# #EngineersWeek: Broadening our Understanding of Community Engagement Through Analysis of Twitter Use During the National Engineers Week

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**Abstract**

Community engagement efforts have become an important avenue for raising public interest and know-how related to engineering. These efforts draw the young and the diverse into seeing engineering as a worthwhile profession. One such effort at the national level in the U.S. is the "National Engineers Week". This is a week-long celebration held every February that consists of numerous events and activities organized for the general public with a focus towards students, women, and under-represented groups. In this paper, we examined this effort through the lens of social media and analyzed Twitter data collected for two hashtags used during the National Engineers Week 2017: "#eweek2017" and "#engineersweek". Our dataset consisted of 6,583 original tweets and 10,885 retweets. To study the impact of the outreach we used three analytical approaches: descriptive analysis, content analysis, and network analysis. We found that the Twitter campaign participation was dominated by engineering companies and individual users followed by a limited participation of educational institutions, professional engineering associations, and non-profits. As opposed to other popular hashtag campaigns, not a single news media organization was identified as a participating user signaling a lower new media-driven propagation of the campaign among the public. From a content perspective, the tweets can be categorized as event promotion, showcasing employees of engineering companies, or encouraging and inspiring public (especially women and children) towards engineering. With the growing popularity of social media, community engagement efforts need to strategically leverage hashtags and other media elements for a broader impact.

**Keywords:** Big data analytics, Content analysis, Social Network Analysis, Twitter, Social media, National Engineers Week, STEM

## 1. Introduction

Studies indicate that the public has a limited understanding of engineering [1], [2]. Engaging the public through outreach efforts is critical to improve engineering and technology literacy so that the public can better participate in policy making [2], be more inventive and improve economic competitiveness [3], and, most importantly, leverage different aspects of engineering to nurture the interest of the youth, especially girls and underrepresented minorities to pursue engineering studies and career [4]. Public outreach is an important component of the national STEM education ecosystem and is reflective of the reality that there are ample opportunities for the public to know about science and technology outside of formal classroom settings [5]. In the USA, a majority of the public (62%) encounters science at informal science venues [6] such as festivals, fairs, exhibitions, summer camps, hands-on workshops, and online resources developed for STEM outreach. These programs are designed to provide exposure and spark interest through exploring, experiencing, and engaging public in different activities. Although these efforts are largely categorized as outreach, we view them as an important component of community engagement as they often provide the first hands-on introduction to engineering for many members of the public. Despite the many small and large scale efforts made by public agencies, non-profits, and other

entities (such as AAAS Center for Public Engagement with Science, Science Festival Alliance, and The Citizen Science Association), it has been hard to effectively assess the impact of these efforts.

In this paper we take a preliminary step towards addressing this shortcoming by using social media data around an event, specifically, Twitter data, to better understand who is engaged with the event and how. This analysis is important as over the last few years the Internet and in particular social media has become a prime source for the public to know and learn about science and technology but also to engage with it, either via contributing original content or by sharing information [7]. Despite the fact that online users are spending a large chunk of their time for generating and consuming content (e.g. statuses, photos, videos, news, links) on various social media platforms [6], [8], [9], the current assessment and understanding of these platforms for outreaching public for science and technology is largely non-existent. Specifically, little is known about how different social media platforms through their unique affordances support in outreaching public for various engineering related engagement programs.

In this paper we focus on the National Engineers Week campaign that started back in 1951 and now uses a number of online channels, including Twitter, to engage the public. Despite being one of the well-known campaigns for engineering in the USA, there is a lack of understanding around how effective the Twitter use is and who is engaged in this campaign. We go beyond the usual methodological tools such as surveys and interviews and contribute to the literature by providing insights into the participation during this campaign using data-driven analytics to answer who participates in the campaign and who interacts with others in which ways. We further explore and present relevant details about the communication as well as participation pattern of various entities. Finally, by employing social network analysis approach, we also provide insights to the key influential entities involved in the campaign.

