access: 29 April 2022)	04:15 min
11	Science Behind the 2020 Sparta, North Carolina Earthquake	North Carolina, USA, EQ	https://youtu.be/JDz5UDbVGb8 (last access: 29 April 2022)	03:40 min
12	Science Behind the 2020 Aegean Sea Earthquake	Turkish and Greek Islands, EQ	https://youtu.be/MMBFY-LahNc (last access: 29 April 2022)	05:01 min

* EQ – Earthquake, VE – Volcano eruption, TS – Tsunami, FI – Fissure.

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 Robert 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 03:41 min (SD = 01:18 min) and that of the 21 General GeoEd videos is 03:55 min (SD = 01:13 min). The range of lengths of Geonews and General GeoEd videos is also similar (from ∼ 02:30 to ∼ 05:00 min). 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 to as "average percentage viewed"), and like / dislike ratio, as well as analyzing all comments (Azer et al., 2013; Allgaier, 2019; Ozdede and Peker, 2020). The number of views reflects 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 were collected from YouTube Analytics. 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 March 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.

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 and 3 years. 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. 3a and b). The like / dislike ratio is reported in the text below. Lastly, we compared comments for both groups of videos (Fig. 4). These metrics are as of 3 October 2021.

There are in total about 50 000 views for the 12 Geonews videos and ∼ 110 000 views for the 21 General GeoEd videos. The average number of views per video in 2018 and 2020 of General GeoEd videos ($N = 21$) is 5202 and that of Geonews ($N = 12$) is 3669. The standard deviation for General GeoEd group (SD = 6862) is much larger than that for the Geonews group (SD = 1650). The median views of Geonews videos is ∼ 3426, which is more than that of General GeoEd videos (1958 views). The maximum views of General GeoEd and Geonews groups are 23 035 and 7117, respectively, and the minimum views are 335 and 1287,

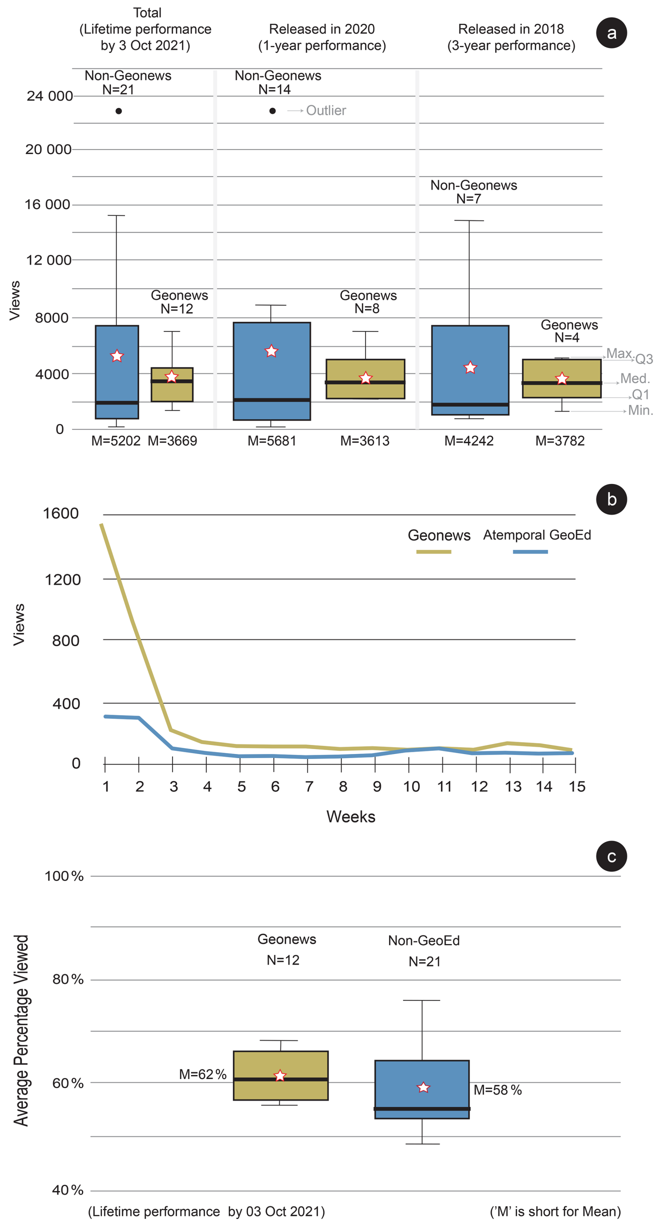

Figure 2. Comparison of views and average percentage viewed of Geonews and General GeoEd videos. **(a)** Views of Geonews and General GeoEd videos in lifetime: 1 year and 3 years. **(b)** Average views of Geonews videos and General GeoEd videos over first 15 weeks following posting on YouTube. **(c)** Average view percentage of Geonews videos and General GeoEd videos.

respectively. There are three General GeoEd videos with 15 000 to 25 000 views, which strongly influences the group mean and standard deviation (Table 2 and Fig. 2a).

