Exploring TikTok as ~~an effective~~a promising platform for geoscience communication

Emily E. Zawacki[1], Wendy Bohon[2], Scott Johnson[3], Donna J. Charlevoix[3]

[1] School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85287, USA
[2] Incorporated Research Institutions for Seismology, Washington, D.C., 20005, USA
[3] UNAVCO, Boulder, CO, 80301, USA

Correspondence to: Emily E. Zawacki (eezawack@asu.edu)

Abstract. With TikTok emerging as one of the most popular social media platforms, there is significant potential for science communicators to capitalize on this success and share their science with a broad, engaged audience. While videos of chemistry and physics experiments are prominent among educational science content on TikTok, videos related to the geosciences are comparatively lacking, as is an analysis of what types of geoscience videos perform well on TikTok. To increase the visibility of the geosciences and geophysics on TikTok and to determine best strategies for effective geoscience communication on the app, we created a TikTok account called "Terra Explore" (@TerraExplore). The Terra Explore account is a joint effort between science communication specialists at UNAVCO, IRIS, and OpenTopography. We produced 48 educational geoscience videos over a four-month period between October 2021 and February 2022. We evaluated the performance of each video based on its reach, engagement, and ~~viewer retention~~average view duration to determine the qualities of a successful video. Our video topics primarily focused on seismology, earthquakes, topography, lidar (light detection and ranging), and GPS (Global Positioning System), in alignment with our organizational missions. Over this time period, our videos garnered over 2 million total views, and our account gained over 12,000 followers. The videos that received the most views received nearly all (~97%) of their views from the *For You* page, TikTok's algorithmic recommendation feed. We found that short videos (< ~~20~~30 s) had a high ~~viewer retention rate~~average view duration, but ~~they often~~longer videos (>60 s) had ~~a low~~the highest engagement ~~rate, leading to less overall visibility.~~rates. Lecture-style videos that were ~~between 40~~approximately 60 seconds ~~and two minutes~~ in length had more success in both reach and engagement. Our videos that ~~went~~received the ~~most viral~~highest number of views featured content that was related to a recent newsworthy event (e.g., an earthquake) or ~~explaining place~~explained location-based geology of a recognizable area. Our results highlight the algorithm-driven nature of TikTok, which results in a low barrier to entry and success for new science communication creators.

1 Introduction

Given the current popularity and ubiquity of various social media platforms, scientists have a unique opportunity to directly interface with a diverse public audience. Not only can scientists use social media to improve the public perception of science, but they can also work to combat the growing tide of scientific misunderstanding and misinformation (Hilary and Dumebi, 2021; Shu et al., 2020). Over the last decade, scientists have found success using social media, especially Twitter, to share scientific discoveries (Côté & Darling, 2018; Schmitt, & Jäschke, 2017; Smith, 2015) and affect social change (Jahng & Lee, 2018). However, the social media landscape is frequently changing, and scientists must adapt to new changes and trends to effectively reach an audience.

Over the past two years, TikTok has dominated the social media landscape and currently boasts over one billion monthly active users (TikTok, 2021a). On TikTok, users create and interact with short-form video content (~15 seconds to 3 minutes). TikTok is exceptionally popular among ~~the~~a younger ~~generation~~demographic, with 25% of users in the U.S. being under the age of 19 (Statista, 2022a). With the growing popularity of TikTok among users of all ages, TikTok presents an excellent opportunity to strategically examine how scientists can use social media to broaden their reach and create a more scientifically literate public. On TikTok, science communication is highly personalized, as science practitioners are presented in an approachable and relatable way (Zeng et al., 2020).

Of the STEM (science, technology, engineering, and mathematics) disciplines, the geosciences are especially relatable; essentially everyone has personal experience with geoscience-related information in their daily lives. Effective communication of geoscience topics is important because the geosciences are intrinsically linked to the human and natural world, and it is beneficial for everyone in society to understand the basics of geoscience. Increased awareness and understanding of geohazards like earthquakes, landslides, floods, and global climate change can help to improve personal safety and increase support for public policy. Additionally, geohazards are often the subject of considerable misinformation—persistent rumors that Yellowstone is about to catastrophically erupt serves as a frequent example—so providing high-quality, scientifically accurate information is especially important.

~~In recognizing~~Recognizing the substantial potential for geoscience communication on TikTok, we created a TikTok account called "Terra Explore" (@TerraExplore) to share educational geoscience and geophysics videos. With these videos, we sought to not only enhance the visibility of geoscience and geophysics on TikTok but also to assess the most effective methods for science communication on the platform~~.~~ and assess what factors may impact how well a video performs on the app. We analyzed the reach (how many individuals saw the video), the engagement (the number of interactions with the content, e.g., "likes" or "comments"), and the ~~viewer retention rate (how much of the video is watched on~~ average~~)~~ view duration of each video we posted to determine the qualities of a successful educational geoscience TikTok~~.~~ video. The longer that someone watches a video and the more engagement the video receives demonstrates interest in the video and the impact of the science communication, which will likely be rewarded within the algorithm with expanded video reach. Through this work, we are able to determine the factors of a video that help maximize the reach and potential for geoscience communication on TikTok.

2 Basics of TikTok

TikTok is a short form video app that allows users to create videos using music, filters, text, and camera effects on their mobile phones. The app is free to download on Apple and Google Play stores. While TikTok videos were originally all less than a minute long, TikTok increased the upper limit to three minutes during late summer of 2021 (Kirchhoff, 2021). There is now also the limited ability to upload a single 10-minute video file from your device to TikTok. The COVID-19 global pandemic served as a catalyst for the growth and success of TikTok among different demographics (Feldkamp, 2021). During the first quarter of 2020, TikTok had more than 315 million installs across the Apple and Google Play app stores, which was the most downloads ever for an app in a single quarter (Briskman, 2020). This was a significant increase from the 219 million installs during the fourth quarter of 2019 (Statista, 2022b~~), and TikTok currently stands as the third largest social media platform behind Facebook and Instagram (Insider Intelligence,~~). During the first quarter of 2022, TikTok was the most downloaded app worldwide (Sensor Tower, 2022).~~ 2021).~~

TikTok provides two primary feeds on which a user can watch content: *Following* and *For You*. Upon opening the app, videos immediately begin playing on the *For You* page. Users can toggle between the two feeds at the top of the screen. TikTok uses AI algorithmic recommendations to determine what videos are shown on a user's *For You* page, which are often based on the user's profile settings, their location, and their activity on the app (Smith, 2021). In order to help users discover new content categories and creators, as well as to avoid a repetitive experience, TikTok also provides diverse recommendations on the *For You* page (TikTok, 2020). The *For You* page is notable and unique amongst social media feeds, as videos with extremely few views (~10 views) can be recommended, thus guaranteeing a potential audience for every post regardless of the number of account followers. ~~The more engagement a video receives, the more likely it will be shown to other users on the *For You* page.~~ Based on TikTok's internal data, 69% of a user's time on the app is spent on the *For You* page (Stokel-Walker, 2020), making it the primary way users view and discover new content. Only videos from accounts that someone follows are shown on the *Following* feed, although these videos may also be shown on the *For You* page. Videos additionally can be viewed on a creator's profile page or by searching video hashtags or sounds. While TikTok does not publicly disclose any information regarding how their AI recommendation algorithm functions, independent data analysis of trending videos on TikTok found that a higher level of video engagement through likes, comments, and shares leads to a higher chance of the algorithm showing the video to more people via the *For You* page (Klug et al., 2021).

3 Educational landscape on TikTok

Despite the common perception that TikTok is a “dance app” for kids, there is an abundance of educational content on the app that is widely consumed. Research shows that youths agree that TikTok serves as a window for online learning and aids in educational development (Azman et al., 2021). This positive educational potential led TikTok to be integrated into various aspects of instruction in higher education (Draganić et al., 2021; Escamilla-Fajardo et al., 2021~~).~~; Radin and Light, 2022). As well, studies show that TikTok allows non-expert users to participate in scientific discussions—such as those related to climate change—that oftentimes only take place among expert-level scientists and journalists (Basch et al., 2022; Hautea et al., 2021).

The TikTok leadership has also worked to strengthen and promote educational content on the app. In May of 2020, TikTok launched their “#LearnOnTikTok” campaign, where they partnered with 800 public figures, educational institutions, and professional experts to bring learning material to TikTok (Thoensen, 2020). These partnerships included notable science communicators such as Bill Nye and Neil deGrasse Tyson. While the campaign partnered with specific creators, anyone on TikTok can create videos and use the #LearnOnTikTok hashtag. As of February 2022, videos using the “LearnOnTikTok” hashtag have a collective 240.4 billion views. The success of the #LearnOnTikTok campaign demonstrates the desire for consumption of educational material on the platform and provides an ideal opportunity for science communicators to capitalize on a platform with a large user base. By leveraging this already well-known and popular hashtag, geoscientists can promote their content to a receptive audience, potentially increasing knowledge of and interest in geoscience topics.

The manner in which science content is presented on TikTok—lecture style vs. demonstration—influences user engagement. Habibi and Salim (2021) evaluated the engagement of lecture-style and experimental educational science videos from one account on TikTok, largely related to biology, and found that scientific experiments presented in dynamic ways received the most engagement. Hayes et al. (2020) observed that TikTok videos of at-home chemistry experiments can increase knowledge of and interest in chemistry for viewers. In addition to videos showing chemistry experiments, Hight et al. (2021) found that students enjoyed creating and consuming content on TikTok that featured anthropomorphized chemistry concepts. Based on an analysis of memetic science content on TikTok, Zeng et al. (2020) found that the presence of science on TikTok is dominated by chemistry and physics experiments.

Thus far, the geosciences have ~~largely~~ been excluded from evaluations of science content and science communication on TikTok. Much of geoscience-related content on TikTok is created by young individuals who have recently or are currently completing undergraduate or graduate degrees in the geosciences. Videos typically feature geology-related “memes” or jokes, showing what’s inside a rock when you break it open, or explaining geoscience topics. Content related to geology and geophysics on TikTok has significantly fewer views than content related to physics, biology, and chemistry (**Table 1**). Unlike chemistry and physics, the geosciences do not as easily lend themselves to at-home experiment-based content, but do allow for unique, hands-on demonstrations as well as the potential for “field trip” style presentations. Additionally, geoscience is a discipline that every person has had some level of interaction with (soil, geohazards, GPS on their phone, etc~~.)~~.). Our aim was to not only enhance the visibility of geoscience and geophysics content on TikTok but also to determine and evaluate the most effective strategies for geoscience communication on TikTok.

Hashtag	View Count
#physics	3.3 billion
#biology	3.2 billion
#chemistry	3.0 billion
#geology	617.6 million
#geophysics	2.7 million

Table 1. Number of total video views on TikTok for different science-related hashtags, as of October 2021 before our project began. Within the app, TikTok denotes the total number of video views per hashtag.

4 Account and video creation

In October 2021, we created an account "Terra Explore" to evaluate the potential of TikTok for geoscience communication (**Fig. 1a**). Between 10/8/2021 and 2/6/2022, we published 48 videos. The "Terra Explore" name is a nod to the many ways scientists explore Earth (Terra) using geoscience tools and techniques. The Terra Explore account is a joint effort led by science communication specialists from UNAVCO, IRIS, and OpenTopography. UNAVCO and IRIS are non-profit university-governed consortiums ~~and manage~~that operate the GAGE and SAGE facilities (respectively) on behalf of the National Science Foundation (NSF), serving the geophysics community. OpenTopography is co-managed by the San Diego Supercomputer Center at the University of California San Diego, UNAVCO, and Arizona State University and facilitates community access to high-resolution, Earth-science-oriented topography data and related tools and resources, also on behalf of NSF.