## 2. Online outreach and community engagement

Since the inception of the Web, the use of online platforms (e.g. discussion forums, online articles, blogs, and traditional websites) by scientists and scientific organizations has played a key role in reaching the public and engaging them with science-related information [10], [11]. A 2016 survey carried out by National Science Board indicate that internet has become the leading source for the public to assess science and technology news and specific scientific issues [7]. As online presence of the public increases, the online mechanism for reaching and engaging people becomes popular [11]. Online social media platforms, e.g. Facebook™, Twitter™, LinkedIn™, and Reddit™, provide a variety of means to get and share science-related information [11], [12]. A recent study by PEW Research indicates that 79% of the US-based social media users (55% of all US adults) view science related posting on these platforms and 26% of them actively follow science-related social media accounts [6]. In contrast to traditional online technologies, social media offers distinct affordances such as reach, interactivity, and instant communication, which makes them highly effective. Social media platforms not only encourage public participation in various activities but can be highly supportive in getting direct and prompt feedback [13]. Furthermore, the magnitude of the potential audience that the engineering and science community can reach through social media is enormous [11]. Therefore, it is not surprising that a large number of scientific community

including scientists, educational institutes, federal agencies, and associations have actively embraced social media for communication and outreach endeavors [10], [14].

As science outreach on social media platforms has increased, scholars have started to explore and understand various aspects of these outreach efforts on different social media platforms notably, Facebook, Twitter, and YouTube. For instance, a study on the Facebook page of Monterey Bay Aquarium Research Institute found that photos and videos were considered more significant than text and links in reaching a wider audience. The study also pointed out the potential of Facebook for developing public interest towards science [15]. Another fairly recent study explored users' engagement with a number of science communication items on five social media channels of CERN including two Twitter accounts (English and French), Facebook, Google+ and Instagram. The study revealed a similar pattern of engagement across different platforms with slight variations. One of the highly appealing forms of content across all the platform was photos which are used not only for marketing purposes but for public engagement and education too [16]. Lastly, another study describes the usage of Twitter by scientific institutes for science festivals' communication. Using NanoDays (an annual nationwide science festival) as a case study, researchers outlined that Twitter supports organizations through three communicative functions i.e. information, participation, and community and most of the tweets were informational and contained external links [14].

## 2.1. The National Engineers Week

The National Engineers Week is an annual weeklong celebration held in February predominantly in the United States and the event is hosted to recognize the contributions of engineers to the modern society. Hundreds of events and activities that take place throughout the country emphasize the importance of learning and engaging with STEM. Majority of the events that are targeted towards the general public especially students and the underrepresented groups. The week which is organized under the umbrella of DiscoverE (formerly Engineers Week Foundation) – a coalition of over a hundred corporations, governmental agencies, academia, and professional societies including American Association of Engineering Societies, Georgia Tech, IEEE, National Science Foundation, and Electronic Arts. In addition to the National Engineers Week, DiscoverE supports and mobilizes a number of volunteer program including DiscoverE Family Day, Dream Big, Future City, Girl Day, and Global Marathon. The mission of DiscoverE is to sustain and grow a dynamic engineering profession through education, celebration, outreach, and volunteerism. The main aim of the National Engineers Week that started back in 1951 by the National Society of Professional Engineers can be classified into the following major themes:

a) Recognizing and celebrating the achievements of engineers that make positive impacts on our society.
b) Advancing and promoting the social and professional interests of engineering as a profession.
c) Increasing the dialog among the public about the need for engineers.
d) Presenting and showcasing engineering to kids, parents, and educators.
e) Advancing the public knowledge, awareness, and appreciation of engineering.
f) Continuing the support of engineering education through scholarship and scholastic competitions.

## 3. Research objectives and methodology

The current study examines the usage of Twitter during the National Engineers Week and the analysis is focused on the following questions:

RQ1: What was the engagement pattern for the National Engineers Week campaign on Twitter?
RQ2: What sort of conversational activity about National Engineers Week took place on Twitter?
RQ3: Who participated in the campaign and who were the influential entities?

### 3.1. Data Gathering

To identify the hashtags that were being used for the event, we used Twitter website and found the two most commonly used hashtags (#eweek2017 and #engineersweek). We used the Twitter search API to collect the shared messages (*tweets*) based on these two hashtags. The data were collected from February 13th, 2017- about a week before the official commencement of the campaign (February 19th). In order to have a streamlined and reliable metadata of retweets and favorites count associated with tweets, we collected the data until May 22nd, 2017 - about three months after the campaign officially ended. The final dataset is composed of a total of 17,468 tweets that includes 6,583 original tweets and 10,885 retweets. The collected metadata for each of the tweet includes: tweet text, retweet count, favorite count, time of the tweet, Twitter handle, location, followers, following, and likes. Our research has been approved by the Institutional Review Board at our university.