Figure 2a summarizes the number of views of videos released in 2018 (3-year lifetime) and 2020 (1-year lifetime) separately; data for each video are in Table 2. The mean of views for General GeoEd videos released in 2018 (∼ 4243) is greater than that of 2018 Geonews videos (∼ 3782). The

Table 2. Details of 12 Geonews videos and General GeoEd videos created in 2018 and 2020.[a]

(a) Geonews videos

No.	Video example	Event date	Release date	Intensity (M_w, VEI, or TIS)	Interval (d)	Views[a]	Average view percentage	Comments
1	The Feb 2018 Sinabung Volcano Eruption	19 Feb 2018	27 Feb 2018	VEI 4 Little Damage And Largely Observed	18	2397	68 %	3
2	Science Behind the Earth Suswa Fissure (Kenya)	27 Mar 2018	14 Apr 2018	Little Damage And Largely Observed	18	2309	67 %	1
3	Science Behind Hawaii Eruption 2018[b]	6 May 2018	18 May 2018	VEI 0–3 Very Destructive	12	5001	61 %	7
4	Science Behind the Sept 2018 Sulawesi Tsunami	28 Sep 2018	14 Oct 2018	TIS X–XII Very Destructive	16	5407	66 %	8
5	Taal Volcano Eruption 2020	12 Jan 2020	16 Jan 2020	VEI 4 Little Damage And Largely Observed	4	2417	59 %	0
6	Science of the Magnitude 5.7 Magna, Utah earthquake[b]	18 Mar 2020	29 Mar 2020	M_w 5.7 Frightened All, Damage Negligible	11	4893	67 %	3
7	Science of the Magnitude 5.0 Mentone (TX) earthquake[b]	26 Mar 2020	6 Apr 2020	M_w 4.7–5.0 Damage Negligible, Felt by Most	11	1986	61 %	5
8	Science Behind Idaho's 2020 Earthquake[b]	31 Mar 2020	16 Apr 2020	M_w 6.5 Fright General, Damage Slight	16	7135	59 %	16
9	Science Behind Nevada's 2020 Earthquake[b]	15 May 2020	29 May 2020	M_w 6.5 Frightened All, Damage Negligible	14	4252	57 %	13
10	Science Behind Mexico's 2020 Earthquake	23 Jun 2020	5 Jul 2020	M_w 7.4 Fright General, Considerable Damage	12	1420	60 %	1
11	Science Behind the 2020 Sparta, North Carolina Earthquake[a]	9 Aug 2020	25 Aug 2020	M_w 5.2 Frightened All, Considerable Damage	16	4147	65 %	10
12	Science Behind the 2020 Aegean Sea Earthquake	30 Oct 2020	16 Nov 2020	M_w 7.0 Cracked Ground, Damage Serious	17	2732	57 %	7

[a] as of 3 October 2021; [b] indicates USA-related events. VEI: Volcanic Explosivity Index (Global Volcanism Project, 2013). M_w: 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).

Table 2. Continued.

(b) General GeoEd videos							
No.	Year	Video type	Video example	Views[a]	Average view percentage	Total length	Comments
1	2018	Topical	Permian Basin intro	15 681	59 %	06:19 min	12
2	2018	Topical	What's happened inside Siberia's Mysterious Craters?	1958	51 %	04:24 min	1
3	2018	Topical	Nuclear Bomb and Radioactive Dating – Dating .. Wrong??	807	65 %	03:27 min	2
4	2018	Topical	Three Types of Igneous Rocks at Wichita Mountains	1329	54 %	05:02 min	1
5	2018	Topical	Why is the Moon white?	7425	48 %	03:54 min	18
6	2018	Topical	Evolution of the Permian Basin	658	48 %	05:19 min	0
7	2018	Topical	Drilling to the Mantle	1905	64 %	03:21 min	5
8	2020	Topical	Are there volcanoes in Texas?	23 191	60 %	05:33 min	37
9	2020	Simulation	Formation of a new subduction zone	451	55 %	03:03 min	1
10	2020	Topical	What Happens When a Plane Flies into Volcanic Ash?	1984	67 %	02:33 min	2
11	2020	Basic concept	The Four Types of Volcanoes	23 617	52 %	02:45 min	13
12	2020	Topical	Induced Seismicity – The Oklahoma Story	826	69 %	03:45 min	1
13	2020	Topical	Creatures of the Burgess Shale	5164	52 %	03:38 min	13
14	2020	Topical	Big Bend National Park	1095	77 %	03:01 min	2
15	2020	Topical	The Ogallala Aquifer	8563	55 %	04:20 min	15
16	2020	Basic concept	Geodes: How Nature Creates Beautiful Mineral Formations	3300	60 %	03:16 min	2
17	2020	Video abstract	Formation of a New Subduction Zone by Lithospheric Collapse around the Margins of a Large Plume Head	423	54 %	03:15 min	1
18	2020	Basic concept	How do Fossils Form?	7671	52 %	04:34 min	7
19	2020	Video abstract	How Far South Might Himalayan Earthquakes Occur?	2345	52 %	04:26 min	5
20	2020	Basic concept	Emergence: A chaotic system pushed into organization	753	68 %	02:36 min	4
21	2020	Basic concept	CO_2 Drawdown – Where Should the Water Go?	1042	62 %	05:38 min	7