Our primary aim with the Terra Explore account was to determine effective strategies for geoscience communication on TikTok and increase the presence of geoscience and geophysics content, ideally targeting users aged 19-and-under and female/girl users. Our videos featured three rotating front-facing hosts and were typically done in a "lecture-style" format, where the host ~~explains~~talks directly to the audience explaining a geoscience topic while using engaging background visuals. Two of the hosts are female and presented the majority of the videos, and one is male. We primarily used TikTok's "green screen" feature to add visual imagery to videos, in addition to image and text overlays (**Fig. 1b**). TikToks were filmed in individual home offices using simple equipment such as iPhone/Android devices, small lights, and low-cost lavalier microphones. We used TikTok's built-in captioning feature to provide captions on all of our videos to increase their accessibility.

We largely produced content related to our organizations' missions. Video topics primarily focused on seismology, earthquakes, topography, lidar (light detection and ranging), and GPS (Global Positioning System). We often used and incorporated existing educational graphics and animations produced by IRIS and UNAVCO. The videos we produced ranged between 9 seconds and 2 minutes 30 seconds in duration, with an average video duration of 57 seconds. Each video post contained a short description and approximately five relevant hashtags. Due to staff time limitations, we did not set a specific video posting schedule, but averaged between one to four videos posted per week, with the most videos posted during the first two months of the project. A number of videos were cross-posted and promoted on UNAVCO, IRIS, and OpenTopography's other social media accounts.

Our video content largely did not include TikTok "memes" or sounds. "Memes" are among the most common videos on TikTok and use viral audio clips that are transformed and applied to different visual imagery, capitalizing on popular culture or shared experiences. Given the educational aspect of our videos, we chose to follow a more traditional video format where the video host speaks directly to the audience as a teacher would to a classroom.

The most common type of video we produced presented ground motion visualizations (GMV) for notable earthquakes magnitude 6 or higher (**Fig. 1c**). These GMV animations were already being produced by IRIS and disseminated through other social media channels. On the Terra Explore TikTok, the front-facing video host explains what is shown in the animation: earthquake waves pass across seismic stations in ~~the United States~~North America, and we can see representation of the ground moving up and down (although the movements are too small to feel). Videos were timely in that they were typically posted the day of or the day after the earthquake occurred. As the content and style of these GMV videos were largely identical, they provided a way to more clearly evaluate specific factors that may affect a video's performance.

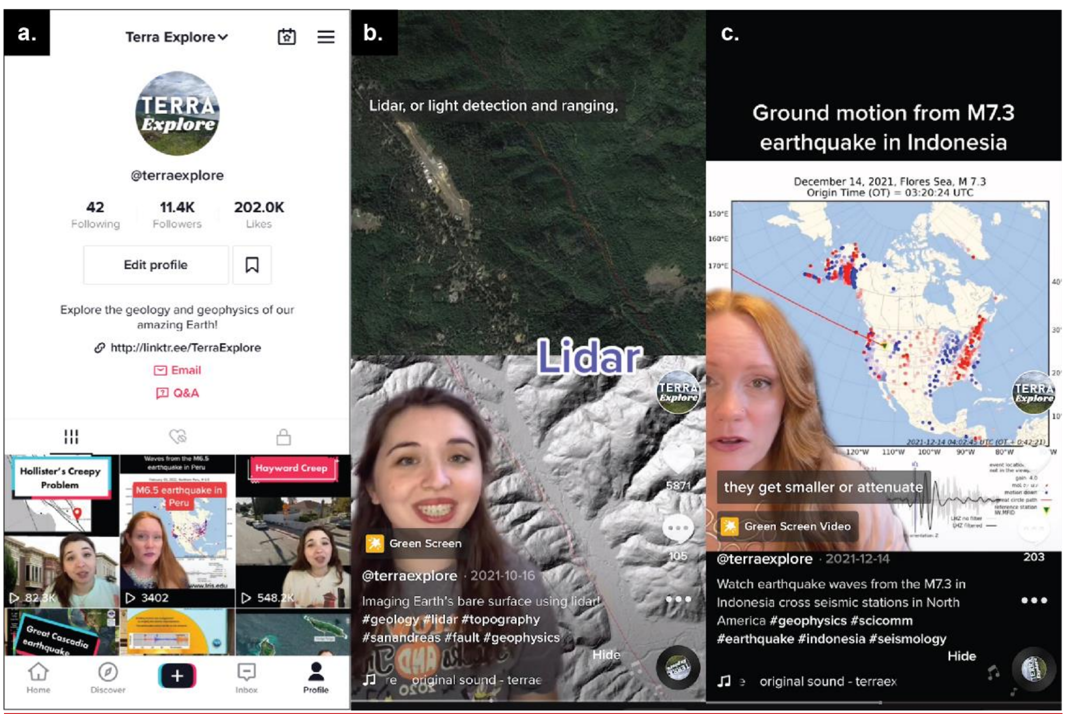


Figure 1. (a) Representative screenshot of the Terra Explore account. Our profile page has a Linktree that provides external links to the UNAVCO, IRIS, and OpenTopography websites. (b) Screenshot of typical video using the "green screen" effect. (c) Example screenshot of a GMV video.

5 Methods

We used TikTok's built-in account analytics to download and record video and account metrics for the period between 10/8/2021 and 2/6/2022~~.~~ to evaluate the performance of each video and analyze what factors may impact the success and impact of a video. With our analyses, we largely sought to evaluate the features of geoscience content that users watch the most and engage with the most on TikTok, as well as what may impact the performance of a video within the algorithm. (Does the length of a video matter? The time of day it is posted at? Etc.) We began collecting data upon video publication and continued until the end of the reporting period, ensuring that there was a minimum of two weeks of available data per video. We found that videos typically received the majority of views and engagement within the first week after publication, and thus this timeframe is generally sufficient to observe video trends.

We collected all of the ~~following~~ summary data for each individual video that TikTok provides: video views, likes, comments, shares, total cumulative play time, average duration the video was watched, percentage of viewers who watched the full video, unique reached audience, ~~and~~ the percentage of video views by section (*For You*, personal profile, *Following*, hashtags~~).~~), and the percentage of views by region/country. Prior to August 2022, TikTok ~~does~~did not provide information on the gender or the age of users who view a video~~.~~ , although they now provide this information for videos created after that date.

We evaluated the "success" of videos based on reach and engagement metrics, as well as ~~viewer retention (how long a~~average video ~~is watched).~~view duration. We used metrics of reach (number of unique users the video was seen by) and engagement (likes, comments, and shares) to calculate the engagement rate of each video. The engagement rate is calculated as the engagement parameter as a percentage of total reach (e.g., Likes / Audience Reached *100). We hypothesize that the videos with the highest engagement rates and longest view durations will receive the highest views and reach (Klug et al., 2021). Longer view duration indicates greater interest in the video and subject, and engaging with the video through likes, comments, or shares demonstrates additional interest, indicating that the science communication was successful and impactful. This interest and engagement with the video is likely to be rewarded within the algorithm, with the video being shown to more people on the *For You* page.

We performed correlation analyses of variables related to views, engagement rate, and view duration to evaluate any trends in video performance. We calculated the Pearson correlation coefficient to determine the correlation between variables and calculated p values to determine the statistical significance of each relationship ($p < 0.05$ is selected to indicate statistical significance). All individual plots and values from the correlation analyses are available in the Supplementary Materials.

We also recorded weekly account metrics including total video views, profile views, total account likes, total comments, total shares, total followers, new followers, ~~and~~ gender of followers~~. The only~~, and region/country of followers. TikTok reports gender ~~information TikTok readily provides in analytics is the~~as a binary percentage of male and female followers. Of these metrics, we most closely evaluated the gender percentage of followers over time to see how well we were able to reach specific demographics.

6 Results

6.1 Video and account metrics

During the four-month test period, the Terra Explore account gained over 12,000 followers, and the 48 videos published garnered 2,106,504 views~~.~~, 3,579 comments, and 5,144 shares. The videos had a combined 22,297 hours of watch time. Individual video views ranged between 522 views and 684,100 views, with a median of approximately 2,400 views. Seven videos received over 90,000 views, and 30 videos received less than 3,000 views ~~(**Fig. 2**).~~. Videos were uploaded at various times throughout the day, and the videos that received the most views (>90,000) were uploaded either in the morning or early afternoon Mountain Standard Time (MST) (~~**Fig. 3**~~UTC-7) (**Fig. 2**). However, there was no statistically significant correlation between video upload time and the number of video views ($p > 0.05$). We did not spread video publication evenly throughout the week, and the greatest number of videos ~~was~~were posted on Tuesdays. Videos that were published on Wednesdays and Thursdays received ~~significantly~~ fewer views than other days of the week, with videos published on Mondays receiving the most cumulative views on average (**Fig. ~~4~~3**).

Tables 2–3 record the topic and metrics of our ten most viewed and ten least viewed videos. Our highest viewed video described an offset curb in Hayward, California that was famous among geologists for recording the continual slow motion along the Hayward Fault (part of the San Andreas fault system). Three of our ten most viewed videos were GMVs, one was a demonstration, and the rest were lecture-style videos. The lecture-style videos were either related to discussing a geologic topic related to a specific location or a recent newsworthy event/anniversary. Our ten least viewed videos included five lecture-style videos, two demonstration videos, one in-person video, one miscellaneous video, and one meme-style video. These lecture-style videos were all explainer videos of topics related to seismology or geodesy. Our least viewed videos were all published in either October or November 2021 when we first began our account. However, our second and third most viewed ~~video was~~videos were also published during this timeframe. Our top ten most viewed videos averaged 67 seconds in length and had an average video view duration of 58%, while our ten least viewed videos averaged 44 seconds in length and had an average video view duration of 37%. The top ten most viewed videos had an average engagement rate of 11% for likes, while the ten least viewed videos had an average engagement rate of 8% for likes.

Of the account's over 2.1 million video views, 95% of those views came from videos shown on the *For You* page. Nearly twice as many videos were viewed on the Terra Explore profile page than on the *Following* feed. Videos were rarely discovered by a user directly searching for a specific hashtag (**Table 4**). Our most viewed videos received nearly all (~97%)

of their views from the *For You* page. Videos with fewer views were shown to fewer ~~viewers~~users on the *For You* page and received a higher percentage of views from the Terra Explore profile page or the *Following* feed (**Fig. ~~5~~4**).

85% of the account's followers are located within the United States, followed by 3% from Canada. 84% of the total number of video views came from users located within the United States, with each individual video averaging 78% of its views from users in the United States. Canada was the second highest video viewer region on 22 videos, Australia on 17 videos, the United Kingdom on five, and the Philippines on four, with the secondary country yielding on average 5% of a video's views. As of February 2022, the Terra Explore account had 36.5% female and 63.5% male followers. This percentage remained relatively unchanged over the four-month duration of video posts ~~(**Fig. 6**).~~.