### 3.2. Coding

In order to address the research questions, we coded tweet text and tweet author (user). Three reviewers participated in the process by employing open coding approach. During the first stage of this process, two reviewers went through a sample of 300 unique user profiles to come up with suitable categories. This stage yielded a compact set of 9 categories and a codebook for further analysis was developed. During the second phase using the codebook, the first author coded each of the 2,812 unique users of the dataset in a mutually exclusive category.

In the next stage out of the 6583 original tweets, 10% of the tweets (N=658) were randomly selected for content analysis. First, two reviewers went through a sample of 200 tweets and organically organized them into categories. Each category was given a descriptive name that captured the underlying pattern of the tweets text. After refining the terminologies 12 major categories evolved from the first stage of the coding process and a codebook was developed. During the second phase, two of the reviewers were assigned half of the collection for tweets coding, meanwhile, the third reviewer coded all the tweets. All the categories were original as the existing taxonomies or frameworks for categorizing event analysis on Twitter address varied context. We specifically categorized community engagement and outreach event in the context of STEM education.

## 4. Observations and analysis

### 4.1. Descriptive analysis

Of the 17,468 tweets, original tweets and retweets accounted for 6,583 (37.6%) and 10,885 (62.4%) of the data respectively. A total of 2812 unique users tweeted averaging 2.34 tweets per user. With respect to embedded multimedia, more than half of the tweets (59.3%) contained a photo, while a limited number of tweets included a video (3.9%) or an animated gif (2.9%). Majority of the tweets were in English (94.2%) and were from non-verified Twitter users (90.6%). In total, 13,098 hashtags were used within the tweets. An overview of various descriptive features of the National Engineers Week campaign is presented in Table 1.

Table 1. Overview of #eweek2017

| | | |
|---|---|---|
| Total tweets<br>17,467 | Tweets with photo<br>3,902 (59.3%) | Total hashtags<br>13,098 |
| Original tweets<br>6,583 (37.6%) | Tweets with video<br>255 (3.9%) | Unique hashtags<br>1897 |
| Retweets<br>10,885 (62.4%) | Tweets with animated gif<br>190 (2.9%) | Tweets in English<br>6,208 (94.2%) |
| Tweets by verified user handles<br>617 (9.4%) | Tweets with URLs<br>3,180 (48.3%) | |

In addition to the thematic hashtags associated with the campaign (#eweek2017 and #engineersweek), 1,895 other hashtags were used within the dataset. The most commonly used hashtags include #eweek2017 (N=3,751), #engineersweek (N=2,968) followed by #engineering (N=483), #STEM (N=462), and engineers (N=395). Some other important hashtags include #girlday2017 (N=245), #dreambig (N=111), and #womeninstem (N=61). In addition to hashtags, we also analyzed external URLs appended with the tweets. In total 3,180 (48.3%) of the tweets contained a URL. Majority of those URLs were unique and only 516 of the total links (21.7%) were used more than once. The main page of the National Engineers Week (*http://www.discovere.org/our-programs/engineers-week*) providing details about the campaign and various events was linked most frequently (N=35). The second most frequently used link (N=21) was a video posted on YouTube by the campaign organizer in which two astronauts Shane Kimbrough and Peggy Whitson relayed National Engineers Week message from the International Space station (https://youtu.be/TMPwRcUsnI0). The link to the "Twenty Great Engineering Achievements of the 20th Century" section of the book 'Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future' (2007) by The National Academies Press was tweeted 20 times (*https://www.nap.edu/read/11463/chapter/4*).

Analysis of tweets and retweets six days before and after the Engineers Week indicates that the activity started to pick up a day before the event. A significant upsurge in the activity (number of tweets and retweets) was observed during the first six days of the event. Tweets and retweets

