Nano Online: Tracking NISE Net's Digital Footprint

Final Report

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I. Background

The main goal of our project is to examine online discourses about the Nanoscale Informal Science Education Network (NISE Net) related work by tracking media coverage and discussions online.[1] We are particularly interested in exploring how NISE Net and its products get mentioned in and help inform these online discussions. The findings will allow us to have better understandings of how science centers and museums communicate with their stakeholders and various publics using social media tools, how the public attends to scientific discussions online, and the real world impacts that organizations, such as NISE Net, can have on public communication of science.

Given that the development of new communication technologies and increased Internet access have dramatically changed the way information about science and technology issues is conveyed and consumed (Brossard & Scheufele, 2013), our project explores the public impacts of NISE Net in online environments. When asked where they go to learn more about specific science and technology issues, more than 60% of Americans mention the Internet (National Science Board, 2014). The emergence of the Internet as a scientific information source further highlights the need for researchers to explore how science centers and museums engage the public and how lay audiences attend to scientific events online.

Science Public Relations in Web 2.0 Environments

Social media has spread across a growing number of organizations who seek to employ them to create new ways of connecting with stakeholders (e.g., Grunig, 2009; Lovejoy & Saxton, 2012; Waters, Burnett, Lamm, & Lucas, 2009). The distinct affordances of social media, in contrast with other forms of computer-mediated communication technologies, have opened up new possibilities for organizations to cultivate relationships with their stakeholders (Treem & Leonardi, 2012). For instance, a majority of the Fortune 500

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[1] The NISE Network is a national community of researchers and informal science educators dedicated to fostering public awareness, engagement, and understanding of nanoscale science, engineering, and technology. It is supported by the National Science Foundation under Award Numbers 0532536 and 0940143.

companies have corporate Facebook and Twitter accounts (80% and 83%, respectively), with 10% and 6% increases in usage since 2013 (Barnes & Lescault, 2014).

Not only in non-profit organizations and business industries, but public relations practitioners in scientific organizations also have been empowered to create new communication and engagement strategies using social networking sites. Science public relations efforts often serve as science communication tools, which can be utilized to help scientific organizations achieve strategic goals and facilitate dialogic communication with the public (Shipman, 2014). Enhancing understanding of the practices of science public relations professionals, who are from well-known research institutions, private research organizations, scientific and environmental government agencies, and non-profit science associations, in the current Web 2.0 environment can have profound implications.

Social media is one of the emerging digital tools available for public relations practitioners as part of the proposed PR 2.0 movement (Breakenridge, 2012). Facebook and Twitter are the two dominant communication tools used by public relations practitioners (e.g., Barnes & Lescault, 2014; Sharma, 2014). With more than 800 million daily active users and more than 16 million local businesses having created pages on the network (Facebook, 2014), Facebook provides public relations practitioners with enormous opportunities to connect with stakeholders. Twitter, with more than 284 million monthly active users (Twitter, 2014), is a microblogging service that allows its users from across the globe to broadcast real-time information through private and public messages of 140 characters or fewer, which are known as tweets.

A set of unique technical features and socially constructed affordances of social media enable public relations practitioners to develop new engagement and promotion strategies. High visibility, which refers to the ability of social media to allow once invisible communication to become visible, can help organizations disseminate their names, announcements, and advertisements to multiple audiences (Treem & Leonardi, 2012; Vaast & Kaganer, 2013). Facebook and Twitter represent the full spectrum of communications, from personal, private, and semi-public individuals to government sectors and mainstream media (Wu, Hofman, Mason, & Watts, 2011). Using the technical functions of social media (e.g., the retweet function on Twitter), these social media sites have the potential to reach massive audiences. The large volume of traffic brought to the sites may in turn generate traffic to an organization's website or other advertising materials.

Posts on Facebook and Twitter are short and relatively easy to construct and send, and they lend themselves to near real-time response to current events and rapid exchange of information (Lovejoy, Waters, & Saxton, 2012; Wang, Can, Kazemzadeh, Bar, & Narayanan, 2012). The high level of interactivity and immediacy of social media allow public practitioners to discover new audiences while cultivating long-term relationships. The ability of Facebook and Twitter to communicate with brief messages in real-time has garnered increasing attention from organizations and individuals. Analyses of social media data provide us with a more systematic understanding of the ways science centers and museums communicate nanoscience with different audiences over time. In particular, the findings not only provide a foundation for studying online public communication models evolving within the NISE Net community, but also provide researchers with a clearer understanding of the public and professional impacts of NISE Net in a broader sense.