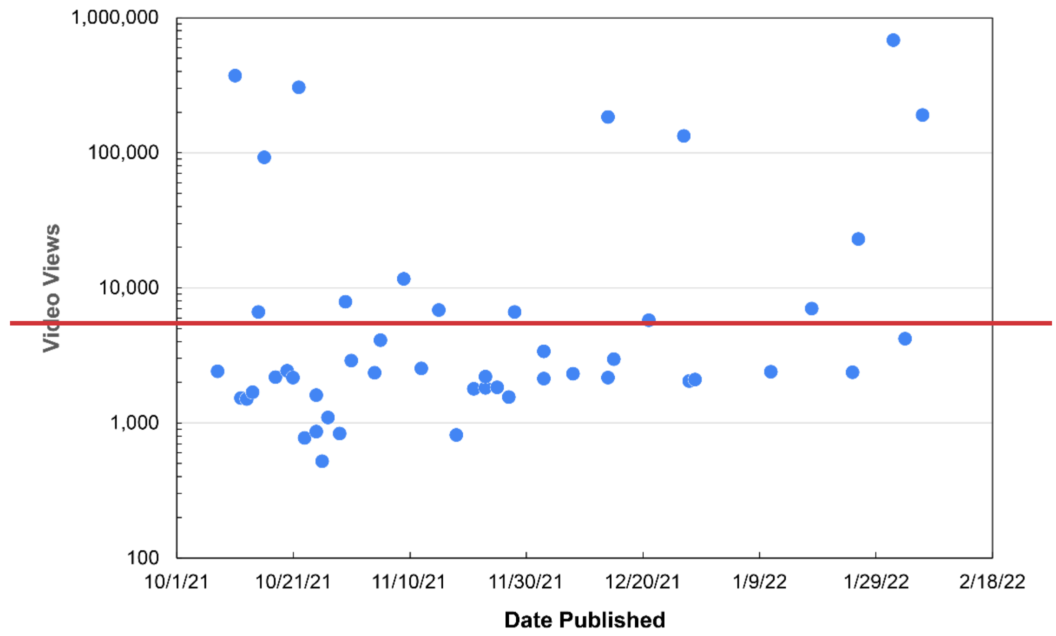
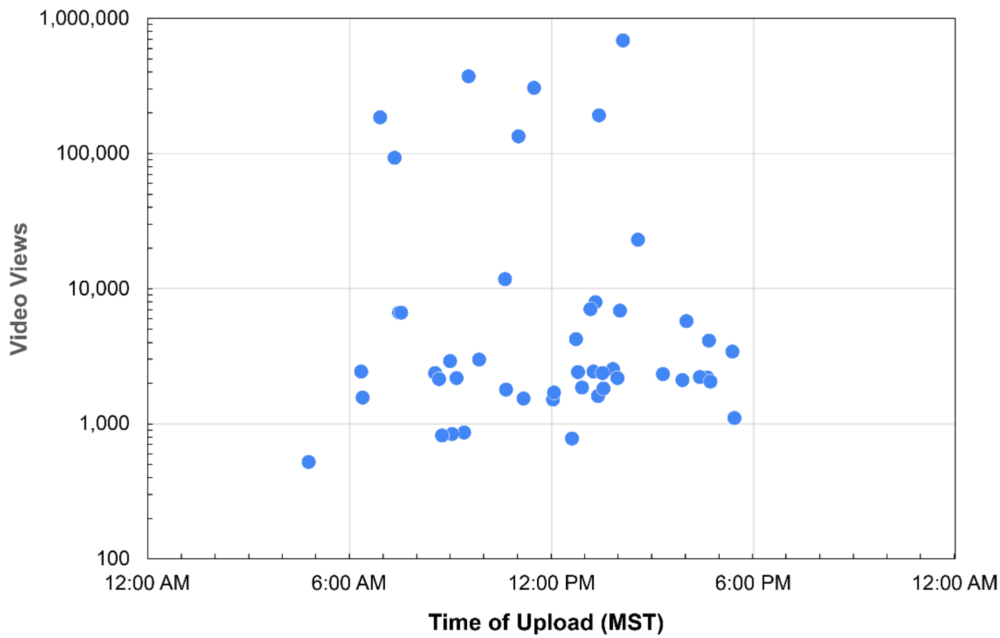


Figure 2. ~~**Number of video views each Terra Explore video received and the date that each video was posted on. Note video views are shown on a logarithmic scale.**~~



~~Figure 3.~~ **Time of video upload in Mountain Standard Time (MST) (UTC-7) and the number of views the video received (on logarithmic scale). Videos that received ~~the most views (>~~>90,000~~)~~ were uploaded in the morning or early afternoon~~.~~ MST (UTC-7). There is no statistically significant correlation between the time of video upload and the number of video views (p > 0.05).**

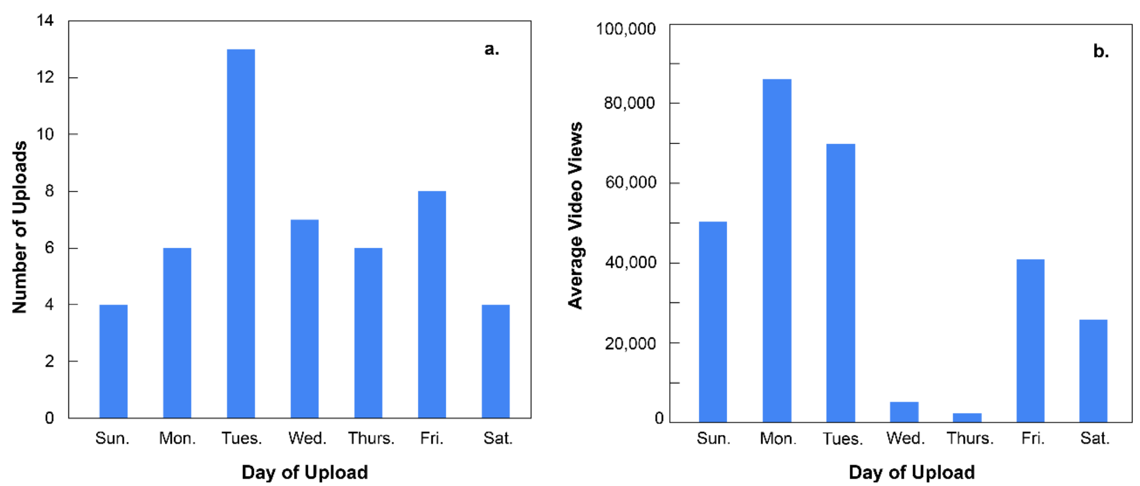


Figure ~~4~~3. (a) The number of videos uploaded per day of the week. (b) The average total number of video views received based on the day of video upload. Videos that were posted on Wednesdays and Thursday received the lowest number of views on average.

Video Topic	Date Published	~~Duration~~ Length (s)	Views	Likes (ER %)	Comments (ER %)	Shares (ER %)	Avg. % Watched
Hayward, CA offset curb (Hayward fault creep)	2/1/2022	108	684,100	104,600 (16)	1,209 (0.19)	2,332 (0.37)	51
GMV of M6.2 Hawaii earthquake	10/11/2021	30	372,300	43,900 (13)	558 (0.16)	1,066 (0.31)	85
Demonstrating earthquake magnitude with spaghetti	10/22/2021	34	305,500	24,300 (8)	444 (0.15)	346 (0.12)	78
GMV of M7.3 Indonesia earthquake	12/14/2021	56	184,600	14,000 (10)	205 (0.55)	344 (0.15)	60
Hollister, CA fault creep and impact on infrastructure	2/6/2022	88	190,300	19,600 (11)	386 (0.22)	612 (0.34)	41
Wallace Creek (San Andreas Fault, CA) stream offsets	12/27/2021	73	133,500	6,871 (5)	128 (0.10)	48 (0.04)	55
Lidar "x-ray vision" of Earth's ~~bare~~ surface (San Andreas Fault, CA)	10/16/2021	48	92,900	5,859 (7)	105 (0.12)	49 (0.05)	56
Cascadia 1700 earthquake and tsunami anniversary	1/26/2022	147	21,600	1,861 (10)	83 (0.42)	71 (0.36)	43~~.5~~
GMV of Nicaragua M6.2 earthquake	11/9/2021	39	11,700	1,102 (10)	37 (0.34)	29 (0.26)	55
Using lidar to uncover ancient Mesoamerican complexes	10/30/2021	47	7,896	1,339 (17)	20 (0.26)	13 (0.17)	53

Table 2. Top ten most viewed videos between 10/8/2021 and 2/6/2022 on the Terra Explore and corresponding metrics. GMV = ground motion visualization, M# = earthquake magnitude. ER = engagement rate (Metric / Audience Reached *100). All videos had an average ~~viewer retention (how long a person watches the~~ video~~)~~ view duration of 40% or higher. These videos correspond with #1–10 in Fig. ~~5~~4.

Video Topic	Date Published	~~Duration~~ Length (s)	Views	Likes	Comments	Shares	Avg. % Watched
Difference between earthquake magnitude and intensity	10/25/2021	57	1,606	189 (12)	4 (0.25)	6 (0.37)	34
Difference between hazard and risk	11/27/2021	38	1,562	110 (7)	1 (0.07)	1 (0.07)	36
Attending a scientific meeting, Geological Society of America 2021 meeting	10/12/2021	60	1,539	87 (6)	8 (0.53)	9 (0.60)	25
Earthquake yoga (~~Types~~Demonstrating types of seismic waves)	10/13/2021	59	1,511	58 (4)	6 (0.43)	6 (0.43)	18
Different earthquake waves: P waves and S waves	10/27/2021	56	1,101	135 (12)	5 (0.44)	1 (0.09)	34
Call for 'Ask a Geoscientist' questions	10/25/2021	11	863	59 (6)	3 (0.33)	1 (0.11)	49
Demonstrating types of faults using candy bars	10/29/2021	59	840	110 (8)	6 (0.19)	5 (0.13)	35
Wave refraction explained	11/18/2021	39	815	62 (7)	1 (0.12)	0 (0.00)	37
How GPS is used to monitor Earth's systems	10/23/2021	50	775	78 (10)	4 (0.50)	1 (0.12)	27
Mandalorian "baby seismometer" meme	10/26/2021	9	522	27 (7)	1 (0.27)	0 (0.00)	76

Table 3. The ten least viewed videos and corresponding metrics on the Terra Explore account between 10/8/2021 and 2/6/2022. ER = engagement rate (Metric / Audience Reached *100). These videos correspond with #39–48 in Fig. ~~5~~4.

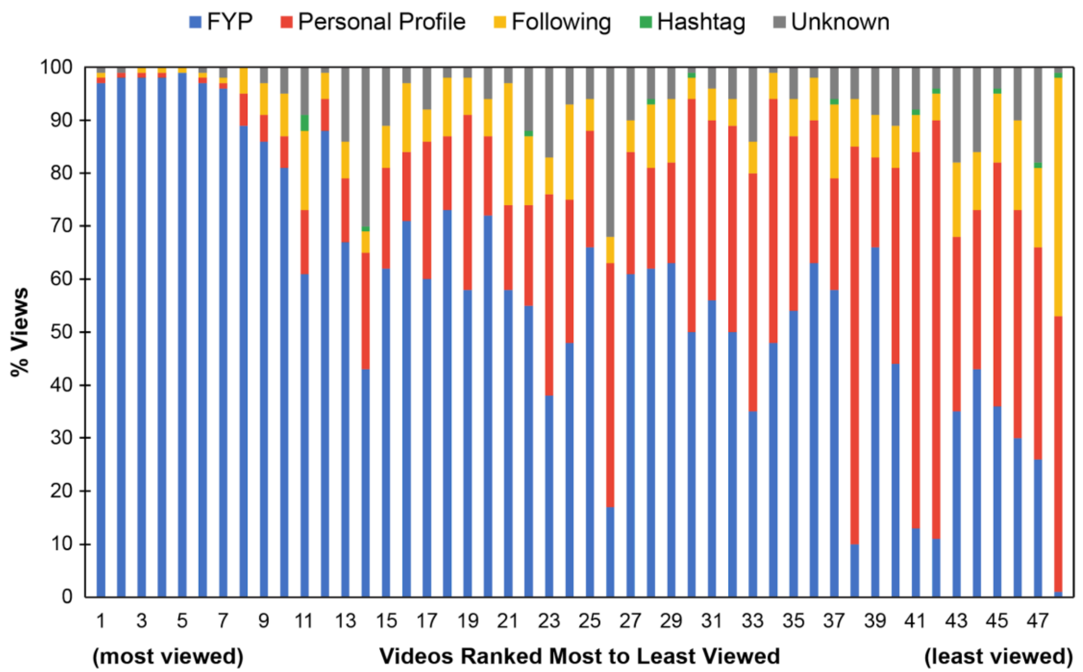
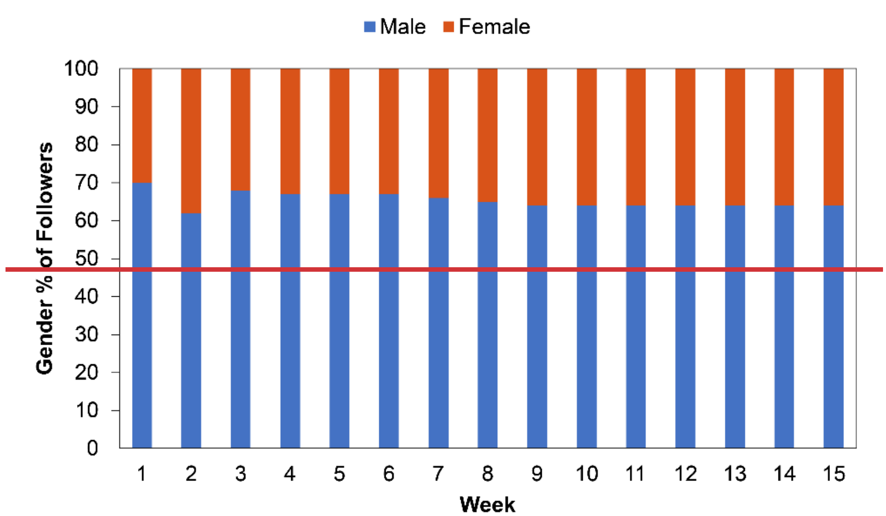


Figure ~~5~~4. Percentage of video views by section (*For You* page, personal profile, *Following*, hashtag, unknown), with videos ranked from the most (1) to the least (48) viewed (See Tables 2 and 3 for the ten most and ten least viewed videos). The videos with the highest number of views received nearly all (~97%) of their views from the *For You* page. The seven most viewed videos each received over 90,000 views.



