

The power of dinosaurs: lessons learned from the sharing of #SciArt on Twitter

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Abstract

We used netnographic analysis to outline a structure of the #SciArt community on Twitter/X finding a surprising interest in dinosaurs, even in the midst of a pandemic. Recently, SciArt, broadly, science-themed art, has gained attention among science communicators for its ability to engage a wide range of audiences in scientific findings. We gained insights into how paleoart passes between and among audiences and explored the phenomena of perennially popular dinosaur-themed works of SciArt in popular science communication. We discussed these effects and how they could be used to engage people with SciArt in science communication efforts.

Keywords

Popularization of science and technology; Public perception of science and technology; Representations of science and technology

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Context

A scientifically engaged public, one that engages with science in complex and meaningful ways, can make informed decisions about current issues [Irwin & Wynne, 1996]. Especially throughout the COVID-19 pandemic, scientific information played a part in guiding policy and personal choices, that determined outcomes for the world population [Klenert, Funke, Mattauch & O'Callaghan, 2020].

An art-based method of communicating scientific concepts with non-specialists, SciArt, is gaining popularity for its ability to engage people [Fleerackers, Brown Jarreau & Krolik, 2022]. SciArt, science-based or themed art, can illustrate science concepts with scientifically non-traditional means and engage people in science and scientific discovery. During the Renaissance, polymaths took inspiration from art to invent and push forward technological progress while simultaneously creating art inspired by scientific discoveries [Zhu & Goyal, 2019]. This type of collaboration had fallen out of popularity in the Western world by the modern era,

however, wherein the separation of art and science was emphasized [Richmond, 1984]. Science was understood to be a way of objectively understanding the world which we inhabit; art was considered a subjective interpretation of one's personal experiences [Richmond, 1984].

The rift between art and science was criticized in the mid-twentieth century though, and in 1959, Snow [1993] described the breakdown of communication between art and science. He emphasized how this separation of the disciplines affects our ability to properly address the world's issues, and integration of these ways of thinking has been shown to promote a more comprehensive understanding of our surroundings and promote innovation [Buntaine, 2014; Dail, 2013]. In light of this paradigm shift, in recent years, there has been a push to encourage collaboration between the sciences and arts which has developed into the STEAM (Science, Technology, Engineering, Arts, and Math) movement [Hall, 2013]. The STEAM movement seeks not only to have people incorporate art into their studies but to also allow the creation of art to inspire and guide the direction of science [Dail, 2013].

Programs across the globe partner artists with scientists and display works in galleries or shows that are available to the public [Lesen, Rogan & Blum, 2016]. However, only individuals able and willing to attend the event can be exposed to the creations if they are not published online. Public exhibitions like these allow non-specialists to engage with SciArt, however, these exhibitions are inherently exclusive in terms of who can produce and consume the works [Rock & Adler, 2019]. Potential audiences are limited by time, institution, location, and financial access, and the creators are chosen based on prestige, skill, institutional access, and other exclusionary criteria. Those creators are institutionally limited as well, as participants are usually chosen from pools of active science academics, and artists chosen by universities, non-governmental organizations, and museums [Lesen et al., 2016].

Even though efforts have been made to provide digital access to all modern scientific publications, a large portion of science information online remains financially inaccessible behind paywalls in academic journals and books. In light of this, to share their messages with a wider audience, scientists kept blogs and online personal journals to communicate their research [Wang, Jiang & Ma, 2010]. The rise in pop-sci communications also demonstrates the efforts of those in the scientific community to reach and appeal to a broader non-specialist audience.

Using SciArt as a tool for science communication is one strategy that has been particularly effective in reaching non-scientists [Sleigh & Craske, 2017]. Anyone can create SciArt; it's not the sole domain of either scientists or artists. However, mixing these two cultures [Snow, 1993] is most effective when two-way communication between scientists and artists occurs [Hall, 2013]. SciArt allows non-specialists to appreciate scientific discoveries through an emotional connection. Through SciArt, scientists can also perceive their own studies through a different lens, as interpretations of their research by an artist or through their own artistic expressions [Parks & White, 2021]. Communicating science through SciArt allows a wide diversity of people to experience and gain an appreciation for science, while also allowing scientists to re-imagine their own work and foster a deeper connection to their studies [Zaelzer, 2020].

Sharing on social media has allowed greater access to SciArt and science more generally, expanding reach beyond the art and science institutions, museums, galleries, and other exclusive spaces in which it was historically developed [Riedlinger, Schiele & Barata, 2021]. Online SciArt expands accessibility and broadens the audience of traditional SciArt. It also has a much greater reach [Lau, Barriault & Krolik, 2022] than previous modes. The event SciArt Week expanded the reach of SciArt on Twitter (now rebranded “X”), a forum in which it already had substantial interest, and was accompanied by extensive use of the #. The event was envisioned with the intention of exposing artists’ creations to a wider audience and was launched on Twitter/X by Scientific American’s art blog, Symbiartic. Since then, it has amassed a huge collection of creations under the # #SciArt [Woolston, 2015].

As a platform where conversation happens outside of closed communities, Twitter/X is effective in reaching non-scientist audiences [Côté & Darling, 2018] and has been shown to allow the diffusion of scientific information [Alperin, Gomez & Haustein, 2019]. Because of its reach, many large scientific organizations have a Twitter/X account with which they share their research [López-Goñi & Sánchez-Angulo, 2018]. It has been used across many disciplines to connect with and inform a targeted audience about a specific topic [Thompson, 2015].