frequency started to taper off during the last day of the campaign and the pattern continued for the next 6 days after the event (see Fig. 1).
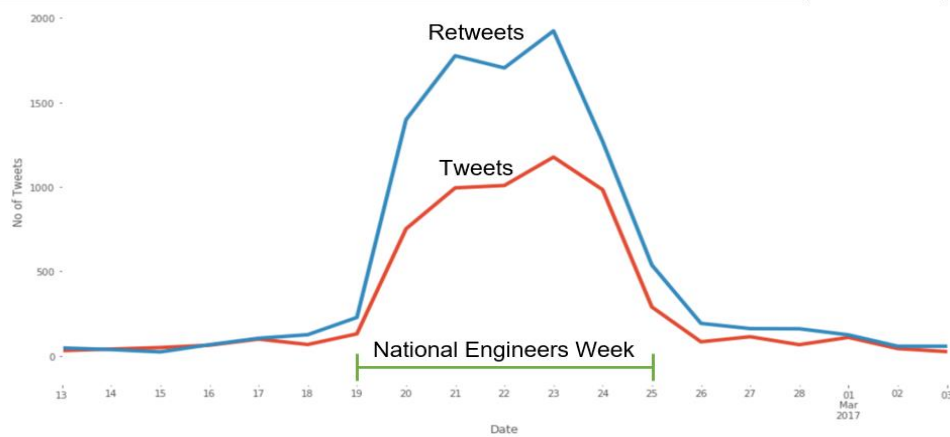


Fig. 1. Number of tweets and retweets using #eweek2017 or #engineersweek

## 4.2. Content analysis

### 4.2.1. Tweets categorization

The majority of tweets (15.9%) were about promoting an event related to the National Engineers Week campaign. This was followed by the tweets (14.3%) with an embedded URL pointing towards an external informational resource. A number of organizations also tweeted the profiles of their engineers and their contributions, which accounted for 14% of the total tweets. Around 12% of the tweets were about involvement of students in various STEM-related activities or providing inspirations to them. Some of the tweets by companies (11.4%) were promotional in nature as they promoted the company or their products. Tweets encouraging the public accounted for roughly 10%, meanwhile, 8% of the tweets were related to the contribution, encouragement, and empowerment of women in STEM. Table 2 presents all the categories with codes, and their prevalence together with a description and a representative tweet of each category.

Table 2. Categorization of the campaign tweets

| Code | % of tweets* (N) | Description | Sample tweet |
|------|------------------|-------------|--------------|
| Event promotion (EV) | 15.9% (146) | Tweet advertises, promotes, or celebrates the eweek event or happenings | @GETRANSPORT highlights engineering at the STEM Fair for #engineersweek. Locomotive simulator in use. https://t.co/hD32ue4idr |
| Resource (RE) | 14.3% (131) | Tweet provides information to a resource, fact, or | Learn how #technology can be used to foster #sustainable agriculture by monitoring key indicators -… https://t.co/lvIP2UcnfW |

| | | | |
|---|---|---|---|
| | | link to an external information source | |
| Employee story (EM) | 14% (129) | Tweet by an organization about contributions of their engineers | HyeKyoung Park is a @JLab_News mechanical engineer who designs particle accelerators for research! #EngineersWeek https://t.co/1ES3dAcvrl |
| Students (ST) | 12.2% (112) | Tweet portraying students involvement in STEM activities or encouraging them to pursue STEM | Primary Schools excited about Engineering in a Box....Boxes ready for collection for training this evening here in… https://t.co/4T8AfnCZ0Y |
| Company promotion (CO) | 11.4% (105) | Tweet advertises or promotes organization or its products | Happy #EngineersWeek! #DYK the #GE9X contains more than 230 new technologies!? Thanks to all the #engineers who pus… https://t.co/hb7HAk5k5E |
| Inspiration (IN) | 9.7% (89) | Tweet encouraging others to pursue engineering in general | Engineers Dream Big and Make a World of difference @NHAgriculture Happy #engineersweek!!#AutonomousVehicles… https://t.co/jTJhNNKkJX |
| Women (WO) | 8.0% (73) | Tweet related to encouragement, contributions, and empowerment of women in STEM | In honor of National Engineers Week, we debunk 6 common myths about women in engineering: https://t.co/02Cs3b9pCu… https://t.co/gs0oz9Kd0z |
| Gratitude (GR) | 7.1% (65) | Tweet expressing regards, thankfulness, or acknowledging engineers for their contributions | Happy #eweek2017 to all of my colleagues and engineering friends! I hope you advocate the profession this week more than you already do :) |
| Personal (PE) | 2.0% (17) | Personal opinion or contribution as an engineer | When I grew up, I wanted to be just like my dad. He was an #engineer who drove #trains. Now, I work with #cars. -… https://t.co/tw7sceHyAG |
| Minorities (MI) | 0.5% (5) | Tweet about minorities in STEM e.g. Afro-Americans or Hispanics | Robert Bland 1959 1st Af-Am Engr Grad UVa @UVAEngineers @NSBEatUVA @NSBE @DiscoverEorg #BlackHistoryMonth… https://t.co/BgaGodaqus |
| Unknown (UN) | 2.0% (19) | Tweet is non-English, cannot be accessed, deleted, or suspended etc. | شاركونا غدًا في تجمع الافرع الطلابية في كورت CECالهندسة من الساعة 12 الى الساعة 2 # #ASCE# IEEEJU #IISE_UJ #aeeju… https://t.co/JZlBkaaaOf |

