1 Introduction

In an increasingly digital world, science communicators and educators must change their current strategies to interact with diverse communities who are interested in continuing their education in nontraditional contexts. One of the prevailing approaches to this shift is the usage of social media platforms as part of the science educator's tool kit. Social media platforms like Facebook, Twitter, and Instagram are powerful tools that provide avenues to interact with learners from diverse backgrounds, including younger generations, and serve to make science more accessible (Schuch et al., 2018; Hines, 2019; Hines and Warring, 2019; Lam et al., 2019). Social media platforms allow learning to take place outside of a formal learning environment; thus, they are places where informal learning occurs. Most often, such informal learning environments traditionally include museums, science centers, or aquaria (Gerber et al., 2001; Marsick and Watkins, 2001; Falk and Dierking, 2016). However, informal learning about scientific topics has also expanded to online environments, such as social media (Lam et al., 2019; Lundgren et al., 2020).

Research concerning learning about scientific topics on social media is still developing (Lundgren and Crippen, 2017; Lundgren et al., 2018; Hines, 2019; Hines and Warring, 2019; Jarreau et al., 2019; Lam et al., 2019); much of the research on Instagram is focused on microbiology, or geared toward science communication practitioners (Hines, 2019). Instagram first launched in 2010 as a platform for photographers to share their work through static posts.[1] As of January 2021, Instagram reported an audience of 1.22 billion worldwide. Of this audience, nearly 63 % are ages 18–34 (Hootsuite and We Are Social, 2021) – indicating that Instagram content has the ability to reach users of that demographic (Schuch et al., 2018).

As there is an increased emphasis on the inclusion of people from across the continuum of expertise in scientific endeavors, science educators and scientists can develop and deliver content that is both scientifically accurate and educational in nature by using established social media platforms such as Instagram. Educational organizations that focus on natural sciences, such as museums and universities, can communicate with a diverse population because Instagram is particularly visually based and has a younger community (Perrin and Anderson, 2019). Scientific topics include the study of paleontology, which can be described as understanding the natural world through the collection, preparation, curation, and study of fossils (Crippen et al., 2016). This scientific discipline has been most often described as field-based, with the "typical" image of a paleontologist being a person excavating fossils in a remote locale

[1] https://about.instagram.com/

(Plotnick et al., 2014). However, paleontology also includes diverse practices that are not necessarily field-based. Curation, digitization, and study of fossils are foundational paleontological research practices that regularly take place indoors. Additionally, paleontology includes a dedicated community of amateur (also called avocational) paleontologists who contribute to the field via curating their personal fossil collections, working with museums, and sponsoring graduate students through scholarships (Catalani, 2014).[2] Paleontology outreach and education has a long history in communities connected to local natural history museums (Clark 2014; Sheffield and Bauer 2017; Perez et al., 2020) and has moved to a model of meeting people where they are (i.e. nontraditional spaces of learning like comic-cons) to reach new and more diverse audiences (Stoneburg et al., 2020). More recently, paleontologists have recognized the power of online tools and communities that can strengthen the field by adding new media and diverse populations to the field (MacFadden et al., 2016). As an effort to build a diverse online community interested in all aspects of paleontology, educational researchers and paleontologists created social media platforms for the FOSSIL Project, a National Science Foundation–funded project that aimed to unite paleontologists from across the continuum of expertise (Crippen et al., 2016). The following research describes this work conducted on the specific social media platform of Instagram.