II. Research Area 1: NanoDays Events

Research Questions

The main goal of this project is to examine the potential of NISE Net related work to leave an online footprint, with focuses on NanoDays and the *Nano* mini-exhibition. In the first part of this project, we focus on NanoDays as a case study to empirically explore the impacts of NISE Net. We examine the practice of NanoDays public relations through social media, with a particular focus on Twitter and Facebook. NanoDays is known as the largest nationwide scientific festival about nanoscale science and engineering with an audience reach of up to more than 180,000 visitors per year. The attendance number was 69,075 in 2008 and has increased almost three times to 183,555 this year (Svarovsky, Goss, & Kollmann, 2015). It takes place at more than 250 institutions including science and children's museums, research centers, and universities across the United States. In addition, it engages people of all ages in learning about new research on nanomaterials and nanotechnologies. Online discussions of NanoDays events, therefore, offer a perfect opportunity for examining how science centers and museums employ social media for public relations efforts.

In recent years, science centers have begun to employ a two-way engagement model, which seeks to create dialogues between scientific experts and lay audiences, in some areas of their work. In the field of informal science education, the traditional pedagogical model of "public understanding of science" focuses on one-way communication with the goal of increasing the public's knowledge of scientific facts and processes (McCallie et al., 2009). It was not until the recent decade that the two-way engagement model, known as the "public engagement with science" model, has emerged within the informal science education field.

Practitioners adopt this new model to engage both the public and scientists in two-way dialogue about science- or technology-related issues to facilitate mutual learning and strengthen communication (Kollmann, Bell, Beyer, & Iacovelli, 2012; Scheufele, 2014). In fact, the two-way model has been more widely introduced in Europe than in the United States as most U.S. science centers have been traditionally more engaged in the one-way model.

The emerging two-way model highlights the increasing importance of public engagement with science elements within science centers, museums, and other relevant organizations. In fact, the inherent needs for high levels of interactivity and engagement of informal scientific activities provide science communication scholars a perfect opportunity to examine how organizations facilitate two-way communication with the public. As a result, we examine what communication strategies are being used by informal science education and public relations professionals using NanoDays as a case study through analyzing the content of the social media messages and close examination of the organizational usage of communication tools (e.g., public messages, retweets, and hyperlinks). While retweets highlight the act of information dissemination and rebroadcasting of messages, they can be viewed with conversational purposes. Organizations can also include hyperlinks in their tweets to encourage followers to retrieve more information by following links to external non-Twitter websites.

In particular, we also analyzed the relationship between the volume of social media discussions within a geographic region and the presence of science centers within that region. Understanding this relationship is relevant since some of our earlier research on social media traffic surrounding nanoscience suggests that the presence of NSF-funded Nanoscale Engineering Centers in a particular state can significantly influence the amount of Twitter traffic in a region (Runge et al., 2013). We therefore anticipate that Tweets cluster around NISE Net partners, where online science users are more likely to encounter information about nanotechnology and relevant events and engage in online science discussions. Overall, understanding the communication of ideas and the flow of information between science centers and lay audiences on the Internet is vital to pubic engagement in nanoscience and to the sustainability and growth of organizations like NISE Net in Web 2.0 environments.

We tracked social media posts surrounding NanoDays events on Twitter and Facebook. The analysis relies on opinion mining software developed by Crimson Hexagon ForSight that extracts linguistic patterns from small samples of online/social media content that human coders identify as representative of particular types of content. The software then develops generalizable algorithms from these patterns and uses them to track the underlying content in every captured Tweet and Facebook post. Using Crimson Hexagon ForSight, we can therefore track and analyze all discourses surrounding NanoDays events in a comprehensive and real time fashion. We focus our analyses on four aspects of discourse:

1. Tracking the volume of online discussions about NanoDays events on Twitter and Facebook, comparing traffic before and after NanoDays events, and performing cross-year comparisons of the volume of discourses from 2010 to 2014.
2. Analyzing the types of discourse surrounding NanoDays events in different domains and comparing discussions about NanoDays events from 2010 to 2014 on Twitter.
3. Examining for what functions science organizational social media is employed and the extent to which scientific organizations are utilizing Twitter communication tools such as mentions, retweets, and hyperlinks.
4. Exploring the relationship between the amount of Twitter traffic surrounding NanoDays within a geographic region (e.g., a state in this study) and the presence of NISE Net partner sites within that area.