| Other (OT) | 3.0% (28) | Tweet that cannot be classified under any of the categories above | Science, Technology, Engineering, and Mathematics #STEM  Happy #eweek2017 |
|---|---|---|---|

* The sum is larger than 100% as some of the tweets were assigned multiple codes (non-exclusive categorization)

## 4.2.2. User profile analysis:

Categorizing the user profiles of 2812 unique tweeters among the dataset indicates a predominant participation of individuals and companies. Males, females, and unclassified individuals combined together (39.7%) account for the majority of unique users who tweeted during the campaign. Companies (30.4%) accounted for roughly one-third of the unique users who participated in the campaign. A moderate level of participation is also observed for educational institutes (11.3%), association/interest groups (6.4%), and governmental agencies (4.2%). With respect to the number of tweets, the participation of companies was quite high as more than one-third of the total tweets (35.2%) originate from the accounts of various companies, most of whom are from engineering, defense, and information technology domain. Individuals also accounted for a reasonable high number of tweets (28.7%) followed by educational institutes (14.2%), association and interest groups (7.9%), and governmental agencies (6.5%). Table 3 presents the sum and percentages of unique users and number of tweets by each user entity.

Table 3. Composition of the campaign participants

| Entity | | Unique users | Total tweets |
|---|---|---|---|
| Companies | | 855 (30.4%) | 2316 (35.2%) |
| Individuals | Females | 546 (19.4%) | 952 (14.5%) |
| | Males | 466 (16.6%) | 788 (12.0%) |
| | Unclassified | 103 (3.7%) | 148 (2.2%) |
| Education | | 317 (11.3%) | 937 (14.2%) |
| Associations/Interest groups | | 180 (6.4%) | 522 (7.9%) |
| Government | | 118 (4.2%) | 430 (6.5%) |
| Online resources* | | 55 (2.0%) | 145 (2.2%) |
| STEM resource/advocacy | | 39 (1.4%) | 165 (2.5%) |
| Miscellaneous | | 81 (2.9%) | 113 (1.7%) |
| Unable to classify | | 52 (1.8%) | 67 (1.0%) |
| *Total* | | *2812 (100%)* | *6583 (100%)* |

* Twitter accounts operated for informational purposes and not directly associated with an individual or entity

## 4.3. Network analysis:

For network analysis, we constructed a network visualization using Gephi [17]. The network is composed of 10,397 nodes and 9,422 edges. Each node represents a user meanwhile each edge represents a user whose tweet has been retweeted.  The node size represents the number of retweets a user has received. Network analysis of the National Engineers Week is presented in Fig. 2.
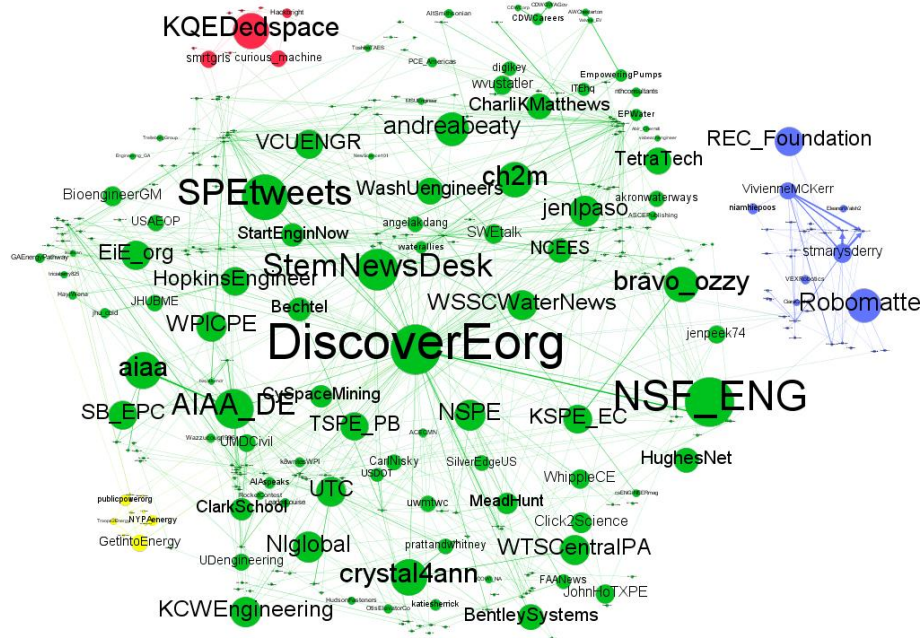
Fig. 2. Social Network Analysis of National Engineers Week