~~**Figure 6. Gender percentage of followers during each week of posting, beginning 10/8/21 (week 1). A gender split of 64% male and 36% female followers remained relatively consistent throughout the period, ending 2/6/2022.**~~

~~6.2 Viewer retention and engagement rate~~

6.2 Video view duration and engagement rate

The average percentage of ~~watch~~ time ~~of~~ a video was viewed was 44% of its duration, and ~~on average~~ 19% of users on average watched the full duration of a video. We evaluated the relationship between the average view duration of a video ~~(viewer retention)~~(%) and the number of video views based on the length of the video (< 30 seconds, 30 seconds to 1 minute, 1 to 2 minutes, and > 2 minutes in duration) ~~(**Fig. 7**). Videos less than 30 seconds in length had the highest viewer retention, although this high viewer retention did not necessarily equate to higher video views. Videos that were between 30 seconds and 2 minutes in length most frequently received the highest number of views, although there lacks a clear relationship between viewer retention and the number of video views.~~ to see if the longer that someone watches a video the more it will be promoted to other users, resulting in higher views (**Fig. 5**). Amongst all videos, there is a weak positive correlation that is statistically significant between the average video view duration and number of video views ($r = 0.37$, $p = 0.008$). Amongst the individual video length populations, only videos between 30 s to 1 min long showed a statistically significant correlation between average video view duration and number of video views ($r = 0.57$, $p = 0.002$). Videos < 30 s averaged the highest average view duration (63%). However, there is a statistically significant negative correlation between the average video view duration and the length of a video ($r = -0.41$, $p = 0.004$) (**SF6**), indicating that the average view duration is in part tied to the length of the video itself.

Videos had ~~an~~ average engagement ~~rate~~rates of 10%, 0.38%, and 0.21% for likes, comments, and shares, respectively. These engagement rates are similar to the engagement rates of other analyzed educational science content on TikTok (Habibi and Salim, 2021). ~~However~~We found a statistically significant strong positive correlation between the number of video views and the engagement rate of likes for videos with over 90,000 views ($r = 0.90$, $p = 0.006$). However, there is no statistically significant correlation between the number of video views and the engagement rate of likes for videos with fewer than 90,000 views ($p > 0.05$). We also observe no statistically significant correlation between the number of video views and the engagement rate of comments or shares ($p > 0.05$) (**Fig. 6**). Therefore, videos that received a large number of views (>90,000) did not necessarily have a higher engagement rate than ~~videos with far fewer views (~2,000) (**Fig. 8**). Videos that received the lowest number of views (< 1,000) had engagement rates for likes and comments similar to other videos with more views, but they had among the lowest engagement rates for shares (some at 0%).~~ did videos with far fewer views (~2,000).

~~The average viewing duration largely did not show any relationship with engagement rate (**Fig. 9**). However, the viewer retention rate is in part linked to the duration of the video itself. Shorter videos (< 20 seconds) are more likely to have a higher viewer retention rate (**Fig. 7**), but these videos received some of the lowest overall engagement rates (**Fig. 10**). In fact, longer videos (>100 seconds) had among the highest engagement rates.~~

We observed no statistically significant correlation between the average video view duration (%) and the engagement rate of likes, comments, or shares ($p > 0.05$) (**Fig. 7**), two factors that are hypothesized to strongly impact the reach (views) a video can receive. Just because a user watches more of a video, that does not indicate that they are more likely to engage with the video. However, our analyses indicated that the average video view duration is in part tied to the length of the video. In looking at video length, we found a weak positive correlation that is statistically significant between the length of a video and the engagement rate of likes (r = 0.34, p = 0.017). There was no statistically significant correlation between video length and the engagement rate of comments ($p > 0.05$), but there was a weak to moderate positive relationship that is statistically significant between video length and the engagement rate of shares (r = 0.46, p = 0.001). Thus, longer videos tended to have higher engagement rates (**Fig. 8**).

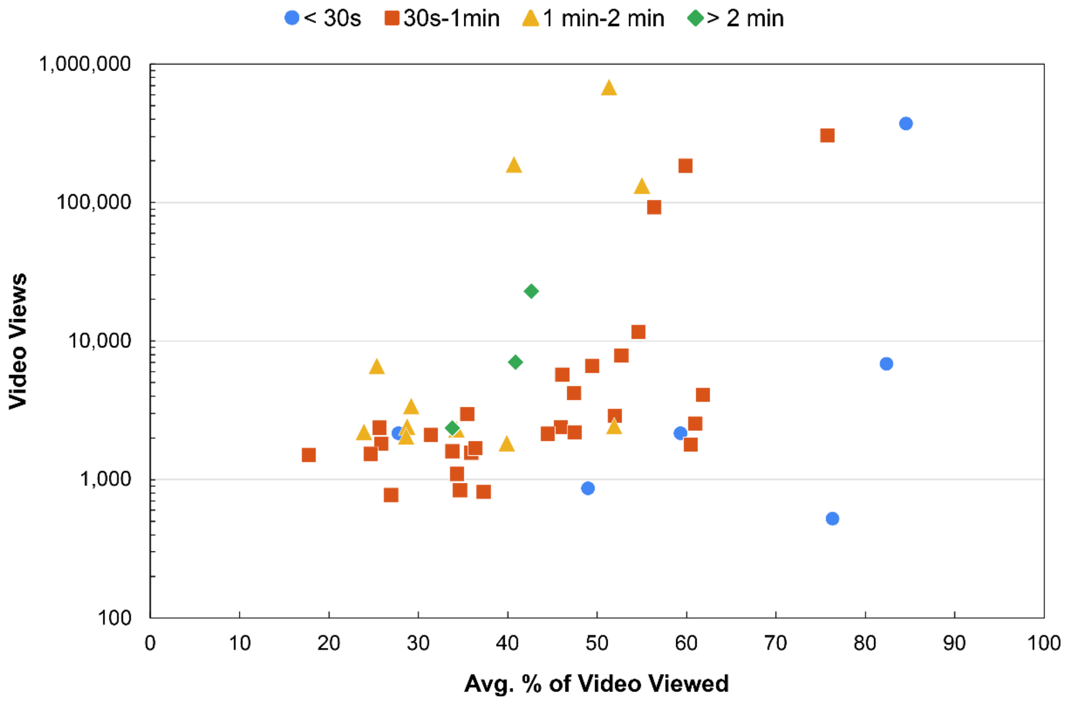


Figure ~~7~~5. Average percentage of the video viewed ~~(viewer retention)~~ based on the length of the video (< 30 seconds, 30 seconds to 1 minute, 1 to 2 minutes, and > 2 minutes) compared to the number of video views. Note that video views are shown on a logarithmic scale. There is a weak positive correlation that is statistically significant (r = 0.37, p = 0.008). See Supplementary Materials for full correlation analysis.

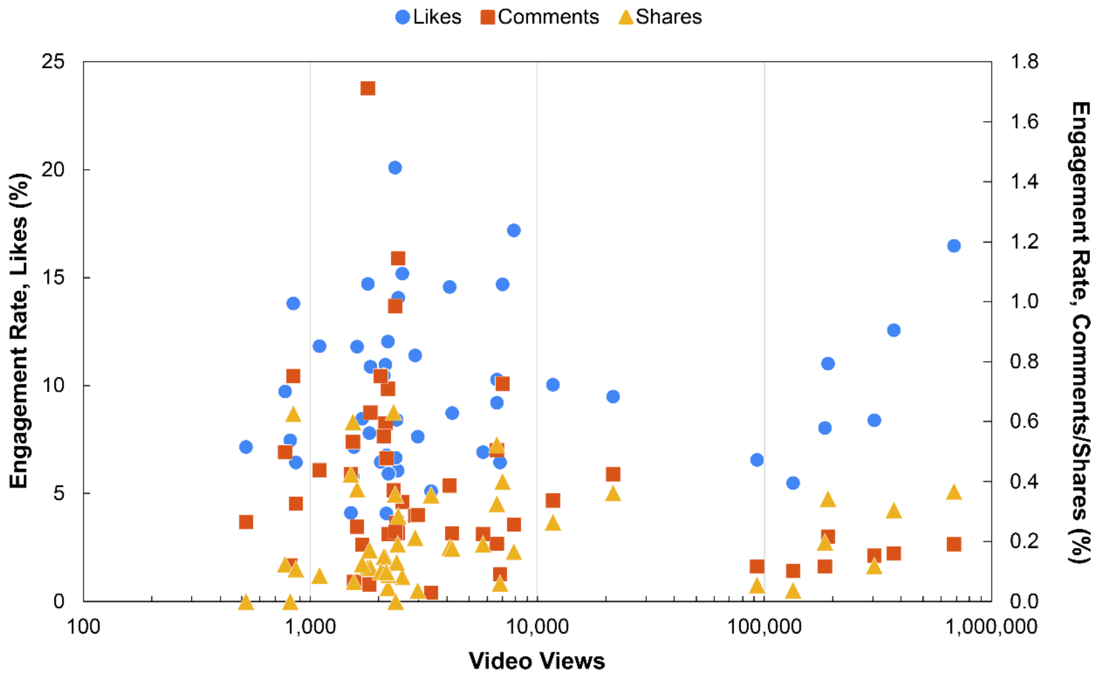


Figure ~~8~~6. Engagement rate of likes, comments, and shares from each video compared with video views (plotted on log scale). ~~Videos with a lower number of video views (~2,000) could have engagement rates as high or higher than videos that received hundreds of thousands of views~~ **There is a statistically significant strong positive correlation between the number of video views and the engagement rate of likes for videos with over 90,000 views (r = 0.90, p = 0.006), but no statistically significant correlation between the number of video views and the engagement rate of likes for videos with less than 90,000 views ($p > 0.05$). There is no statistically significant correlation between the number of video views and the engagement rate of comments or shares ($p > 0.05$). See Supplementary Materials for full correlation analysis.**