As social media becomes an avenue for scientists to effectively measure and evaluate their education and outreach efforts, it is necessary to establish protocols to quantify the ways in which people interact with scientific content online. Some social media platforms, including Twitter and Facebook, provide metrics to quantify such engagement. Engagement on social media is the common measure of "success" or the popularity of posts. On Twitter, measures of a successful post are related to engagements, impressions, and engagement rate, three metrics that are provided by Twitter Analytics (Bex et al., 2019; Lundgren et al., 2020). Engagement is defined by Twitter as "the total number of times a user has interacted with a tweet,"[3] or the total number of likes, retweets, follows, replies, and clicks on the tweet itself. Impressions are the "number of times users saw the tweet on Twitter." The calculated metric that Twitter provides is engagement rate, which is the number of engagements divided by the number of impressions. On Facebook, post-performance is determined using the metrics' engagement and reach.[4] The way to determine the "success" of Instagram content has not been studied in regard to educational outreach; however, Instagram provides an avenue to further communicate science (Jarreau et al., 2019). Unlike Facebook and

[2] http://drydredgers.org/ [3] https://twitter.com [4] https://facebook.com

Twitter, Instagram does not provide exportable data analytics; additionally, publicly available and empirically measured protocols for recording or analyzing data are lacking. Thus, if scientists, science communicators, and educators are interested in using Instagram as a means to engage in educational outreach, it is necessary to define useful metrics for gauging success on Instagram as well as provide methods for collecting and analyzing data based on these metrics.

Here, we describe measures of success for engaging and effective Instagram posts and stories that are centered on educative scientific content. Research questions to be directly addressed include the following: (1) How can science educators and communicators measure the success of Instagram content? (2) How do people interact with content within a specific online environment? Our work largely shows that posts about our team's activities and informal posts perform better than other post types, and that shorter Instagram stories ensure viewers are retained for the duration.

2 Theoretical Framework and Related Literature

We ground the study in this Element in the affinity spaces theoretical framework (Gee, 2004; Gee, 2005; Gee, 2017), in which people's thoughts, beliefs, values, actions, and social relationships can be examined as they interact with the content of an online environment. We see this theoretical framework as aligned with our research questions in that we seek to describe the content and interactions that are found within online, scientific environments. Affinity spaces are sites for informal learning within the virtual or physical world where individuals interact with others around a common interest or endeavor (Gee, 2005). When describing affinity spaces, Gee (2005) explains that the spaces are composed of portals, content, and interactions. Portals provide individuals with access to the affinity space. The content within these spaces serves as the topic or domain of interest and provides a reason for the space to exist. Within these spaces, there are typically various ways for interactions to occur. For affinity spaces to support sustained learning experiences for people, they require the following: individuals with different expertise/orientations in the domain of interest; multiple modes of engagement that enable individuals to take on roles within groups and contribute and interact in a variety of ways; and diverse ways of learning and varied learning experiences. Membership in affinity spaces is more fluid than in other community-based environments (i.e. communities of practice; Lave and Wenger, 1991); additionally, affinity spaces are less formalized in structure. This framework is particularly well suited for virtual social spaces, such as Twitter or Instagram, because the designs of these platforms allow

multiple ways for individuals to interact and converse without formally becoming of a community (Greenhalgh, 2020).

Previous research into the ways that affinity spaces have been considered for learning has encompassed studies of interactions within online environments. Sharma and Land (2018) describe an online social networking service that was used by patients with diabetes; multiple studies have explored Twitter as a site where multiple affinity spaces are developed by educators (Staudt Willet, 2019; Greenhalgh, 2020). While these studies show that affinity spaces can inform our understanding of learning in informal contexts, there has been limited research into how Instagram, a popular social media platform, can be considered an affinity space.

This Element focuses on the ways that Instagram acts as an affinity space; we indicate the ways in which the platform meets the eleven criteria that have been used to define such spaces here, specifically using examples of science-specific content created on Instagram (Table 1).

3 Materials and Methods

Case Study: The FOSSIL Project

The FOSSIL Project was active from 2013 to 2019 and sought to foster interactions with people across the continuum of paleontological expertise through social media platforms and the myFOSSIL website (www.myfossil.org; MacFadden et al., 2016). FOSSIL, which is an acronym for Fostering Opportunities for Synergistic STEM with Informal Learners, was a collaboration between the University of Florida College of Education and the Vertebrate Paleontology division of the Florida Museum of Natural History. This collaboration of different research interests and backgrounds resulted in a six-year project with a focus on both paleontology and social learning outcomes. The Vertebrate Paleontology division provided content insight and outreach experience, whereas the College of Education developed the social learning research questions and protocol used as a framework for shareable products and outcomes.