### 4.3.1. Node-level metrics (Degree and betweenness analysis):

In general, there are two key measures including degree (in-degree and out-degree) and betweenness centrality. These metrics are used to better understand and map the participation of different entities within the network. High out-degree identifies the entities initiating the most conversations, meanwhile high in-degree reveal the participants having most of the conversations directed towards them. Betweenness centrality ascertains the most influential entities in a social network or a specific discussion topic. The importance of a node within a network is indicated by the high betweenness centrality. Node-level metrics of the campaign highlighting the top 10 entities are presented in Table 4.

### 4.3.2. Community analysis (network-level metrics):

Another important component of network analysis is community analysis that is measured by the density of the network. The density of a network graph can be derived through the ratio of the actual number of connections and the number of possible connections. In order to identify the communities within the network, we applied the Louvain community detection algorithm in Gephi and the resulting communities are represented through different colors of the entities (see Fig. 2).

Table 4. Central entities of the campaign

| Highly Sociable | | Highly Referred | | Highly Influential | |
|---|---|---|---|---|---|
| Twitter handle | Out-degree | Twitter handle | In-degree | Twitter handle | Betweenness |
| ScienceMarchDC | 775 | DiscoverEorg | 37 | DiscoverEorg | 58403 |
| exxonmobil | 571 | jenlpaso | 30 | NSF_ENG | 24172 |
| LockheedMartin | 420 | InfrastrucWatch | 17 | NSF | 13963 |
| Boeing | 316 | Gravel2Gavel | 15 | SPEtweets | 10053 |
| ASCETweets | 150 | waterallies | 12 | StemNewsDesk | 5092 |
| DiscoverEorg | 120 | BraddockElem | 11 | AIAA_DE | 3704 |
| ulalaunch | 109 | NSPE | 10 | aiaa | 2598 |
| NSF | 103 | WalterPMooreEng | 7 | crystal4ann | 2512 |
| NSF_ENG | 103 | CA_Engineers | 7 | KQEDedspace | 2230 |
| USDOTFHWA | 103 | karybeck | 7 | ch2m | 2072 |

## 5. Discussion

By applying three analytical approaches (descriptive analysis, content analysis, and network analysis) the current study sought to examine the outreach of a public engagement campaign – The National Engineers Week through one of the popular social media platform Twitter. The dataset from two hashtags #engineersweek and #eweek2017 consisted of a total of 17,468 tweets (6,583 original tweets and 10,885 retweets) supported us in answering the following research questions: a) what was the engagement pattern for the National Engineers week campaign on Twitter? b) what sort of conversational activity about National Engineers Week took place on Twitter? c) who participated in the activity and who were the prominent entities?

### a) Engagement pattern

Descriptive analysis of the collected dataset reveals that a total of 2,812 unique users posted 6,583 original tweets (an average of 2.34 tweets per user). Meanwhile, over sixty percent of the tweeting activity relied on retweets. With respect to content type embedded with tweets, photos were most popular as over half of the tweets contained a photo. Other forms of media including videos and animated gifs were used less frequently within the campaign tweets. This finding aligns with other studies indicating the popularity of photos in the Twitter-based campaign as compared to videos or animated gifs [16], [18]. Hashtags are one of the integral features of Twitter used not only for initiating the conversation but for searching, collating, and spreading tweets around a specific theme or discussion topic. As anticipated #eweek2017 and #engineersweek were the frequently used hashtags during the campaign. Analyzing the other popular hashtags further reveal two distinct discussion topics. The first topic related to the involvement of women in science and technology can be captured from hashtags such as #girlday, #womeninstem, #womeninscience, and #talentgap. The second theme of tweets is more generic and relates broadly to science and technology by hashtags including #engineering, #engineers, #STEM, and #tech. A large number

of unique hashtags appended with the campaign-related tweets indicate that a wide array of topics were discussed by the users.