Conversations on Twitter/X are diverse and networked. Analyzing the structure of these conversations allows us to classify the participating communities [Mazumdar & Thakker, 2020]. There are six major pattern types in Twitter/X conversations [Himmelboim, Smith, Rainie, Shneiderman & Espina, 2017].

The first of these patterns was deemed in-hub and spoke, or “broadcast” networks. In these high-density networks, the flow of information mirrors that of traditional mass media in that it is unidirectional from one or a few central vertices (nodes). Another type of hub and spoke network was also identified. This has the opposite directionality and is called an out-hub and spoke network or “support” network. The hubs in these high-density networks reply, retweet, mention, and comment on many of their spokes’ tweets. These patterns are traditionally seen in companies’ support accounts. Users interact with them to make complaints or get help with a certain product [Himmelboim et al., 2017]. This pattern can also be seen with bots and organizations that promote a certain topic.

Networks with low density are made up of two subtypes. The first of these is called fragmented, isolated, or “brand” clusters. These communities are composed entirely of single accounts, or isolates, who create content that is not retweeted or shared by any other accounts [Hawe, Webster & Shiell, 2004]. The second type of low-density network is called clustered, or “community clusters”. These networks are similar to brand clusters in that they tend to contain many accounts that are sparsely connected. Community clusters however form many small and diverse conversations around a given topic.

A set of high-density networks make up the final two types of conversations. These networks, unlike hub and spoke networks, are not centralized; they do not have one or a few thought leaders at the centre of the network. Instead, these networks are more democratic and tend to feature multi-way communication among their vertices [Himmelboim et al., 2017]. The first type is called unified, or “tight crowd”

networks. These groups are highly connected, promote the quick flow of information, and are stable over time [Carley & Kaufer, 1993]. The final type of network, another dense and decentralized community structure, is called divided, or “polarized” networks. These kinds of communities happen when multiple tight-knit communities with differing opinions form around the same topic.

The information that is shared spreads from user to user through these established communities. The speed and ease at which information spreads is related to how closely connected (tight knit) the people in these communities are [Zubcsek, Chowdhury & Katona, 2012]. To understand how information, and therefore SciArt, is shared throughout networks, it is necessary to characterize these networks.

Objective

Although the sharing of SciArt is widely practiced on Twitter/X, the extent, and the way this sharing occurs remains largely unquantified. Assessing this sharing is a first step toward understanding the reach or impact of #SciArt. If we want to make recommendations about best practices, we need to assess the use of this # in terms of frequency of use, and how the networks that share SciArt behave. To build on previous research around how science is communicated, especially online, we need to characterize the way that SciArt spreads between users on Twitter/X with the following research question:

What trends emerged in the sharing of SciArt through networks on Twitter/X from January 2020 to March 2021?

Approach and methods

To view a big-picture idea of the community involved with SciArt, we quantitatively analyzed the use of the #SciArt # on Twitter/X. To do so, we collected the set of tweets that included the #SciArt # and analyzed this set for network trends including both a time series and netnographic analysis examining trends in topics, #s, and clusters.

Data collection

To view a big-picture idea of the community involved with SciArt, we quantitatively analyzed the use of the #SciArt # on Twitter/X. We collected a large volume of data, which allowed us to analyze network trends, across the 15 months of January 2020 to March 2021. The fifteen months were selected deliberately in order to investigate any patterns that may have emerged with the discovery and spread of a global pandemic. Although the impact of COVID-19 on the behaviors of tweeters is most likely not insignificant, this pilot allows suggestions for further studies including a comparison of trends over years of data. Tweets from this period include those that were retweets of earlier tweets, and thus some that were authored prior to 2020 were included. This inclusion is necessary as it ensures that tweets that have long-lived popularity and are still being shared are included in the study.

We focused on a single platform; Twitter/X. This focus allowed us to limit the data collected to ensure the depth and accuracy of the analysis. Excluding other

platforms through which content is shared via #s within communities (Instagram, Facebook, etc.) does mean that parts of the communities that use and explore SciArt are uncharacterized but allowed us to have a well-defined dataset and conduct a more accurate evaluation and support the reliability and validity of results. [Mayr & Weller, 2016].

This study focused only on tweets and interactions that include the # #SciArt, in order to first characterize the core idea of SciArt rather than include more, peripherally related #s. Both Meltwater and NodeXL handled capitalization in #s as identical to lowercase. For example, #SciArt was treated as identical to #sciart. In this study, #s were represented in camel case [Horvath, 2013] for the sake of readability and accessibility. The use of only the # #SciArt provided a clearly defined look at the activity in the community. This limit also ensured that a workable volume of data was maintained, as including other #s would have resulted in having too much data to work with. To be included in this study, tweets simply had to contain the # #SciArt. Mentions, replies, comments, and retweets (all types of tweets) were collected in addition to standard tweets. Tweets of any language were included so long as the English # was used. The inclusion of mentions, retweets, replies, and comments in addition to original tweets ensures that the full conversation was captured. During the collection time frame, #SciArt was still the dominant # in use, as #SciArtTweetStorm grew in popularity in the spring of 2021.