The FOSSIL Project initially used social media (Twitter, Facebook, and YouTube) as a way to expand communication to a more diverse range of participants. After seeing the success of these platforms, the project expanded to Instagram in October 2017. The FOSSIL Project's Instagram account started with an initial social media intern, then expanded to two active managers and curators of the content in May 2018 (authors SBO and MJH). Because the study involves multiple content creators, we chose a study time frame that reflects only the second set of content creators (SBO and MJH).

Table 1 Characteristics of affinity spaces with examples of how Instagram fits into this framework.

Affinity space Characteristic (Gee, 2004; Gee, 2005)	**Example of Instagram Fulfilling the Characteristic**
Common endeavor, not race, class, gender, or disability, is primary.	People can participate in photography-centered online interactions.
Newcomers, masters, and everyone else share common space.	Celebrities, Instagram "influencers" (those with established audiences and credibility), scientists, students, and the general public all create profiles to interact on Instagram.
Some portals are strong generators.	On Instagram, various portals such as hashtags, links to external websites, or links to other profiles, exist for unique opportunities to participate in affinity groups. Participation in these portals is not required to belong within an affinity group, but rather as chances to further explore and enact identities on Instagram.
Internal grammar is transformed by external grammar.	Vocabulary and knowledge from the outside (e.g. development of Fossil Friday posts) are incorporated into Instagram; for example, the development of #FossilFriday, which originated on Twitter, is widely used by paleontology-focused Instagram accounts.
Encourages intensive and extensive knowledge.	On Instagram, there are participants who are scientists who have specialized knowledge (i.e. a paleontologist who studies Blastoidea) as well as those with broad knowledge (i.e. a museum educator who runs programs about paleontology).
Encourages individual and distributed knowledge.	Instagram provides the capacity for one person's idea (e.g. a post in which someone asks others to identify a fossil for them) to be brought to the eyes of many.

Table 1 (cont.)

Affinity space Characteristic (Gee, 2004; Gee, 2005)	**Example of Instagram Fulfilling the Characteristic**
Encourages dispersed knowledge.	Participants can share knowledge gained from other sources (e.g. paleontology-specific websites, Twitter, academic conferences, group outings to collect fossils).
Uses and honors tacit knowledge.	On Instagram, participants are able to explain the knowledge, skills, and abilities that they have gained through experiences (e.g. how to develop a "search image" for fossils while in the field).
Many different forms and routes to participation.	Instagram allows participants to engage with content through creating posts or interacting with them (e.g. reading posts, liking them, commenting on them); creating or interacting with stories; following hashtags; and finding content via the search function.
Many different routes to status.	Participants might gain status as someone who regularly and positively interacts with content; as content creators; or as potential partners.
Leadership is porous and leaders are resources.	Within Instagram, there are no set leaders; individuals can gain leadership status by becoming valuable resources (i.e. points of reference in specific areas of expertise).

The FOSSIL Project Instagram has over 6,300 followers; of these followers, there is global representation, with only 33% of followers from the United States and 67% male. The average age of users is between 25 and 34 years old. The study period of Instagram posts was over one year from May 24, 2018 to July 24, 2019. Instagram stories were studied over one year from July 15, 2018 to August 15, 2019. We aimed for a similar duration but began implementing stories later during the study period.

Instagram

Instagram was chosen as our platform of study due to the fact that it has been relatively under-studied by the scientific community and provides a way to reach more diverse audiences (Perrin and Anderson, 2019). Instagram has several means of sharing content: posts, stories, and InstagramTV. Each content medium provides associated performance data that can be used to assess how successfully the content was received. InstagramTV was excluded from our study because it was introduced to the platform after the start of our first study period and it was not primarily used by the FOSSIL Project social media team.