standard deviation of 2018 General GeoEd videos is 5126 while that of Geonews videos is 1438. Moreover, for General GeoEd videos released in 2020, the average number of views is 5681 (SD = 7537). Geonews videos released in 2020, on the other hand, have a slightly smaller mean (3613 views) and a much smaller standard deviation (1744).

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 (1563 of 3669). About 72 % of views occurred in the first 2 weeks (2646 of 3669), and approximately occurred 78 % in the first 3 weeks (2880 of 3669). Geonews group views in the first 15 weeks averages about 82 % of the total (3011 of 3669). In comparison, General GeoEd videos average only 272 views in the first week of their release, which is only 5 % of their total views. The number of views in the first 3 weeks on average is 609 views, which is about 12 % of the average total. In the first 15 weeks, the General GeoEd group got 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 videos 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 %, respectively. The median average percentage viewed of Geonews videos is 61 %, which is 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 b). 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 differs. 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 is the 45- to 64-year-old group. Both video groups got little interest from viewers younger than 25 years old (Geonews got 3.8 %, and General GeoEd got 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 like / dislike ratio for Geonews videos is 98 % (total like = 998, $N = 12$), while that for General GeoEd videos is 95 % (total like = 1968, $N = 21$) by 3 October 2021. The small difference may not be significant.

Lastly, we summarized the comments ($N = 222$) of Geonews and General GeoEd videos into five 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 ("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 clarifying some terms), arguing about science, or 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 per video on average, SD $= \sim 4.4$) and 149 comments for General GeoEd videos (~ 7.1 comments per video on average, SD $= \sim 8.4$). The number of comments for Geonews videos is 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 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.).

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 (Figs. 2 and 3). In addition, Geonews videos have a slightly higher like / dislike ratio than General GeoEd videos. These results indicate that the YouTube audience is interested in Geonews

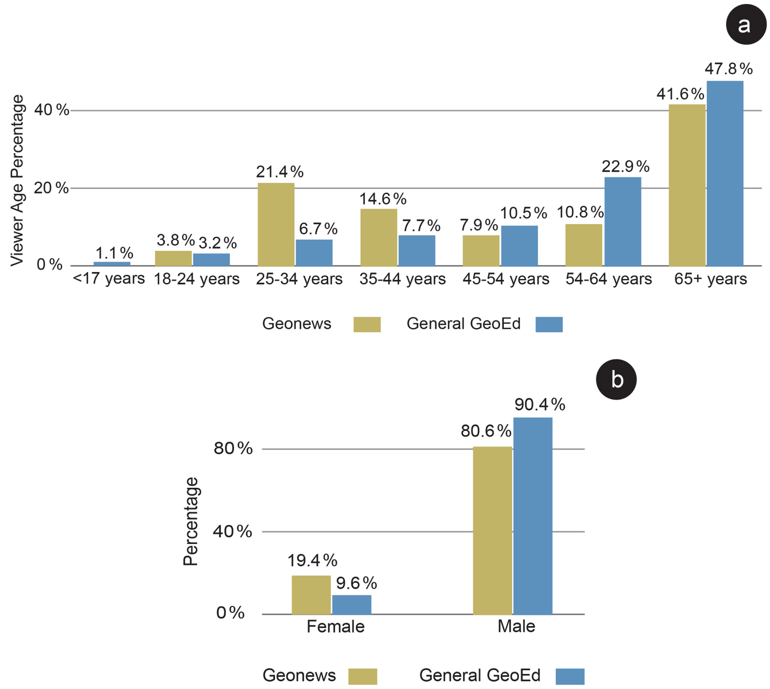

Figure 3. Histogram of viewer ages **(a)** and gender **(b)** of Geonews and General GeoEd videos. The data are from 167 000 views of 33 YouTube videos by 10 March 2021 (∼ 50 000 views of 12 Geonews video, ∼ 110 000 views of 21 General GeoEd videos).