We retrieved tweets from Twitter/X via Meltwater (meltwater.com) using the search term “#SciArt”. Meltwater is a platform for social media analysis that allows users to pull information from Twitter/X and other social media and news sites using keyword searches [Frederick, Pegoraro & Schmidt, 2022]. Meltwater accesses the Twitter/X API to collect tweet data. Search terms like content query (in this case “#SciArt”) and a time frame dictate what tweets are retrieved. Searches return tweet ID (an identifier unique to every tweet ever published), date created in UTC (universal time coordinated), and tweet text. We combined the collected tweet IDs for analysis.

Data analysis

We conducted this analysis on a data set that would provide a snapshot of activity large enough to distinguish trends and small enough that the data could be analyzed in a reasonable amount of time. Collecting fifteen months of data allowed for a balance of depth and length, providing enough data for a preliminary exploration into the differences in network activities over the months while still being short enough that the analysis was feasible with the resources available.

We conducted our analyses using NodeXL, which is a network analysis software developed by the Social Media Research Foundation [Smith, Rainie, Himelboim & Shneiderman, 2014]. It is an open-source and free template for Microsoft Excel and provides access to cloud computing and more analysis tools with the pro version. It has a long history of development and is trusted in network analysis research [Smith et al., 2014] across a variety of topics and media [Søreide et al., 2019; Akrouf, Meriem, Yahia & Eddine, 2013; Cline, 2012]. For this study, we employed the pro version to have access to the cloud computing and network analysis functionalities.

NodeXL software builds a network from the compiled list of tweet IDs, collected using Meltwater, rehydrated, (i.e. with their metadata) by accessing the Twitter/X API (application programming interface).

Network graphs in NodeXL can be extremely varied in structure. They can take many forms, from a simple web of just a few members to huge, dense networks with hundreds of thousands of vertices. With graphs containing anywhere from 1,000 to 150,000 tweets, depending on the size and computational power of one's computer, the calculation and layout of these networks can take minutes to days. To maintain workable files (file sizes that can be processed by the virtual machine without crashing), we created fifteen netnographic analyses, one for each month in the study's time frame. The size of each network ranged from 4,660 vertices (about 6,000 tweets) to 18,224 vertices (about 30,000 tweets) in size.

We conducted a time series analysis of the collected tweets. Quantifying tweets per day identifies trends in the use of the #, including increases or decreases in popularity and spikes in # use all of which could correlate with events within the community [Brunner, Hemsley, Dann, Togher & Palmer, 2018], possibly allowing us to infer cause or association [Barisione, Michailidou & Airoidi, 2019].

In addition to the time series analysis, we also analyzed the tweet data netnographically, using the software NodeXL. Tweets from each month were imported into NodeXL and rehydrated using only the tweet ID to restore the tweet metadata. We conducted fifteen separate analyses, one for each month in the period of this study. NodeXL rebuilt the networks, with vertices representing accounts and edges representing tweets from the dataset.

We applied the Clauset-Newman-Moore clustering algorithm [Clauset, Newman & Moore, 2004] to the dataset with NodeXL. This algorithm identifies and separates groups of more closely connected vertices to determine the separation of communities. This algorithm is useful for large networks (especially those with vertices in the hundreds of thousands) as it allows calculations to take place in a reasonable timeframe. In addition, we applied group-in-a-box sorting to this layout in NodeXL. By using this sorting algorithm, the structure of individual clusters no longer overlap and it is easier to determine the connection patterns of the network visually. When networks of this size are visualized without this sorting, they appear more as a single cluster of connections that resembles something like a hairball. The teased-apart group-in-a-box layout allows each group to be visualized on its own [Rodrigues, Milic-Frayling, Smith, Shneiderman & Hansen, 2011].

This practice, called netnography, is the application of ethnography on the internet and entails the study of culture created on the internet by describing groups through patterns of activity and their digital artifacts [Kozinets, 2015]. This virtual ethnography explores the complex social structures of interaction on the internet in an attempt to describe an online community [Hine, 2008]. The interactive and networked nature of Twitter/X is especially suited to this type of analysis as it allows users to directly reply to content with their own content, as well as share content that they encounter and deem valuable. This connected nature is useful in constructing a snapshot of the community around #s [Rogers, 2013].