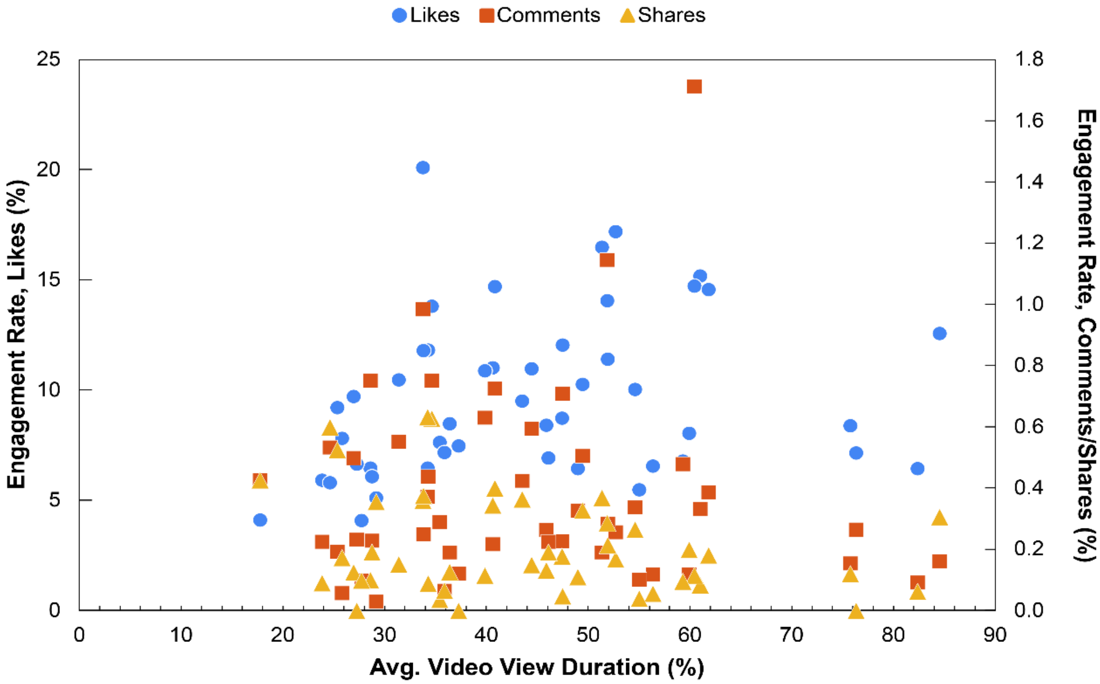


Figure ~~9~~7. Engagement rates from each video compared with the average view duration (%) of the video. There is no statistically significant correlation with the average view duration and any engagement rate metric (p >0.05). See Supplementary Materials for full correlation analysis.

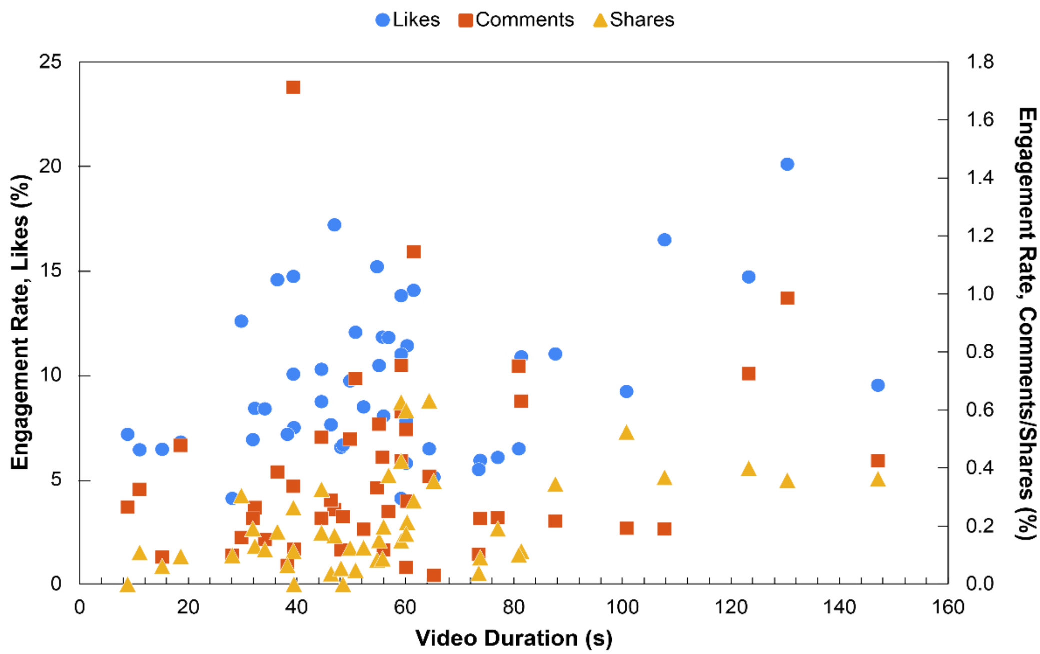


Figure ~~10~~8. Engagement rates from each video compared with the duration of the video. Short videos under 20 seconds have a lower overall engagement rate than do longer videos. There is a weak positive correlation that is statistically significant between the length of a video and the engagement rate of likes (r = 0.34, p = 0.017), and a weak to moderate positive relationship that is statistically significant between video length and the engagement rate of shares (r = 0.46, p = 0.001). There is no statistically significant correlation between video length and the engagement rate of comments (p > 0.05). See Supplementary Materials for full correlation analysis.

6.3 Hashtags

Across our 48 published videos, we used a total of 81 unique hashtags. Our videos most commonly used the hashtags "geophysics," "geology," and "earthquake" (**Table 4**). Even though the hashtags "geophysics" and "geology" were used on the most videos, videos that used the hashtag "earthquake" generated the most cumulative views. Hashtags like "SanAndreas" and "California" that were only used in four videos were also associated with a large number of views.

Only one video had higher than 1% of its views come directly from searching for hashtags or clicking on a hashtag to view videos (video ranked number 11 on **Fig. 5**). ~~A~~That video, explaining the Hunga Tonga-Hunga Ha'apai volcanic eruption in January 2022, received 3% of its views from direct hashtag searches. This post included the hashtags "HungaTonga" and "Tonga," from which the views were likely derived.

Between October 2021 and February 2022, the cumulative views of all videos using the "geology" hashtag across TikTok increased by 167.5 million views, with Terra Explore videos contributing 9% of those views, and the "geophysics" hashtag increased by 1.2 million views, with Terra Explore videos contributing 89% of those views.

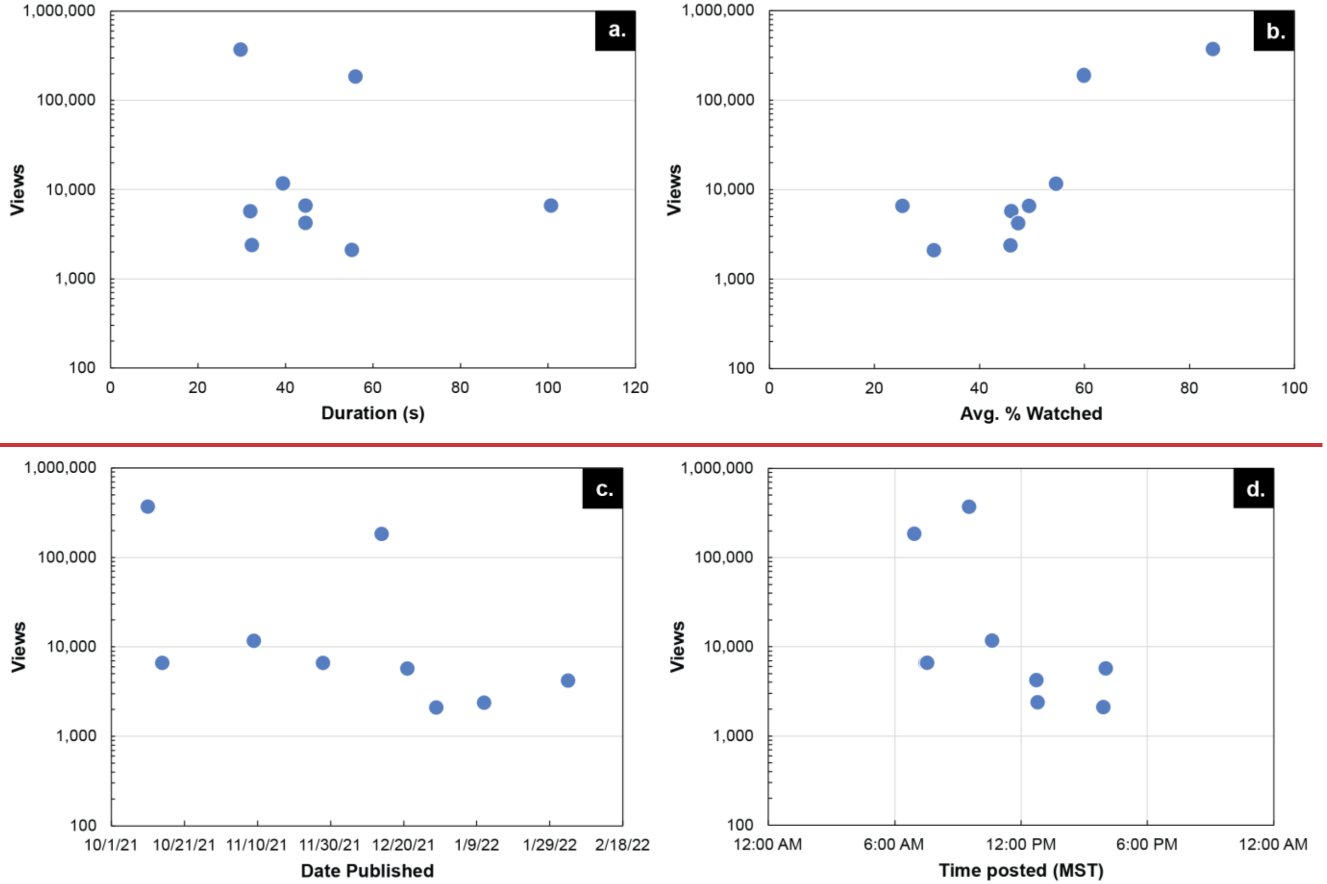
Hashtag	# of Videos Used in	Cumulative Views
Geophysics	38	1,073,171
Geology	36	1,511,813
Earthquake	31	1,974,026
Seismology	22	949,459
Science	8	148,978
Lidar	6	110,251
GPS	5	12,190
~~LearnOnTiktok~~LearnOnTikTok	5	32,854
SanAndreas	4	418,542
Earthquakes	4	11,651
FYP	4	15,079
California	4	1,013,653
Geoscience	3	4,221

Geodesy	3	5,861
SciComm	3	187,259

Table 4. Top 15 most commonly used hashtags on the Terra Explore videos indicating the number of videos they were used on, and the cumulative views associated with hashtag use. (FYP = "For You Page.")

6.4 GMV videos

Nine of the 48 videos produced featured ground motion visualizations (GMVs) of recent notable earthquakes. All nine of the GMV videos ~~produced~~ highlighted earthquakes that were magnitude 6 or larger. GMV videos were posted the day of or the day after an earthquake occurred and ended up being posted relatively consistently throughout the period of video production. Views for these videos ranged between 2,106 and 372,300 views. ~~All~~Eight videos were under 60 seconds in length ~~aside from~~, and one~~, which~~ was 100 seconds long~~, and the~~. The videos with the most views had a duration between 30–60 seconds, but there is no statistically significant correlation between video length and the number of views ($p > 0.05$) (**Fig.** ~~**11a**).~~ ~~The GMV videos~~ **9a**). We found that ~~had the highest viewer retention rates received the most views, and videos with lower retention rates generally received fewer~~there is a strong positive statistically significant correlation between the average video view duration and the number of video views ($r = 0.847$, $p = 0.004$) (**Fig.** ~~**11b**). GMV videos ended up being posted relatively consistently throughout the period of video production~~**9b**). There was no statistically significant correlation between the number of video views and the engagement rate of likes, comments, or shares ($p > 0.05$) (**Fig.** ~~**11c**), and videos~~**9c**). Videos were posted at different times during the day, with the videos that received the most views being posted in the morning Mountain Standard Time (MST) (~~**Fig. 11d**~~UTC-7). However, there is no statistically significant correlation between time posted and number of views ($p > 0.05$) (**Fig. 9d**). Regardless of the global location where the earthquake occurred, 84% of each videos' views on average came from users located within the United States. Therefore, these GMV videos were largely not being shown to users in countries where the earthquake occurred, but rather shown to users in North America (where the visualization is focused).