Instagram Posts

Instagram posts are the primary avenue for sharing content – posts populate a user's feed and are the most striking thing when users first open the app. These consist of a photo, multiple photos, or a video under 60 seconds and are paired with a caption. Our team used the following process to create Instagram posts: First, we held a weekly team meeting to plan content for the Instagram, Twitter, and Facebook accounts and assigned team members to create posts on designated days of the week. Then, team members used an online graphic design program called Canva to create thoughtful and eye-catching graphics. For each post, a graphic of appropriate dimensions was created for each platform; however, the content of the social media posts did not vary between platforms. These graphics followed a branding scheme of designated colors, fonts, and logos created by a company contracted to assist with the website development and graphic design. Next, team members created engaging post captions with relevant hashtags. These hashtags were derived from a previous study of FOSSIL Twitter and Facebook social media content (Lundgren et al., 2020). Both captions and graphics were presented to the team for review, and adjustments were made. Finally, the finished posts were scheduled for posting using another online tool called Hootsuite. Instagram provides analytics for each post that include number of likes, number of comments, number of shares, number of bookmarks, number of profile visits, number of follows, reach, and impressions. As Instagram does not provide data-downloading functionality, these data were manually collected from the Instagram Insights page for each post and entered into a shared Google Sheet once a week.

The different metrics provided by Instagram include (1) Likes, which are garnered by viewers double tapping the image or pressing the heart button underneath a post; (2) Shares, which are recorded when a user sends the post via direct message to another user or uploads the post to their personal story; (3) Bookmarks, which are a way for users to save content to return to at a later time,

accessible through the profile of the user who has bookmarked a post; (4) Reach, which is equivalent to the number of unique accounts that saw an account's content; (5) Impressions, which are a count of how many times an account's post was shown on a screen, no matter whether it was the same account or multiple. During the interval of May 24, 2018 to July 24, 2019, a total of 455 posts were created and shared on the FOSSIL Project account.

Post Type Taxonomy

We followed the methodology of Lundgren and Crippen (2017), who developed a post type taxonomy, called the Paleontological Practice-based Post Type Taxonomy (P3T), using the FOSSIL Project's Facebook and Twitter accounts. The P3T was developed so that social media posts could be analyzed to account for how post characteristics impact social media engagement rate. Unique categories were created based on post characteristics to ensure that posts could be distinguished from one another; the taxonomy does not allow for coding posts with two or more categories. On the rare occasions that human coders thought posts could be coded with two categories, the category that was more prevalent was selected. The P3T was modified herein, incorporating additional data from Instagram, based on the content that was being generated at that time for Instagram. Categories described here include Activity Updates, Information, News, Opportunity, Other, and Promotion (Lundgren and Crippen, 2017;Table 2). The P3T provided by Lundgren and Crippen (2017) was the most appropriate for this study, as it focused explicitly on scientific content on social media; no other examined coding taxonomy that included such criteria were found.

To analyze posts, every post that had been created within the study period was aggregated with a permanent link in a Google Sheet. This Google Sheet was duplicated and given individually to each human coder. The assignment and subsequent coding of post types to the generated content was done on two occasions (February and July 2019) by three coders. Afterward, these coders independently viewed each post. Each coder assigned the category that best fits the content as described in the post by evaluating the graphic and caption alongside a copy of the P3T. A subsequent discussion was held to compare results of the independent coding and determine the level of intercoder agreement (Creswell, 2011). Following the coding of all posts (n = 455), we determined intercoder reliability using the second instance of coding conducted by the first, third, and fourth authors (n = 258), which was determined to have a moderate level of agreement (Fleiss $\kappa = 0.58$), which is well within the bounds of acceptable agreement levels as dictated by Fleiss (1971).

Table 2 Post type taxonomy for generated content.