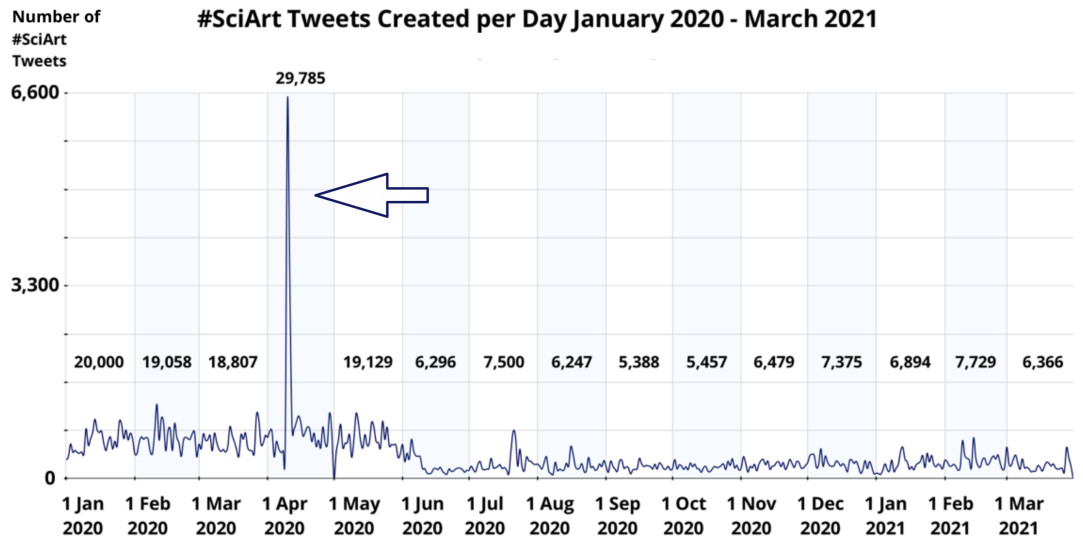


Figure 1. Time series analysis of the number of tweets containing #SciArt tweeted between January 2020 and March 2021. Anomalous peak in tweets indicated by arrow. Total number of tweets collected each month indicated by numbers above trend line.

Results

We collected a total of 172,510 tweets that included the # #SciArt from the period of January 2020 to March 2021. The trend in tweets sent per day over the study period can be seen in the time series analysis graph in Figure 1. Notably, there was a large spike in activity in April of 2020, which will be discussed below. The time series also indicates a drop in activity in June 2020. The cause of this drop is beyond the scope of this paper, but could reflect then current events and further analysis could be interesting.

We conducted a netnographic analysis on each of the 15 months of the study period. The first part of our analysis focused on the trends in community topics from each month. The following two figures demonstrate the prevalence of discussion topics over the fifteen months of analysis.

Strikingly, the top-ranking topics in every month other than April 2020 were dinosaurs and paleontology (Figure 2 and Table 1). These findings use #s to indicate topics of discussion. Discussion in the context of this paper refers to conversations and interactions between Twitter/X users around specific topics. NodeXL categorizes topics of discussion by both words and #s. A word is defined by the analysis as a string of text between two spaces or punctuation, but a # is a word preceded by a hash (#) mark. Therefore, all #s are classified as words but not all words are #s. Analysis based on top words creates similar graphs and figures.

We manually coded topics related to dinosaurs and paleontology which are indicated in Figure 2. A notable 58% of tweets over the entirety of the study period were discussing topics of dinosaurs and paleoart. This was demonstrated by #paleoart being represented in the top four #s being used every month, frequently accompanied by dinosaurs and other dino-related topics. For context, the term dinosaurs alone was used four times more than the term Covid19 in the middle of the COVID-19 pandemic.

The second part of this analysis zoomed in on April 2020, where there was a large