a.
Views
1,000,000
100,000
10,000
1,000
100
0
20
40
60
80
100
120
Duration (s)
b.
Views
0
20
40
60
80
100
Avg. % Watched
c.
Views
10/1/21
10/21/21
11/10/21
11/30/21
12/20/21
1/9/22
1/29/22
2/18/22
Date Published
d.
Views
12:00 AM
6:00 AM
12:00 PM
6:00 PM
12:00 AM
Time posted (MST)

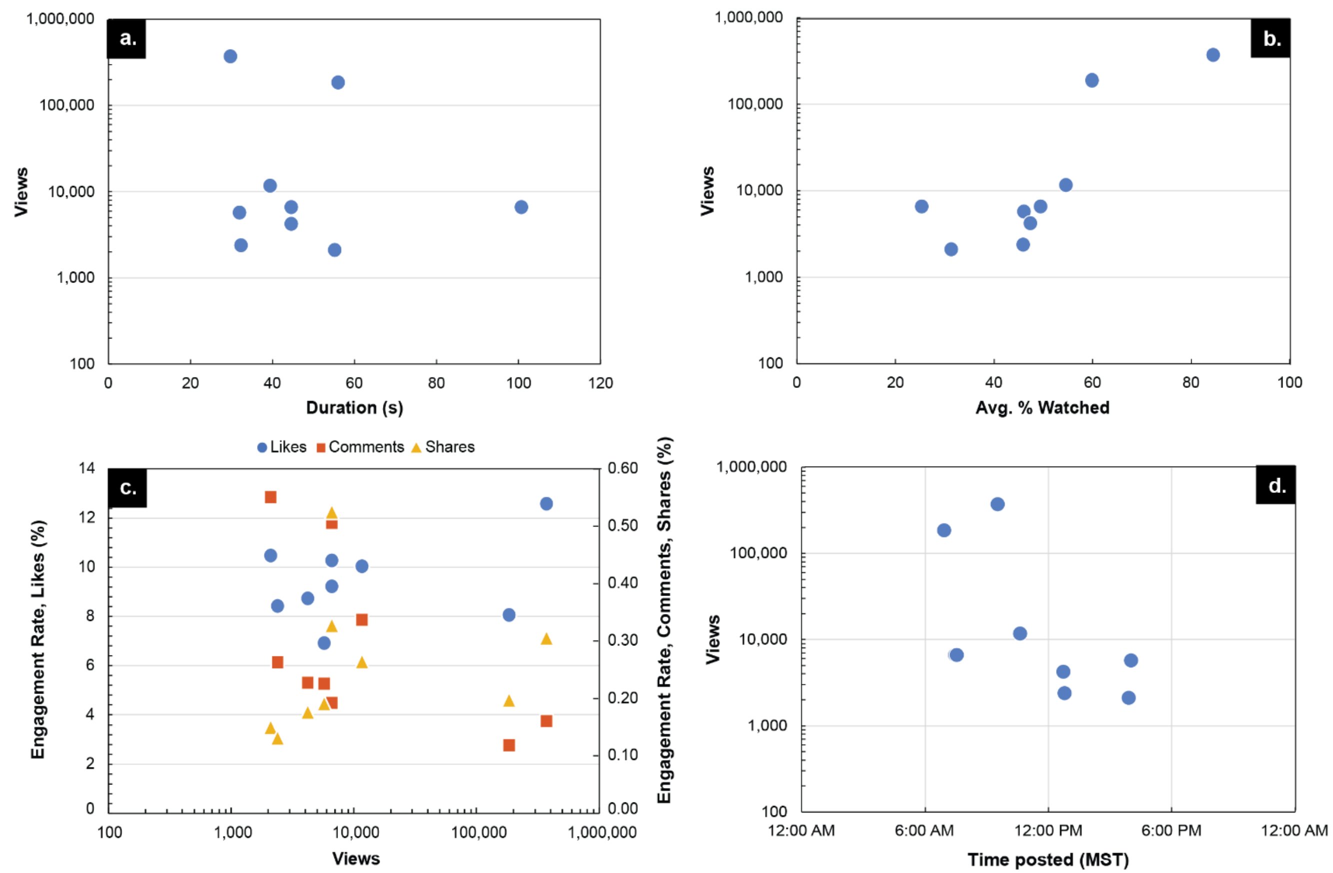


Figure ~~11~~9. Video views of GMV videos on a log scale compared with (a) the duration of the video, (b) the average duration a video was watched, (c) the ~~date~~ engagement rates of the video~~ was posted on~~, and (d) the time of day the video was posted (MST~~).~~) (UTC-7). There is a strong positive statistically significant correlation between the average video view duration and the number of video views (r = 0.847, p = 0.004), but there is no statistically significant correlation (p > 0.05) between the other parameters. See Supplementary Materials for full correlation analyses.

7 Discussion

7.1 Video views and viewership

~~Short videos (~20 seconds or less) on TikTok may have a higher potential to accumulate views as they can easily be played in a "loop" like a GIF, but our data does not indicate any clear correlation between video duration and number of video views (**Fig. 7**). Additionally, short (< 20s) videos had lower engagement rates than did longer videos. Videos 40 seconds to 2 minutes in length received the highest engagement rates (**Fig. 10**). Even though some of these videos did not perform exceptionally well in terms of view counts, they still tended to have relatively high engagement rates. Videos < 20 s had an average engagement rate of 6.5% for likes, whereas videos between 40 s and 2 minutes had an average engagement rate of 10% for likes. High engagement rates on videos with lower view counts likely come from people who are following the account~~

~~and have an express interest in the subject. Based on our findings, post-time optimization such as posting earlier in the day and earlier in the week may aid in having videos reach a wider audience.~~

The vast number of video views ~~being~~ received from the *For You* page rather than the *Following* feed demonstrates that content on TikTok is primarily consumed from the *For You* page, and that the success of a video largely hinges on whether it will continue to be shown to more users on ~~the *For You* page.~~this algorithmic feed. Our findings are in accordance with TikTok's internal data that users spend the ~~vast~~ majority of time (nearly 70%) on the *For You* page on the app (Stokel-Walker, 2020). With users spending less time on the *Following* feed, this feed naturally provides a lower overall source of video views. Even when a person is following an account, those videos can still be shown on the *For You* page. The view, although coming from a follower, would still be marked as a view from the *For You* page. Our findings support other work showing that video views on TikTok are less dependent on the number of followers/subscribers as compared to other platforms like YouTube (Guinaudeau et al., 2021). While the number of followers can support the credibility of an account, a large number of followers is not required to reach a large viewership on TikTok, and having a high number of followers on TikTok does not guarantee equally high video views.

Short videos (~20 seconds or less) on TikTok may have a higher potential to accumulate views as they can easily be played in a "loop" like a GIF, but our data suggests that users are more likely to engage and interact with longer (>60 s) educational science videos (**Fig. 8**). Even though some of these longer videos did not perform exceptionally well in terms of view counts (**Fig. 6**), they still tended to have relatively high engagement rates. Videos < 20 s had an average engagement rate of 6.5% for likes, whereas videos between 40 s and 2 minutes had an average engagement rate of 10% for likes. While it is suspected that higher engagement rates on TikTok videos lead to higher views (Klug et al., 2021), we did not observe any clear relationship between the number of video views and the engagement rate (**Fig. 6**). We found that only for our most highly viewed videos (videos with >90,000 views) there was a strong positive correlation between the number of views and the engagement rate of likes. High engagement rates on videos with lower view counts may come from people who are following the account and have an expressed interest in the subject.

The lack of any discernible relationship between the average view duration of a video and the engagement rate (**Fig. 7**) demonstrates that these two factors are not coupled and suggests that a video likely needs both a high engagement rate and a high view duration to be promoted within algorithmic feeds. Our top ten most viewed videos had an average view duration of 58% and an average engagement rate of 11% for likes (**Table 2**), greater than the average view duration of 44% and 10% likes across all of our videos. Unlike platforms like YouTube where users select which video to view, users on TikTok choose whether to continue viewing a video they were automatically shown. While some highly interested users may watch the majority of the video and engage with it, if too many users quickly scroll away, it will negatively impact the average view duration of the video and its reach. If the intent of the science content is to maximize the engagement level from the viewer, then producing longer (> 60 s) lecture-style videos is preferable. However, the reach of the video may be sacrificed with longer videos if too many users scroll away from the video too quickly. Thus, the communication objectives should dictate what video type and duration is used.

Unlike platforms such as Twitter where users may search for a specific hashtag to view content related to a topic (Chang and Iyer, 2012), viewer behavior in regard to educational science content on TikTok largely does not entail searching for specific hashtags to view content~~.~~, unless related to a specific newsworthy event. On average, only 0.02% of our video views came directly from hashtag searches. Thus, hashtags ~~are~~appear most useful in categorizing content, which may aid in its algorithmic discovery on the *For You* page—although the factors used in TikTok's algorithm have not been publicly disclosed. The use of a hashtag itself will not necessarily determine the popularity of a video, but rather the hashtag is reflective of the content and subject matter of the video.

We also found that there was little relationship between the time a video was posted and how well it performed (**Fig. 2, 9d**). Post time optimization is the concept of posting social media content at a time when most users/followers are active and online and likely to see the content, thus increasing its potential reach. As the majority of our account's followers are located within the United States, we focused our posting during daytime hours within the U.S. before followers would logoff online for the night. However, it would be interesting, especially if wanting to attract an international audience, to see how videos perform if they are posted during nighttime hours in the U.S. We anticipate that videos should be posted at a time local to when the desired or majority audience is primarily online.

7.2 Generating high video reach and engagement

While ~~post optimizations related to video~~ intrinsic features such as the length ~~and posting time can aid in the discovery~~ of ~~a~~the video may impact engagement metrics, the content of the video itself is an equally important consideration when attempting to reach a wide audience and generate high engagement. Based on our most viewed videos (**Table 2**), we found that videos with the highest reach focused on recent newsworthy events (e.g., an earthquake) or discussed specific ~~place-based geology.~~location-based geology. These findings support pedagogical research that suggests that recent, real-world incident examples should be included when teaching geoscience or environmental science topics to increase student engagement and interest (Singh et al., 2022).

Given our organizational missions, a high percentage of our video content focused on earthquakes and seismology, with all notable recent earthquakes being covered in GMV videos. These videos generated high interest by providing real-time ~~videos~~information about earthquakes in the news, shown in a data visualization format that was likely novel to the public. User comments on GMV videos typically expressed how it was a unique, interesting visualization that they had not seen before. Additionally, by showing the motion recorded on seismometers across North America where the vast majority of our followers are located, users in those areas were able to view how the ground moved near them, adding a level of personal, ~~place-based interest.~~ location-based interest. User comments also often expressed interest in the distribution of seismic instruments in North America.

We also found high reach and engagement with videos covering other relevant, newsworthy geology topics. For example, we produced videos covering the January 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption and the anniversary of the January 1700 Cascadia earthquake and tsunami. These videos were our eleventh and eighth most viewed videos, respectively~~. The Hunga Tonga video had the sixth highest engagement rate for comments (0.7%), and the Cascadia 1700 earthquake video had the ninth highest engagement rate for shares (0.4%).~~, and were a “lecture-style” that primarily used image overlays. Comments left on these videos typically expressed that the users enjoyed the overview of information and how it was conveyed. The Hunga Tonga video was also shown to a wider international audience, with only 66% of views coming from users located in the United States. Thus, if the focus of the video is on a specific international location/event, the video may be served to a broader audience. Research from educational geoscience videos on YouTube also suggests that short, timely videos about natural hazards are useful for engaging the public, especially those who live near where the hazards occur (Wang et al., 2022).

Videos describing geologic processes or features were most successful when they were tied to a specific, recognizable location. These videos were done in a “lecture style,” typically using “green screen” backgrounds and image overlays. Based on user comments, videos that were about a geologic feature in a specific location that were tagged with location indicators (e.g., #Hayward #California; #Hollister #California) were shown to many people who live in those cities. Although these users may not have previously interacted with or shown interest in geoscience content, we hypothesize that location-based information was used to deliver these videos to their *For You* page. Based on these video comments, the high engagement was generated in part by users from those geographic locations. Many commented that they were from the locations being covered; some recognized features in the town they were familiar with, and others learned something new and interesting about the geology of where they live.