Although slightly less than half of the original tweets contained an external URL, the majority of them were unique indicating a wide variety of external resources shared through the tweets. DiscoverE webpage that provides details about the campaign and various happenings was the most embedded link. The analysis of hashtags and URLs usage indicate that although these features were actively utilized, there was a lack of discussion based on specific themes addressing the campaign objectives. It is highly likely that using a wide-range of hashtags and URLs might have limited the reach and effectiveness of the conveyed message. Engaging the public and other stakeholders towards such campaigns can be effectively done through promoting a pre-defined and targeted set of hashtags and using them more robustly throughout the campaign period. Streamlining the effort through a confined set of hashtags can also be valuable as it simplifies the tracking and monitoring of audience responses and feedback in Twitter-based campaigns [19].

**b) Conversational activity around the campaign**

We further investigated the conversational activity related to the National Engineers Week on Twitter as it supported in detecting whether the conversation is directed towards the campaign aims or not. Results from the tweets categorization show that most of the tweets were about promoting different events, providing information to a resource through an external link, or portraying engineers. Many companies and educational institutes tweeted and posted photos of employees and students participating in different activities held to celebrate and promote the National Engineers Week. The tweets portraying engineers were mostly from companies in which they highlighted the contributions of engineers at their respective companies. Majority of these tweets also contained a photo of engineer(s) at the workplace. A number of tweets were inspirational in nature targeting the general public. Many of the inspirational tweets specifically focused on students and women. Tweets about students portrayed the involvement of students and in various STEM-related activities as well as were deemed to ignite interest and encouragement to pursue STEM in their future careers. Likewise, tweets related to women were also inspirational representing women engineers and how they contribute to the advancement of the society. Some of the tweets were promotional in nature in which companies highlighted their own engineering contributions as well as their engineering related products and services. Finally, some of the tweets acknowledged the contributions of engineers to our society. The analysis of the conversational pattern indicates that most of the conversation revolved around the key aims of the campaign including themes such as: highlighting the significance and awareness of engineering, appreciating engineers, and inspiring public and under-represented groups towards engineering education.

In order to get an insight to the contributors of the National Engineers Week campaign on Twitter, we manually categorized all the users who posted a campaign-related tweet. This analysis indicates the substantial role of companies and individuals in disseminating information with respect to the number of contributors (unique users) as well as the number of contributions (total tweets). Around 40% of the contributors were individual users (including males, females, and unclassified), while around 30% of the contributors were companies. A reasonable number of contributors were educational institutes and association/interest groups. With respect to total tweets contributed by

each entity, companies accounted for the highest number of tweets followed by individuals. Further analysis of individuals reveals a higher participation of women as compared to males. Though not significant, women posted much more tweets than males as well as the number of women tweeters was more than the male counterparts. This finding aligns with prior studies indicating higher participation and activity of women than males on Twitter [20], [21], [23]. Higher activity of women can be attributed to the fact that many of corporations, educational institutes, and associations portrayed women engineers, highlighted their contributions, and motivated them to pursue further towards engineering. Even though the campaign was not devoted to highlight women rights or issues, yet participation and involvement of underrepresented groups (including women) is one of the notable aspects of the National Engineers Week campaign. It is likely that they participated in the campaign to show solidarity with other women engineers as well as to encourage for the younger generation towards the domain. This findings links to recent studies indicating that women spend significantly more time and effort than males on issues devoted to gender-related issues [22], [23]. Finally, the role of media and news organization entities was non-existent as we did not find any tweet posted by these entities. Research on various campaigns utilizing Twitter indicates the significant role of media organizations in propagating the message to a large audience [18], [24].

The main implication of this finding is that the future National Engineers Week campaigns should plan carefully to involve journalists, media organizations, as well as celebrities to further disseminate the information that can eventually raise the public engagement.