Total Number of Tweets by Hashtag January 2020 - March 2021

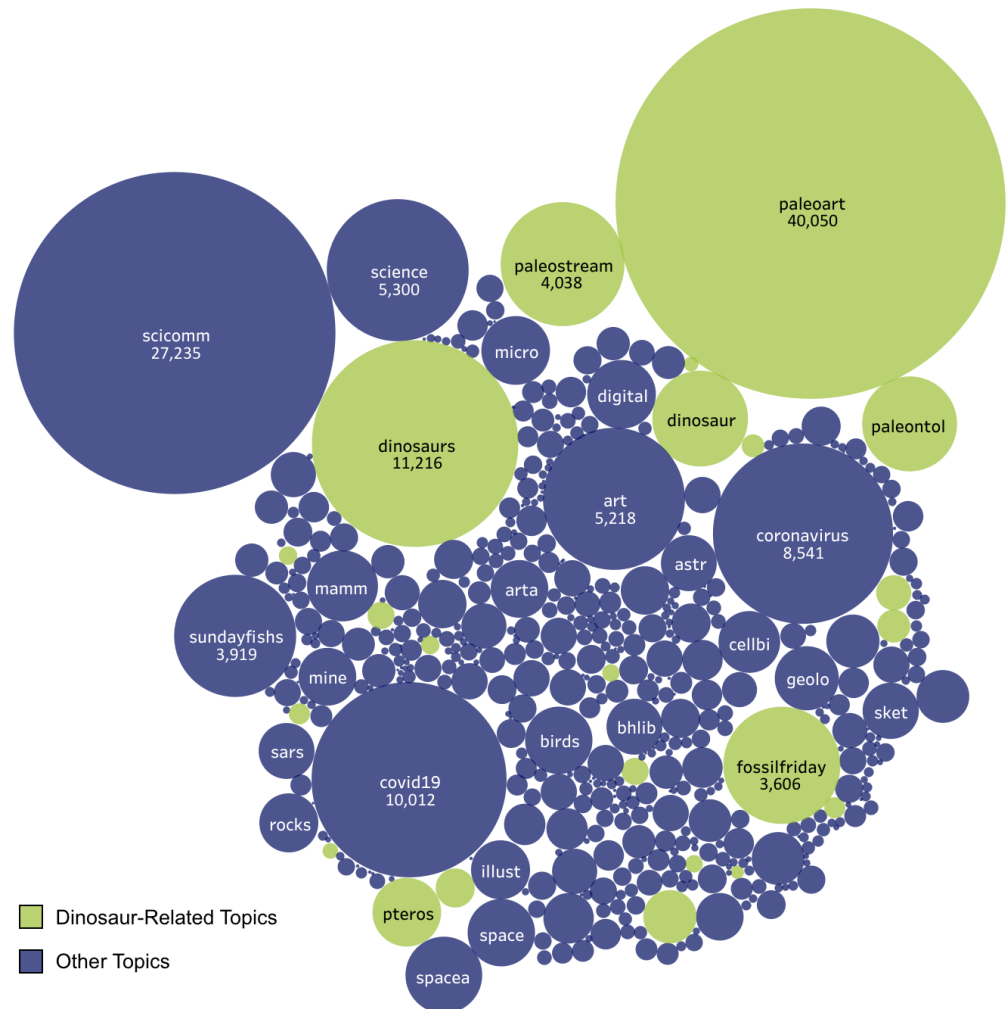


Figure 2. Distribution of #ged topics surrounding tweets containing #SciArt tweeted between January 2020 and March 2021. Tweets related to dinosaurs and paleontology have been indicated with a separate colouring. The top 10 topics have the number of tweets indicated.

spike in activity as seen in Figure 1.

The network graph for April 2020 after applying group-in-a-box sorting to pull apart and isolate all groups can be seen in Figure 3.

The vertices (nodes) on this netnograph indicate individual tweets from April 2020 that contain the # #SciArt. The edges (lines that connect each dot) between nodes represent a connection between any kind of tweet (retweet, comment, mention, reply). The Clauset-Newman Moore algorithm we applied sorts the topics of discussion into groups based on the most prevalent topics and the direction of conversations.

Tweets about COVID-19 dominated in G1 (Figure 3), as can be seen in the top word and top # columns in Table 2 below. This effect is consistent with what was shown in the network graph (Figure 3) as G1 was centered around the one tweet that

Table 1. Top #s per month from January 2020 to March 2021.

| Month | Top #s (in order of frequency) |
|--------------|--|
| January 2020 | #PaleoArt #SciComm #Dinosaurs #Science |
| February | #PaleoArt #SciComm #Dinosaurs #Art |
| March | #PaleoArt #SciComm #Dinosaurs #SundayFishSketch |
| April | #SciComm #Covid19 #CoronaVirus #PaleoArt |
| May | #PaleoArt #SciComm #Science #Dinosaurs |
| June | #PaleoArt #SciComm #Dinosaurs #Science |
| July | #PaleoArt #SciComm #FossilFriday #PaleoStream |
| August | #PaleoArt #SciComm #Dinosaurs #Art |
| September | #PaleoArt #SciComm #Dinosaurs #Science |
| October | #SciComm #Inktober2020 #PaleoArt #Science |
| November | #PaleoArt #SciComm #Art #Science |
| December | #PaleoArt #SciComm #Dinosaurs #ArtAdventCalendar |
| January 2021 | #PaleoArt #SciComm #Science #Art |
| February | #SciComm #PaleoArt #Science #CellBiology |
| March | #SciComm #PaleoArt #Art #Dinosaurs |