In spite of these data, there is still complexity in understanding why certain videos perform better than others. ~~We~~For example, we produced two demonstration videos using food as analogs for geologic concepts. A video using spaghetti strands to demonstrate earthquake magnitude received 305,500 views and was our third most viewed video (**Table 2**), while a video using Halloween candy bars to demonstrate types of faults received only 840 views and was our fourth least viewed video (**Table 3**). Both of these videos presented concepts that were made easy for the viewer to understand by using common food items, and they were both posted on the same day of the week (Friday) and before noon MST~~.~~ (6 pm UTC). It is possible that for demonstration videos like these—which are more analogous to chemistry or physics content showing experiments—that a shorter video duration is better for achieving high reach and engagement. The earthquake spaghetti video was 34 seconds long, while the candy bar faults video was 59 seconds long. A viewer may be more likely to watch a longer lecture-style video but may prefer shorter, dynamic demonstration videos.

7.3 Gender of viewers and target audiences

Although we used the hashtags #WomenInSTEM and #WomenInScience on a number of videos, the majority of the Terra Explore account’s followers remained male (~64% male~~) (**Fig. 3**~~). Given the fact that 61% of users on TikTok are female (Statista, 2021), the gender breakdown of our followers is not representative of the demographics of TikTok users. The large percentage (25%) of TikTok users that are under the age of 19 (Statista, 2022a) represents a critical demographic for maintaining interest in STEM. Research has shown that STEM interest begins to decline in middle school, especially for girls

(Archer et al., 2010; Riegle-Crumb et al. 2017; Sadler et al., 2012). Additionally, many students have little exposure to the geosciences during their K-12 education (Dodick and Orion, 2003; Lewis and Baker, 2010; Ridky, 2002), which means that young girls are often left without geoscience role models. Through TikTok, we can engage with this critical demographic and hope to inspire young women to continue an interest in pursuing STEM and see themselves as future STEM professionals.

However, the presentation of material by female scientists and the use of hashtags like #WomenInSTEM or #WomenInScience on TikTok may not be enough to gain female followers and viewership; the content itself may also have to focus on gender~~.~~ to be shown on women's *For You* pages. Experience from the lead author's personal TikTok account suggests that women~~ and nonbinary individuals~~ may be more likely to receive videos about gender discrimination and gender disparity on their *For You* page than educational science content~~. On the ~~, even if they are interested in science. The lead ~~author's ~~author made a video on their personal TikTok account~~, a video~~ discussing how their follower base had become overwhelmingly male (75% male followers) and used the #WomenInSTEM hashtag. The video gained wide female ~~and nonbinary ~~viewership, leading to a large increase in followers and flipping the percentage of followers ~~flipped ~~to 86.1% female. The second author also had a similar experience on their personal TikTok after making a series of posts about the IF/THEN organization and International Women's Day, with male following decreasing from 65% to 17%.

As TikTok ~~does~~did not provide information about the age of followers or viewers for videos posted prior to August 2022, we are unable to evaluate the full demographics of who our videos reach. Future work may benefit from creating and analyzing new videos where the ~~utilization of~~gender percentage and age of viewers is reported, or from using the paid ~~"Promote"~~'promote' feature~~, an advertising tool used to gain views and followers. This feature~~ that allows ~~the selection of particular viewing~~accounts to target specific demographics~~, as well as a more granular breakdown of viewers, including enhanced gender reporting~~.

7.4 Ethics of TikTok data usage

When conducting research on social media platforms, it is necessary to address the ethical issues related to privacy, anonymity, and consent of human subjects (Vitak et al., 2016). Kanthawala et al. (2022) highlights the specific ethical considerations related to research on TikTok given its heavier dependence on algorithmic curation and its younger user base. More so than other social media platforms, TikTok has faced scrutiny over the data that it collects from its users and user security. TikTok has previously paid $92 million to settle dozens of lawsuits that allege that users' personal data was tracked and sold to advertisers in violation of state and federal law (Allyn, 2021). There additionally has been scrutiny over the biometric data including "faceprints" and "voiceprints" that TikTok can now collect from users (McCluskey, 2021).

According to TikTok's privacy policy, TikTok collects information that the user provides when creating an account, such as their name, age, and email, as well as information from other sources, such as linked social media accounts and third-party services, and device information, including the user's approximate location (TikTok, 2021b). By creating a user account and agreeing to the terms and conditions, TikTok users provide their ~~'consent'~~consent to have their information collected.

However, many users are unlikely to read the privacy policy when creating an account and will not be aware of what they are consenting to.

Although TikTok provides analytical information about the gender breakdown of an account's followers, users do not provide information on their gender when registering for an account. We hypothesize that TikTok either acquires gender information through connected social media accounts or assumes the gender of an account based on a user's activity on the app. We are therefore unable to determine how accurate the information provided on the gender of followers is and whether users are aware that this information is assumed or collected on their behalf. However, we have no reason to believe that this information would be inaccurate due to TikTok's heavy data mining and the fact that this same demographic information is also provided to million-dollar corporations for targeted advertising campaigns.

The information and data we analyze in this study is ~~essentially~~ restricted to video view duration and engagement metrics and is not related to in-depth personal user information that TikTok may collect. We do not evaluate or analyze the individual followers of the Terra Explore account or include specific comments from any users, providing full anonymity. The data on video views, likes, comments, and shares is fully publicly available to all users, and only total cumulative play time, average duration the video was watched, percentage of viewers who watched the full video, and the percentage of video views by section and region is private to the account user. Therefore, the data used is largely public and there is minimal risk to the individual users from this research. While TikTok as a platform may have larger ethical concerns that are beyond the scope of this study, we argue that the data used in this research is ethical.

7.5 Potential for science communication on TikTok

Data collected over this four-month timespan demonstrates that TikTok provides ~~unparalleled~~incredible potential for reach and growth of science communication. As a brand-new account, the second video we posted gained over 165,000 views within the first few days and now has over 370,000 views. The algorithm-driven (rather than follower-driven) nature of TikTok creates a low barrier of entry for new creators. An account does not have to focus on creating a large following in order to achieve a wide reach. As well, there are no materials required to produce content other than a mobile smartphone with a camera. However, given that views from the *Following* feed constitute a low overall percentage of views, there may be pressure to constantly produce "viral" videos that are shown widely on the *For You* page. Having a large number of followers does not guarantee that a video will be seen by a large number of people.

Despite potential shortcomings, TikTok presents an unquestionable opportunity to deliver educational science videos to wide audiences with relatively little effort. All six Terra Explore videos related to lidar were cross-posted on OpenTopography's YouTube channel as "Shorts," which is YouTube's TikTok-like short-form video category. The OpenTopography YouTube channel had 1,900 subscribers at this time. These videos received an average of only ~~34~~35 views on YouTube, while the same videos received between 2,422 and 133,500 views on TikTok. Starting in February 2022, we began cross-posting GMV videos for recent earthquakes on IRIS's Instagram account as "Reels," Instagram's TikTok-like video category. The IRIS Instagram account has approximately 2,300 followers as of Fall 2022. The exact same videos received on average five times more views on TikTok than they did on Instagram. The vast discrepancy in views of the exact same videos posted on different platforms highlights the benefits of TikTok's recommendation algorithm in reaching a wide audience.

A potential challenge is that TikTok videos require an engaging, charismatic video presenter: two people could create the same video, but one video might perform significantly better if one host has a more natural, charismatic presentation style. We have not evaluated how this factor impacts video performance. In addition to the content of the video itself, practice in the presentation style of videos (which is beyond the scope of this study) is also an important component for science communicators to consider. As well, we acknowledge that TikTok's recommendation algorithm may change over time, although we don't anticipate such significant changes would occur in a short amount of time that would invalidate our results. Future studies will benefit from continued analysis of video content, as well as a more qualitative evaluation of the impact and effectiveness of the science communication.

We thus recommend the following for the best chances of high reach and engagement with science communication on TikTok:

- Produce lecture-style videos using ~~greenscreen~~green screen and image overlay effects that are approximately 60 seconds or longer in duration.
- Produce demonstration or experiment-style videos that are ≤ 30 seconds in duration.
- ~~Post videos earlier in the day and earlier in the week and maintain a relatively consistent posting schedule.~~
- Choose video topics that ~~are~~can be related to recent newsworthy events or are tied to a specific place or location.
- Include gender-related topics to reach a wider female audience.
- Select hashtags that are relevant to the video topic, especially ones including locations to provide additional algorithmic video context.
- Pay attention to videos that receive the majority of their views from the *For You* page and work to replicate those qualities.

8 Future plans

As we continue to run the Terra Explore account, we plan to expand the scope of the geoscience topics that we cover and to continue analyses of how to best maximize reach and engagement from these videos. While the geoscience content of our videos has been largely focused on earthquakes thus far, we plan to include discussion of other natural hazards like volcanic eruptions, floods, landslides, etc. This expansion naturally segues into an opportunity to produce content related to climate and climate change. Encouraging science curiosity helps to neutralize polarization on topics like climate change (Kahan et al., 2017), and TikTok provides an ideal platform to promote such curiosity.

While all of our videos ~~produced~~analyzed thus far ~~have been~~were created in home offices, we believe producing content from the field could generate high video views and user engagement. Instead of merely showing photos, field-based videos could present and highlight seismic or GPS instruments and their installation and maintenance, geologic features you can see in the field, or how drones are used in geoscience, among many other possibilities. Five field-based videos that we created between April to September 2022 after our analytical study period received between 3,620 and 779,100 views on TikTok. Given the more costly and time-intensive nature of producing videos on location, a full analysis of their metrics would be necessary to see if they have higher reach and engagement than similar videos produced in home offices.

To better reach target audiences like young women and girls and to improve the overall diversity of scientists shown in popular media, we would like to produce a "Meet the Scientist" video series to highlight female and nonbinary geoscientists, sharing both their research and experiences. These types of videos would complement and expand on the IF/THEN "Women in Geoscience" video series available on the IRIS YouTube channel that features women in the geosciences sharing their work and interests. The geosciences remain one of the least racially and ethnically diverse out of all the STEM fields (Bernard and Cooperdock, 2018), and "Meet the Scientist" interviews featuring underrepresented scientists on TikTok will help to increase the visibility of minoritized scientists and show the broad diversity of scientists and careers that exist in geoscience.

9 Conclusions

TikTok offers ~~unparalleled~~exceptional potential for reach and growth of science communication content. TikTok functions primarily on a model of algorithmic recommendations rather than a follower-based model, which provides a low barrier to entry for new creators. Although the exact nature of the TikTok algorithm is unknown and therefore somewhat challenging in reaching target audiences, ~~particular features, such as the "Promote" tool,~~new age and gender analytics that were released in August 2022 may provide additional insight into the demographics that are engaging with content. In the assessment of our geoscience content, lecture-style videos that were ~~in the range of 40 seconds to 2 minutes~~approximately a minute long yielded the highest reach and engagement. Video topics that discussed recent newsworthy events (i.e., earthquakes) or discussed specific ~~place~~location-based geology resulted in the highest reach and engagement. Shorter-form content (< 30 seconds) did not perform as well unless it was a demonstration-style video, which would be more analogous to the physics and chemistry experiments that are commonly seen on TikTok. Unlike other platforms, user behavior on TikTok does not entail searching for or browsing specific hashtags to view educational science videos. Rather, videos are predominantly viewed via the *For You* page, and hashtags provide a way to categorize and describe content—information which may or may not be used by TikTok's AI to show the video to audiences. Although this study focuses on the geosciences, we anticipate that our findings will be broadly applicable to other scientific disciplines and will allow science communicators success in reaching broad audiences.

Data availability

The video data analyzed in this study is accessible at https://doi.org/10.6084/m9.figshare.20069333 (Zawacki, 2022).