Methods and Analysis

First, we used opinion tracking software that allows us to combine the advantages of human coding with the scalability of machine-based content analysis. ForSight uses algorithms to track linguistic patterns – which are representative of underlying concepts and are identified by human coders – across large amounts of textual data (see Hopkins & King, 2010).

Researchers in the computer sciences have used such analysis—often known as sentiment analysis or opinion mining—to assess opinions in a range of contexts, such as discussion threads in online news websites and public comments on proposed regulations, to name a few. Researchers can employ it to understand the linguistic patterns surrounding particular kinds of content like NanoDays activities and the *Nano* mini-exhibition. Human coders train machine-based algorithms that the software uses. Once reliable, the software uses these algorithms to track and analyze content over time and across types of online outlets.

Based on a carefully constructed keyword search, a series of posts were first randomly pulled from online sources. We then classified those online posts into well-defined categories until each category contains 20 or more representative posts. This practice ensured that the software had a sufficiently reliable number of posts in each category so as to recognize the underlying linguistic patterns of the category. Once the program was sufficiently trained for the computational algorithms to recognize patterns, all online content related to the topic of interest identified by the keyword search – "nanodays," "nanoday," "nano days," and "nano day" – was analyzed and categorized into 3 main functions consisting of categories. All the categories are mutually exclusive and exhaustive. Those posts that do not fit into one of the trained categories are excluded from subsequent analyses. As a result, ForSight codes complete populations of online content across platforms, allowing for a more comprehensive and reliable analysis than is possible with traditional human coding approaches. Currently, because of the intricacies of the Facebook application programming interface, ForSight is only able to analyze the majority but not all of publically available data. Unlike with Facebook data, all publicly shared Tweets are available for analysis via ForSight.

Overall, we focused on Facebook posts and tweets that originate from NISE Network partners that hosted NanoDays events. NISE Network partners include science museums, children's museums, other informal science education organizations, and universes. In particular, we excluded online discussions from the general public in the analyses to examine the social media utilization patterns of NISE Network partners. Analyses include longitudinal analysis of the volume of Facebook posts and tweets, content analysis of scientific organizations' Twitter messages, and examination of organization utilization of Twitter communication tools such as public messages, retweets, and hyperlinks.

Then, to analyze the science public relations efforts in relation to generating online public attention and engagement with the issue of the NanoDays event, we analyzed tweets generated from both NISE Network partners and the general public. One part of the analysis explores the relationship between the amount of Twitter traffic surrounding NanoDays within each state and the presence of NISE Net partner sites within that area. We first analyzed the geographic origins of the geotagged tweets captured from July 2010 to June 2014. We then identified NanoDays participating NISE Network partners by state (see table 1), and input population and educational attainment usage rates (U.S. Census Bureau, 2012a, 2012b) and the number of active Twitter users by state into the same data set. The presence of NISE Network partners participating in NanoDays by state was measured as the average number of science centers of each state listed on the NISE Network's website from 2011 to 2014.

Table 1. Geographic distribution of a) average number of NISE Network partners between 2011 and 2014 and b) relevant Tweets collected from 2010 to 2014.