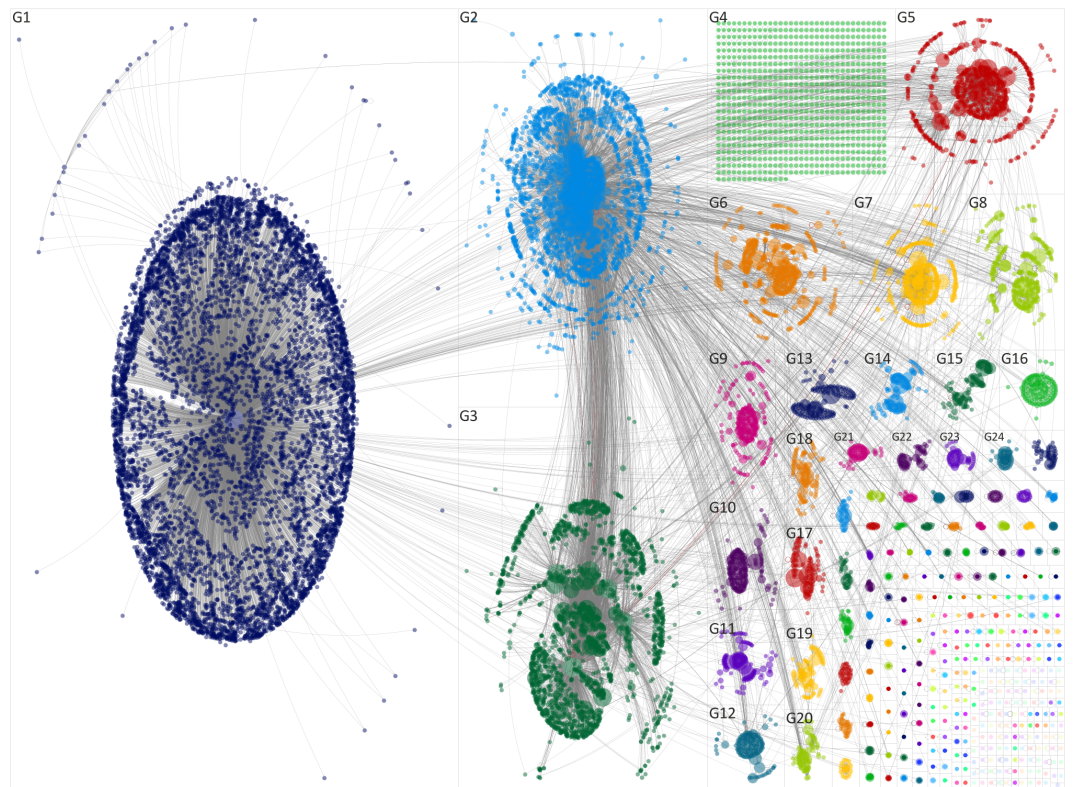


Figure 3. The network graph created by applying the Clauset-Newman Moore clustering and Harel-Koren Fast Multiscale algorithms to #SciArt tweets from April 2020. Groups with 50 vertices or more are labelled and each group has been placed into its own box.

contained a descriptive infographic about the pathology of COVID-19. This account was the most connected to (in the form of retweets, replies, mentions, and comments). In this case, this level of engagement stemmed from one tweet, the previously mentioned COVID-19 infographic by Avesta Rastan (@azuravesta).

Table 2. Network metrics of groups 1–10 created by the clustering of #SciArt tweets in April 2020.

| <i>Group</i> | <i>Vertices</i> | <i>Unique edges</i> | <i>List of top #s</i> | <i>Top words</i> |
|--------------|-----------------|---------------------|---|---|
| G1 | 7737 | 7913 | covid19, sciart, scicomm, coronavirus, sciviz, stayhome, staysafe, covid_19, sars_cov_2, sarscov2 | #covid19 #sciart body affects infection main events occur following hope |
| G2 | 2209 | 4447 | sciart scicomm sundayfishsketch paleoart covid19 fish science illustration coronavirus art | #sciart #scicomm #sundayfishsketch science art more #paleoart fish work time |
| G3 | 2108 | 3349 | sciart paleoart dinosaurs paleontology fossilfriday paleostream spinosaurus dinosaur pterosaurs portfolioday | #sciart #paleoart #dinosaurs more #paleontology late reconstruction #fossilfriday based giant |
| G4 | 773 | 743 | sciart covid19 scicomm science covid-19 coronavirus art microscopy covid stayhome | #sciart great beautiful 19 love covid #covid19 art very illustration |
| G5 | 699 | 1470 | sciart bhlib entomology earthoptimism earthday nationallibraryweek botany nature beetleillustrationoftheday scicomm | #sciart #bhlib flickr beautiful sibilibraries biodivlibrary explore world today happy |
| G6 | 496 | 680 | sciart spaceart astronomy art astroart space scifi sciencefiction digitalart steam | #sciart #spaceart painting #astronomy see dark one #art glow space |
| G7 | 392 | 1792 | sciart covid19 sarscov2 coronavirus medart medicalart scicomm medicine sars_cov_2 medical | #sciart #covid19 #sarscov2 protein viral 19 animation covid utm core |
| G8 | 330 | 457 | sciart portfolioday herper frogs geology shareeguart relaxing colouring phdchat painting | #sciart time art paint amphibians #portfolioday #herper usually katie filmmaker |
| G9 | 255 | 255 | sciart scicomm science sciencetwitter amoebasisters phdchat phd research biology phdadvise | #sciart #scicomm #science one #sciencetwitter job rubisco right more free |
| G10 | 207 | 300 | sciart covid19 sarscov2 scicomm sctistyle coronaviruspandemic coronavirus covid_19 malaria quarantine | spike #sciart #covid19 sars cov #sarscov2 target available illustration structures |

The composition and attributes of groups one through ten (from Figure 3) can be seen in Table 2.

Even with the overwhelming presence of tweets about COVID-19 during this month, paleoart and dinosaurs make an appearance immediately following COVID, in G2 and below. Despite the novel coronavirus being front of mind in April of 2020 when the pandemic had gained global notoriety, there was still a contingent of people discussing dinosaurs, which is a trend that continued throughout the year and into the next as demonstrated in Table 1.

In addition to conversations around popular topics like dinosaurs, there was also a rare, high-impact, event. In April 2020, a tweet of an infographic describing the effects and symptoms of COVID-19 exploded in popularity. This spike illustrated the impact of the disease on the #SciArt network. In the network graph of April

2020 (Figure 3), not only is the entirety of G1 connected to the tweet in question, but connections to this tweet span a variety of clusters and topics. This single tweet and the art associated with it serves as a case study about gaining notoriety on Twitter/X, and by extension, having an impact on wide audiences in general. The infographic had unparalleled reach in the context of the Twitter/X #SciArt community in 2020 and 2021, and although this effect was extremely prominent in April 2020, it was dwarfed by the substantial presence of dinosaurs and paleoart overall.

In light of this one popular infographic and the amount of dinosaur-related discussion in general, we also investigated which accounts were most consistently connected with month over month. The creator of the COVID-19 infographic who dominated in April of 2020 (@azuravesta on Twitter/X) describes herself as a scientific visualization specialist. The other accounts that appear repeatedly on the top connected list every month can be seen in Table 3.