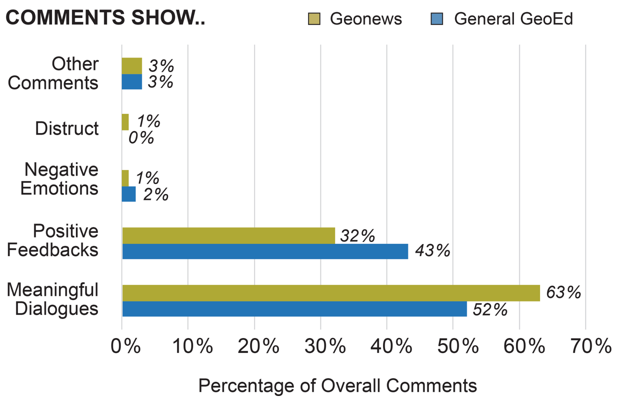

Figure 4. Comparison of comments about Geonews videos ($N = 73$) and General GeoEd videos ($N = 149$). Data are as of 10 March 2021. All the values are rounded to the nearest integer. See the text for a detailed explanation.

and the way it explains Earth processes. Geonews videos attracted an 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 (Fig. 2b). About 82 % of total views of Geonews videos occur within the first 3 weeks after release on YouTube, which is 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 show that Geonews videos engage the YouTube audiences less after the first 3 weeks. Also, the 12 Geonews videos occurred in regions that include the USA, Mexico, Indonesia, and Turkey–Greece areas. Viewers in these regions may be more interested in these videos than people living outside these regions. Moreover, the data show that Geonews videos reach younger and more diverse audiences, at least in terms of gender, than General GeoEd videos do (Fig. 3). An important demographic group that Geonews engaged with better are YouTube users in the 25- to 44-year-old age 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 a 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 news. Younger generations may use YouTube as their major source to watch news. Statistics from the Pew Research Center (2021) show that 95 % of US young adults (18 to 29 years old) routinely use 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 im Dialog (2018) for Germany show that 42 % of 14- to 29-year-old viewers use YouTube frequently or very frequently to inform themselves about science. This 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 are young to mid-life adults (ages 19–44 account for about 48 % of total viewers).

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 are limited (222 comments from 160 000 views) and the commenting audience members may not be representative of their communities (see Limitations section), 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 in 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. We discuss the differences of comments among YouTube, Twitter, and Facebook in later sections.

6.1 How reliable are the YouTube Analytics data, and is it ethical to use these 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 are relatively accurate, especially considering the magnitude of the data, and partially reflect YouTube's 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 by 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 to predict the users' demographic features, with good results (e.g., Ulges et al., 2013). Second, Tschantz et al. (2018) did a survey-based research study 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 as well as 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 the 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 consent was 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 these 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 they 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 person who uploaded the video. 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 possible 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 online 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 are relevant. First, the models consider the upload time and time-dependent 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 the USA 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 for the 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 d; mean = 13.5 d) 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 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 five of the six most viewed Geonews videos (> 4000 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 it encourages local geoscience teams to create Geonews-type videos to engage local audiences.

Lastly, we expect that the significance and type of events will affect the popularity of Geonews videos. Although the significance of an event to the public is related to damage and casualties, the magnitude of the event, and 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 2500 subscribers by February 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 (Incorporated Research Institutions for Seismology (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 into 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 160 000 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 suggest that short, timely videos about natural hazards and events especially engage people who live near where they occur, 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 a 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.

Data availability. The statistical data and analysis of the performance of Geonews videos and General Geoscience videos in this study are accessible at https://doi.org/10.6084/m9.figshare.19687911.v3 (Wang et al., 2022a). Data for the Geonews and General Geoscience videos' YouTube performance in 2018 and 2020 are accessible at https://doi.org/10.6084/m9.figshare.19687920 (Wang, 2022a) and https://doi.org/10.6084/m9.figshare.19687926 (Wang, 2022b).

Author contributions. The Geonews videos and General Geoscience videos listed in this experiment were created or supervised by NW and RS. RS is the director and supervisor of the overall program, and NW is the project manager; they are the creators of the Geonews videos. ZC and AS created most of the Geonews videos. NW designed the research, collected the data and analyzed the data. NW and RS contributed equally to the writing and the research.

Competing interests. The contact author has declared that neither they nor their co-authors have any competing interests.

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