To get detailed insights into the usage of content, we further assessed the hashtags and embedded content used within the most popular tweets with respect to their retweet count. All the tweets that were retweeted more than 100 times (N=13) were selected. The analysis indicates that hashtags within these tweets were carefully crafted to support the tweet content and the number of hashtags was also limited. Most of the tweets relied on only one or two hashtags, meanwhile three hashtags were used in only two of the tweets. The analysis also illustrates that all the selected tweets used some form of embedded content in their tweets. Photos were the most popular form of content appended to these tweets followed by videos, and external links. These findings signify the importance of embedded content in tweets for retweetability. Finally, we also analyzed the @mentions within original tweets. This assessment is helpful to understand the level of engagement and depict the two-way conversational activity [25]. Within the National Engineers Week dataset, around one-third of the tweets used @mentions. Even though we observed a moderate level of dialogic orientation within the tweets of National Engineers Week campaign, the level of conversation is far higher than observed in the similar event – NanoDays science festival [14].

The findings also support the notion that organizers of science festivals and fairs should not expect a high level of bilateral engagement from the public as they are more persuaded towards being informed and educated [26]. Likewise in online context, promoting STEM events and festivals such as National Engineers Week should frame their efforts more as outreach ('first order' science engagement) that aims to promote awareness, learning, and greater public interest towards science

instead of two-way exchange and dialog of knowledge and viewpoints between public and the scientific community [26].

### c) Participation pattern

All the tweets embedded with @ sign indicate that the tweet is directed towards another entity. Conversational tweets, also referred as directed tweets differ from non-directed ones which are not directed towards any other entity and serve merely as a general status update. The network analysis of directed tweets helped us with getting insights into the entities holding a central position in the conversational sphere of tweet and retweet network. Network analysis graph of the National Engineers Week depicts a broadcast network that features a small number of hubs (central figures) surrounded by a large number of spokes (connections). The other key characteristic of the broadcast network is that majority of the spokes are not connected to each other [27].

Analysis of the top 10 high out-degree entities illustrates the composition of governmental agencies, associations/interest groups, and companies. March for Science, ExxonMobil, Lockheed Martin, and Boeing were the most notable hubs as a majority of the conversations were initiated by these entities. Though entities including DiscoverE (the organizer of the National Engineer Week), NSF, NSF Engineering, and American Society of Civil Engineers were also among the top 10, their level of participation was significantly lower than that of the entities mentioned above. Analysis of the in-degrees metrics indicates that the most of the conversational activity is directed towards the event organizer. Though low, conversational activity was also directed towards two women (@jenlpaso and @karybeck), two online resources (@InfrastrucWatch and @Gravel2Gavel), and two companies (@NSPE and @WalterPMooreEng).

For detecting the most influential actors within the network, we also assessed betweenness centrality. In Figure 2, the higher the size of the node the more important that actor is in connecting various communities together. Similar to other node-level metrics, DiscoverEOrg (organizer of the event) scored the highest betweenness centrality. Federal agencies and associations including NSF Engineering, NSF, Society of Petroleum Engineers, and American Institute of Aeronautics and Astronautics also emerged as important players in engaging Twitter users in conversation.

We observed a high modularity and a large number of partitions within the network. This means that network can be partitioned into many small clusters of actors who interact more frequently within each cluster than with the rest of the network. Due to densely populated network, we only evaluated the nodes ranging over 3 degree that resulted in visualizing the four most densely populated communities. Interestingly, organizations such as DiscoverEorg, NSF, NSF_Eng were in the same cluster demonstrating how well connected these organizations were during the event. The implication of these findings is the need for a design of better connectivity and coordination mechanisms among the isolated group efforts.

## 6. Conclusion

To our knowledge, we present a first study of community engagement and outreach effort of the National Engineers Week campaign on a social media platform - Twitter. By employing various descriptive, content, and network analysis techniques, we illustrate the use of Twitter to trace the participation and conversations about a campaign geared towards the promotion of STEM learning and engagement among the public. Through digital trace data, we were able to study the real user activities and communication patterns, complementing the survey-driven approaches.

The study findings can serve as a social media analytics benchmark for a variety of informal STEM-related efforts in the future. The findings of the current study can benefit the future researchers interested in studying the usage of social media platforms for community engagement and outreach as well as other informal STEM-related efforts. Though the findings of this research project are specific to the National Engineers Week campaign, the implications can also be applied to other Twitter-based campaigns initiated by non-profits. As the increasing number of non-profits are utilizing Twitter and other social media platforms for communication, outreach, and promotion, these findings would be helpful in aligning their future campaigns to increase their visibility and outreach among the public at large, the scientific community, and corporations.

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