This list contains many accounts that identify themselves as illustrators and artists as well as those who describe themselves as communicators. It is notable that sharing of #SciArt is very commonly connected with scicomm, or science communication, as reflected in the other #s that frequently appear. Potential future studies could then investigate these accounts and their motivations for sharing SciArt and engaging audiences regarding science on Twitter/X.

Table 3. Top ten most connected accounts overall from January 2020 to March 2021 and their self-descriptions.

| <i>Account</i> | <i>Number of times account appears in monthly top ten</i> | <i>Twitter/X bio text</i> |
|------------------|---|--|
| serpenillus | 14 | Professional Scientific Illustrator, Paleoartist & Herpetologist 🇧🇷 🐉 🦎 Commissions gabugetoillus@gmail.com He/Him/His |
| joschuaknuppe | 12 | German paleoartist, he/him, doing all sorts of prehistoric critters and spec evo too, streams on Twitch every weekend, #paleostream |
| biodivlibrary | 6 | Biodiversity Heritage Library provides free & #openaccess to #biodiversity literature online. |
| villesinkkonen | 6 | Professional paleoartist, concept artist and illustrator. |
| microrockscopica | 6 | Bernardo Cesare Geologist @geounipd RockCommunicator. I study rocks and show their Art under the microscope. (He/Who?) |
| mag2art | 6 | Cell biologist studying how a heart grows and dies. Associate Professor at Vanderbilt. Artist and fashion designer at http://Mag2Art.com . Married to @gillianhoo |
| thelabartist | 5 | Artist and #SciComm I make science-themed art/illustrations, games and sculptures! admin of @IAmSciart+ Science Pusheen. Bio, tech, robotics and space! |
| amoebasisters | 5 | Two sisters demystifying #biology with humor & relevance. We make YouTube videos, GIFs, webtoons, comics, an Unlectured Series. |
| artscience9 | 5 | All things Art and Science! #SciArt #SciComm |
| prehistorica_cm | 4 | Invertebrate Palaeontologist and Palaeoartist from Ontario. Worshiper of Omnidens. he/him @omnidens |

Discussion

A wide variety of topics were discussed in SciArt communities, but by far the most common topic among populous clusters and smaller communities was dinosaurs. At the beginning of this study, before any analysis had been conducted, we expected to see a variety of science topics represented by #SciArt. Because 2020 was the year that COVID-19 was discovered and spread, we thought that art about viruses, public health, or viral transmission may be prevalent in the tweets we analyzed. We were surprised to see then, after analysis of every month, that paleontology and dinosaurs were the most discussed topics in every month except April 2020 (where they came in second after COVID-19). Other topics like fish, birds, microbes, and mammals made it into the rankings, but each of those was consistently beaten by dinosaurs and paleontology. It is important to note that physical sciences like chemistry and physics as well as math are underrepresented in the results, and this is likely due to their more abstract and harder-to-visualize nature. This disparity of popularity online is a potential area of further study, as those interested in the popularization of these less visual fields may want to take advantage of art as a portal to public engagement with their fields.

The conversations about dinosaurs were numerous, diverse, and disconnected. If one of these broadcast conversations was disrupted by a community leader leaving Twitter/X, the #SciArt network would not collapse. This stability happens because, in addition to smaller broadcast networks connected by thought leaders, other common community conversation types included both types of low-density (community and brand) clusters. These community networks have a characteristic lack of connectivity and slow information flow [Lerman & Ghosh, 2010]. Each conversation in a community cluster has its own audience, own information sources and its own smaller-scale influencers. These types of networks have been demonstrated to be stable over time [Hansen, Shneiderman, Smith & Himelboim, 2020], in contrast to hub and spoke networks, which cease to exist with the removal of a few powerful vertices [Wang et al., 2010]. Because community clusters are a collection of spontaneous discussions between different groups of users, they demonstrate the wide variety of opinions that exist in any given topic network. A low-density network can take the form of a small bubble of popularity (one tweet with a few retweets) or more connected small communities that converse and share with each other. These communities contribute to the stability of the #SciArt network as they don't rely on a few popular accounts to interact with. Although users from these communities may interact with the larger thought leaders, they maintain smaller, more disparate, and disconnected clusters. Each cluster has its own audience with its own information sources.

As a set, isolates (single posts that no one interacted with) were usually the second, third, fourth, or fifth-most populous groups (see G4 in Figure 3). These accounts are not connected to each other at all and form a community only based on their shared interest in a given topic (#SciArt). This type of social media posting behaviour tends to happen around well-known brands, celebrities, or phenomena. These community members tweet among themselves about the topic at hand, but not to other groups [Himmelboim et al., 2017]. Although no accounts retweet or interact with these tweets, the accounts continue to share content. What this widespread engagement with dinosaurs and more generally #Sciart tells us is that their brand power is significant. Even without a response, people will continue to create and communicate about dinosaurs through SciArt.