Post Type	Definition
Information	Post about general resources for paleontology, such as geologic map or dissemination of recent organization activity, education materials, and definitions of paleontological terms (see Figure 1).
News	Post about a media outlet story about paleontology (e.g. ScienceDaily) or description of current research in the field but for a lay audience. Includes links to scientific articles.
Opportunity	Post about something that members or broader society can participate in such as field trips, talk, citizen science, or job within the related field.
Activity Updates	Post about conducting fieldwork or visiting a museum that contains materials associated with paleontology.
Other	Post about a topic related to paleontology that does not include specific information, news, or an opportunity attached to the subject.
Promotion	Post about host project or any of the activities that are associated with the project. This includes promotions about the mobile app or information directing back to the website.

Instagram Post Metrics

The Instagram metrics that were analyzed for Instagram posts were engagement, reach, and engagement rate. Engagement is the total audience interactions with a post, defined as the sum of likes, comments, shares, saves, profile visits, and followers gained from a single post. Reach is the total number of unique users who have seen your content.[1] A third metric, not provided by Instagram but calculated by the FOSSIL Project team, was engagement rate (Lundgren et al., 2020). Engagement rate is calculated as follows:

$$Engagement\ rate\ \% = \frac{Engagement}{Reach} \times 100 \quad (1)$$

Engagement rate is a metric that relates the amount of interactions with Instagram post content to the number of users that viewed it. To analyze the FOSSIL Project posts, an engagement rate was calculated for each post. Then, posts were grouped by their post type taxonomic categories, and the engagement rate was averaged per post type. Post metrics were compared through data visualizations, specifically box and whisker plots and engagement through time (Figure 2), across the different post types to determine which categories performed best. To assess the significance of

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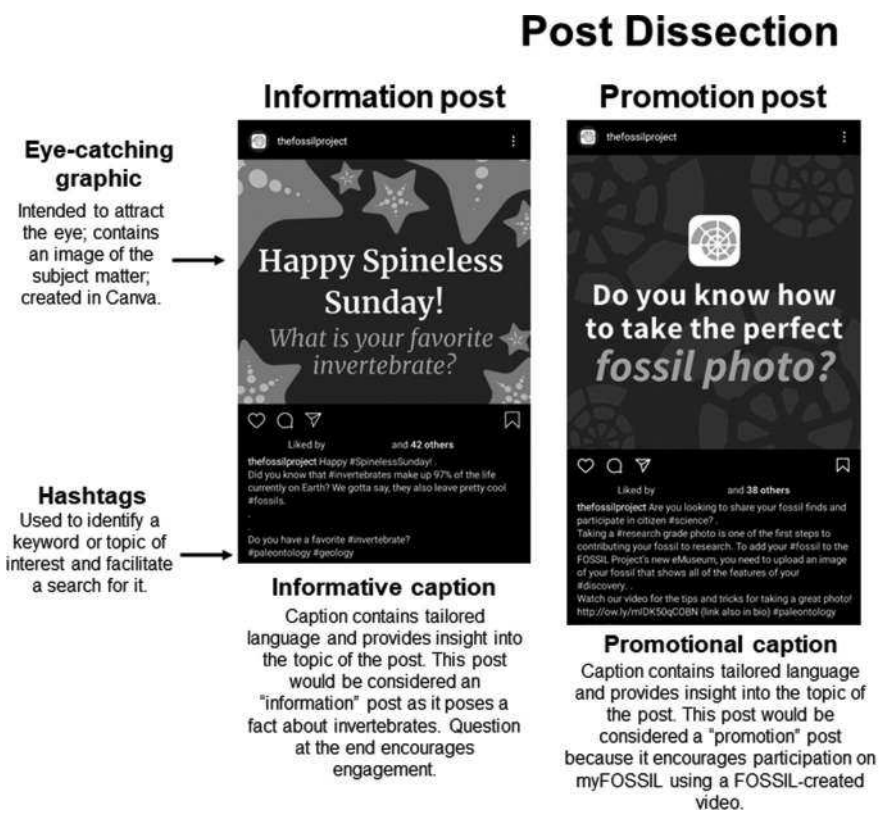

Figure 1 An example of Instagram posts. Key components of a successful Instagram post include
informative caption, and hashtags to promote the discovery of individuals that