Author contributions

The Terra Explore videos analyzed here were created by EZ and WB, in addition to SJ. DC provided project administration and coordination. EZ collected and analyzed the data and wrote the primary draft. WB, SJ, and DC contributed to the writing, review, and editing.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

We thank two anonymous reviewers for their helpful comments on an earlier version of this manuscript. We thank Zhiang Chen for their assistance with the correlation analyses. We thank Christopher Crosby for project guidance.

Financial statement

This work was supported by NSF awards #1724794, #1948997, #1948994, and #1948857.

References

Allyn, B. (2021, February 25). "TikTok to Pay $92 Million to Settle Class-Action Suit over 'Theft' of Personal Data." *NPR*. Retrieved June 14, 2022 from, https://www.npr.org/2021/02/25/971460327/tiktok-to-pay-92-million-to-settle-class-action-suit-over-theft-of-personal-data.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. Pedagogy, Culture & Society, 21(1), 171-194. https://doi.org/10.1080/14681366.2012.748676

Azman, A. N., Rezal, N. S. A., Zulkeifli, N. Y., Mat, N. A. S., Saari, I. S., & Ab Hamid, A. S. (2021). Acceptance of TikTok on the Youth towards Education Development. *Borneo International Journal*, eISSN 2636-9826, 4(3), 19-25. Retrieved February 11, 2022 from http://majmuah.com/journal/index.php/bij/article/view/98

Basch, C. H., Yalamanchili, B., & Fera, J. (2022). #Climate Change on TikTok: A Content Analysis of Videos. *Journal of Community Health*, 1-5. https://doi.org/10.1007/s10900-021-01031-x

Bernard, R. E., & Cooperdock, E. H. (2018). No progress on diversity in 40 years. *Nature Geoscience*, 11(5), p. 292-295. https://doi.org/10.1038/s41561-018-0116-6

Briskman, J. (2020, April). Sensor Tower's Q1 2020 Data Digest: Exploring COVID-19's Impact on the Global App Ecosystem. *Sensor Tower*. Retrieved February 15, 2022, from https://sensortower.com/blog/q1-2020-data-digest

Chang, H. C., & Iyer, H. (2012). Trends in Twitter hashtag applications: Design features for value-added dimensions to future library catalogues. *Library Trends*, 61(1), 248-258.

Côté, I. M., & Darling, E. S. (2018). Scientists on Twitter: Preaching to the choir or singing from the rooftops?. *Facets*, 3(1), 682-694. https://doi.org/10.1139/facets-2018-0002

Dodick, J., & Orion, N. (2003). Geology as an historical science: Its perception within science and the education system. *Science & Education*, *12*(2), 197-211. https://doi.org/10.1023/A:1023096001250

Draganić, K., Marić, M., & Lukač, D. (2021). An application of TikTok in higher education. *E-Business Technologies Conference Proceedings*, 1(1), 114–119. Retrieved February 11, 2022 from https://ebt.rs/journals/index.php/conf-proc/article/view/75

Escamilla-Fajardo, P., Alguacil, M., & López-Carril, S. (2021). Incorporating TikTok in higher education: Pedagogical perspectives from a corporal expression sport sciences course. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 28, 100302. https://doi.org/10.1016/j.jhlste.2021.100302

Feldkamp, J. (2021). The rise of TikTok: The Evolution of a social media platform during COVID-19. In *Digital Responses to Covid-19* (pp. 73-85). Springer, Cham. https://doi.org/10.1007/978-3-030-66611-8_6

Guinaudeau, B., Vottax, F., & Munger, K. (2021). Fifteen Seconds of Fame: TikTok and the Supply Side of Social Video. https://osf.io/zvq8w/

Hautea, S., Parks, P., Takahashi, B., & Zeng, J. (2021). Showing they care (or don't): Affective publics and ambivalent climate activism on TikTok. *Social Media + Society*, 7(2), 20563051211012344. https://doi.org/10.1177/20563051211012344

Hilary, I. O., & Dumebi, O. O. (2021). Social Media as a Tool for Misinformation and Disinformation Management. *Linguistics and Culture Review*, 5(S1), 496-505. https://doi.org/10.21744/lingcure.v5nS1.1435

Habibi, S. A., & Salim, L. (2021). Static vs. dynamic methods of delivery for science communication: A critical analysis of user engagement with science on social media. *PloS One*, 16(3), e0248507. https://doi.org/10.1371/journal.pone.0248507

Hayes, C., Stott, K., Lamb, K. J., & Hurst, G. A. (2020). "Making every second count": utilizing TikTok and systems thinking to facilitate scientific public engagement and contextualization of chemistry at home. *Journal of Chemical Education*, 97 (10), 3858-3866. https://doi.org/10.1021/acs.jchemed.0c00511

Hight, M. O., Nguyen, N. Q., & Su, T. A. (2021). Chemical anthropomorphism: acting out general chemistry concepts in social media videos facilitates student-centered learning and public engagement. *Journal of Chemical Education*, 98(4), 1283-1289. https://doi.org/10.1021/acs.jchemed.0c01139

~~Insider Intelligence (2021, December 16). TikTok is the third largest worldwide social network behind Instagram and Facebook. *eMarketer Newsroom*. Retrieved March 16, 2022 from, https://www.emarketer.com/newsroom/index.php/tiktok-is-the-third-largest-worldwide-social-network-behind-instagram-and-facebook/~~

Jahng, M. R., & Lee, N. (2018). When scientists tweet for social changes: Dialogic communication and collective mobilization strategies by Flint water study scientists on Twitter. *Science Communication*, 40(1), 89-108. https://doi.org/10.1177/1075547017751948

Kanthawala, S., Cotter, K., Foyle, K., & DeCook, J. R. (2022, January). It's the Methodology For Me: A Systematic Review of Early Approaches to Studying TikTok. In HICSS (pp. 1-17). https://hdl.handle.net/10125/79716

Kirchhoff, D. (2021, July 1). More Tok on the Clock: Introducing longer videos on TikTok. *TikTok Newsroom*. Retrieved February 14, 2022, from https://newsroom.tiktok.com/en-us/longer-videos

Kahan, D. M., Landrum, A., Carpenter, K., Helft, L., & Hall Jamieson, K. (2017). Science curiosity and political information processing. *Political Psychology*, 38, 179-199. https://doi.org/10.1111/pops.12396

Klug, D., Qin, Y., Evans, M., & Kaufman, G. (2021). Trick and please. A mixed-method study on user assumptions about the TikTok algorithm. In *13th ACM Web Science Conference 2021* (pp. 84-92). https://doi.org/10.1145/3447535.3462512

Lewis, E. B., & Baker, D. R. (2010). A call for a new geoscience education research agenda. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(2), 121-129. https://doi.org/10.1002/tea.20320

McCluskey, M. (2021, June 14). TikTok Has Started Collecting Your 'Faceprints' and 'Voiceprints.' Here's What It Could Do With Them. *Time*. Retrieved June 14, 2022 from https://time.com/6071773/tiktok-faceprints-voiceprints-privacy/.

Radin, A. G., & Light, C. J. (2022). TikTok: an emergent opportunity for teaching and learning science communication online. *Journal of Microbiology & Biology Education*, 23(1), e00236-21. https://doi.org/10.1128/jmbe.00236-21

Ridky, R. (2002). Why We Need a Corps of Earth Science Educators. *Geotimes*, *47*(9), 16-19.

Riegle-Crumb, C., & Morton, K. (2017). Gendered expectations: Examining how peers shape female students' intent to pursue STEM fields. *Frontiers in psychology*, *8*, 329. https://doi.org/10.3389/fpsyg.2017.00329

Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*, 96(3), 411-427. https://doi.org/10.1002/sce.21007

Schmitt, M., & Jäschke, R. (2017). What do computer scientists tweet? Analyzing the link-sharing practice on Twitter. *PloS One*, 12(6), e0179630. https://doi.org/10.1371/journal.pone.0179630

Sensor Tower (2022). Q1 2022: Store Intelligence Data Digest. *Sensor Tower*. Retrieved August 26, 2022, from https://go.sensortower.com/rs/351-RWH-315/images/Sensor-Tower-Q1-2022-Data-Digest.pdf

Shu K., Wang S., Lee D., Liu H. (2020). Mining Disinformation and Fake News: Concepts, Methods, and Recent Advancements. In: Shu K., Wang S., Lee D., Liu H. (eds) *Disinformation, Misinformation, and Fake News in Social Media*. Lecture Notes in Social Networks. Springer, Cham. https://doi.org/10.1007/978-3-030-42699-6_1

Singh, A., Khandaker, N., Zarine, A., Robbins, K.H., Jackson, S., Ahmed, S. (2022). Assessing student performance and interest from the start of the COVID-19 pandemic to present using engagement, attendance, and grades as indicators. *Geological Society of America Abstracts with Programs*, Vol 54, No. 5. https://doi.org/10.1130/abs/2022AM-379409

Smith, A. (2015). "Wow, I didn't know that before; thank you": How scientists use Twitter for public engagement. *Journal of Promotional Communications*, 3(3), 320-339.

Smith, B. (2021, December 6). How TikTok Reads Your Mind. *The New York Times*. Retrieved March 16, 2022, from https://www.nytimes.com/2021/12/05/business/media/tiktok-algorithm.html

Statista Research Department. (2022a, January). Distribution of TikTok users in the United States as of September 2021, by age group. *Statista*. Retrieved February 14, 2022, from https://www.statista.com/statistics/1095186/tiktok-us-users-age/

Statista Research Department. (2022b, January). Number of first-time TikTok installs from 2nd quarter 2016 to 4th quarter 2021. *Statista*. Retrieved March 16, 2022, from https://www.statista.com/statistics/1078692/china-tiktok-worldwide-downloads-quarterly/

Statista Research Department. (2021, April). Distribution of monthly active TikTok users in the United States as of March 2021, by gender. *Statista*. Retrieved February 14, 2022, from https://www.statista.com/statistics/1095201/tiktok-users-gender-usa/

Stokel-Walker, C. (2020). Inside TikTok's latest big pitch to advertisers with new numbers showing time spent on the app and engagement metrics. *Business Insider*. Retrieved February 8, 2022, from https://www.businessinsider.com/leaked-tiktok-slides-engagement-time-spent-activity-2020-9

TikTok (2021a, September 27). "Thanks a billion!" *TikTok Newsroom*. Retrieved February 8, 2022, from https://newsroom.tiktok.com/en-us/1-billion-people-on-tiktok

TikTok (2021b, June 2). "Privacy Policy." *TikTok Legal*. Retrieved June 14, 2022, from https://www.tiktok.com/legal/privacy-policy-us?lang=en

TikTok (2010, June 18). "How TikTok Recommends Videos #ForYou." *TikTok Newsroom*. Retrieved February 8, 2022, from https://newsroom.tiktok.com/en-us/how-tiktok-recommends-videos-for-you/

Thoensen, B. (2020, May 28). Investing to help our community #LearnOnTikTok. *TikTok Newsroo*m. Retrieved February 8, 2022, from https://newsroom.tiktok.com/en-us/investing-to-help-our-community-learn-on-tiktok

Vitak, J., Shilton, K., & Ashktorab, Z. (2016, February). Beyond the Belmont principles: Ethical challenges, practices, and beliefs in the online data research community. In Proceedings of the *19th ACM conference on computer-supported cooperative work & social computing* (pp. 941-953). https://doi.org/10.1145/2818048.2820078

Wang, N., Clowdus, Z., Sealander, A., & Stern, R. (2022). Geonews: timely geoscience educational YouTube videos about recent geologic events. *Geoscience Communication*, 5(2), 125-142.

Zawacki, Emily (2022): TikTokData.xlsx. *figshare*. Dataset. https://doi.org/10.6084/m9.figshare.20069333.v1

Zeng, J., Schäfer, M. S., & Allgaier, J. (2020). Reposting "till Albert Einstein is TikTok famous": The memetic construction of science on TikTok. *International Journal of Communication*, 15, 3216-3247. https://doi.org/10.5167/uzh-205429