This love of dinosaurs has been seen in other science-oriented communities, both online and off for decades, and is perhaps evidence of greater trends in the science communication and popularization world. When the first discoveries of dinosaurs by paleontologists were communicated to the public in the 19th century through public lectures, “dinomania” arose. In the Crystal Palace, huge dinosaur reconstructions along with recent dinosaur fossil discoveries in the United States ignited peoples’ passion for these prehistoric beasts [Manucci & Romano, 2023]. Since then, paleontology researchers and artists have collaborated on scientific illustrations and imagined dinosaurs together. Initially, scientists were the artists, but eventually the hobby and profession ‘paleoartist’ emerged. These science-based artists aimed to create accurate representations of the prehistoric organisms that were discovered. This phenomenon can also be seen in the exhibitions of science centres and museums around the world. Dinosaur-related exhibits are frequently developed and featured in these institutions based on how popular dinosaurs are with the public. It is no secret within the informal learning world that institutions feature a dinosaur exhibition every two to three years to bring learners through the doors [Manning & Falkingham, 2012]. This thirst for dinosaurs and all knowledge about them over the past century then has been and will continue to be a valuable tool to expand public engagement with science. Like dinosaurs and other fields that have a history of visually compelling imagery, art about science concepts that is freely available to diverse audiences can become a portal into online engagement with those fields. These “portal images” entice audiences by providing a sense of awe that persuaded the audience to engage further with the topic at hand [Gigante, 2018].

When trying to engage audiences in science, it is useful to employ enticing topics like these or strategies that naturally draw in audiences. By connecting research to a popular topic like dinosaurs, communicators can use these themes as a hook to activate engaged audiences and introduce other topics. The same can be said of SciArt as a method of communication. Although a huge part of science communication strategy focuses on narrative design and rhetorical strategies, art about science draws people in differently. By hooking audiences visually, you can compel them with a universal language; art. Sometimes you can’t engage people with words alone.

Limitations and recommendations

Our study timeframe includes the rise and progression of the global pandemic of COVID-19, so the data acquired in this study may not reflect trends in “typical” years.

To get a clearer picture of how the activity of (especially early) 2020 compares to later or even earlier years, further studies will need to be conducted. The selected timeframe of this exploratory study limited our ability to draw conclusions about #SciArt across years or on patterns that are larger. An investigation across years would allow for an understanding of trends in the sharing of SciArt, and the making of a model to predict network behaviours using different keywords. It would then be possible to test predictions and the accuracy of the model. The existence of such a model would be a useful tool: it could be employed by science communicators to refine and target their communications, applying insights from netnographic analysis to create more impactful works and campaigns. Unfortunately, Twitter/X discontinued free researcher access/third party provider

to its API-services in February 2023 making a repeat or expansion of our study currently impossible. Future return of accessibility would allow continuation of this and similar valuable scientific research into internet culture [Davidson et al., 2023].

Although Twitter/X was launched more than eighteen years ago, the structure and flow of information, as well as the types and amounts of data available for research have changed drastically. Not only do algorithms and architecture change, but user and tweet content does as well. Users can both delete their tweets and their accounts and because of this ability, even if they had tweeted about #SciArt, users who have deleted their accounts or data would not be included in this study. Although throughout the period of this study #SciArt was the dominant # in use, other #s that relate to conversations around SciArt have gained popularity. netnogr Given the breadth of people, from science communicators to artists and illustrators, who included #SciArt in their posts, it would also be interesting in future studies to investigate the motivations for sharing SciArt and engaging audiences regarding science on social media.

We focused on large-scale, quantitative analysis rather than select and specific people, and so the resolution and specificity of results were limited. It is important that additional studies consider other social media platforms. By comparing the results of the analysis of each platform, we can get a more complete understanding of the state and extent of interactions among the diverse communities using #SciArt. Social media platforms, and their user demographics, intents, and foci, are constantly evolving. Cross platform studies that directly incorporated and investigated the effects of these differences across platforms would be particularly interesting [Pearce et al., 2020; Vicari & Ditchfield, 2024]. In addition, a qualitative assessment of tweet content, including the art itself, would give insight into who is creating and sharing content and from which communities they hail: scientists, artists, or non-specialists, as well as what kind of content they are sharing. A deeper analysis of the social networks of SciArt sharing can give insights into what kinds of social roles are being performed by the community members. It would also be ideal to qualify how audiences and creators themselves make meaning (if any) from their interaction with the SciArt community. This qualification would bring all the big data analysis into focus and put it in the context of real people and their experiences.

Conclusion

The prevalence of numerous, small, conversations about dinosaurs demonstrates that there is a pattern in the sharing of paleoart (art about dinosaurs and other prehistoric life) and more broadly, SciArt on Twitter/X during the period of our study. These patterns are demonstrated by the existence of disparate isolate and community clusters. These accounts create and engage in their own diverse conversations about dinosaurs through SciArt and indicate that there is an interested and engaged subsection of the population.

When engaging in science communication, these kinds of audiences, who are already initiated in the subject at hand, will be more likely to be receptive to communications even if only because they are familiar with the terms being discussed. These active participants allow the topics we wish to promote to be more widely spread through their already established communities. Even if there

are not yet any thought leaders in broadcast-style networks who disseminate information on a large scale, the presence of these community clusters can promote and grow discussion in the community.

SciArt and dinosaurs are tools that can be used by science communicators to increase public interest in and by extension public understanding of science. As was evidenced by the persistent interest in dinosaurs and the ability of these social media messages to reach huge audiences, people have a desire to interact with scientific art regardless of its relevance to current global matters. In designing our communications, we should consider the incorporation of SciArt for its ability to engage a more diverse audience. If nothing else, we would do well to remember the power of dinosaurs.

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