State	Avg. no.	No. of Tweets	State	Avg. no.	No. of Tweets	State	Avg. no.	No. of Tweets
Alabama	2.25	60	Louisiana	4.5	31	Ohio	4.5	156
Alaska	2.25	0	Maine	2	36	Oklahoma	3	12
Arizona	3.75	106	Maryland	4.25	89	Oregon	5.25	34
Arkansas	4.25	34	Massachusetts	5.75	195	Pennsylvania	9.5	127
California	19	346	Michigan	5.25	169	Rhode Island	1.25	4
Colorado	4.25	49	Minnesota	5.75	53	South Carolina	1.5	30
Connecticut	5	54	Mississippi	2.5	8	South Dakota	1.75	3
Delaware	1.5	28	Missouri	3.25	30	Tennessee	5.25	42
Florida	6.25	90	Montana	1.5	42	Texas	15	329
Georgia	2	40	Nebraska	2.75	96	Utah	2	61
Hawaii	1.75	25	Nevada	2.5	37	Vermont	1.5	56
Idaho	1	17	New Hampshire	2.25	10	Virginia	6.5	108
Illinois	8.5	98	New Jersey	3.25	66	Washington	6.5	116
Indiana	3.5	91	New Mexico	5.5	55	West Virginia	1.25	14
Iowa	1	26	New York	20	334	Wisconsin	5.75	39
Kansas	2	23	North Carolina	9.75	127	Wyoming	1.25	2
Kentucky	2.25	22	North Dakota	2.25	27			

Using volume of tweets by state tracked from July 2010 to June 2014 as our dependent variable, we ran an ordinary least squares (OLS) regression to determine whether the presence of NISE Network partners predicted the volume of tweets. Independent variables were entered in blocks, with educational attainment as block 1, state population as block 2, active Twitter usage as block 3, and average annual participating NISE Network partners as block 4. Another part of the examination analyzes the proportion of social media messages that are originating from organizations versus the public.

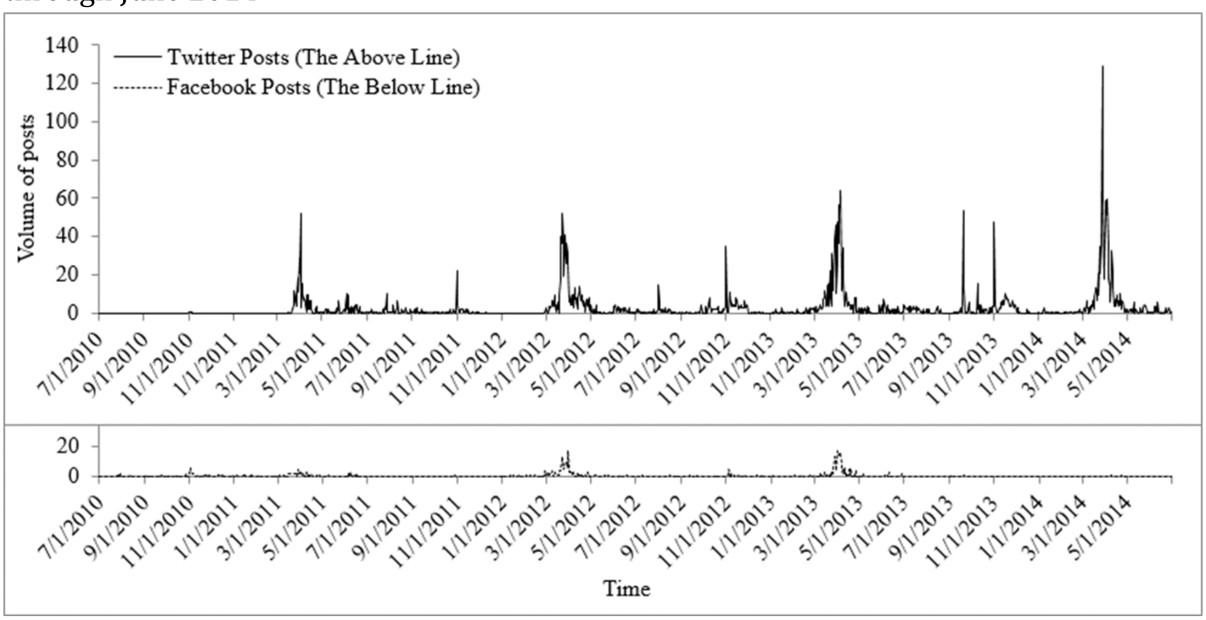
Results and Discussion

Dominance of social media use in science public relations. We tracked the volume of

Facebook and Twitter posts about NanoDays events from NISE Network partners and performed cross-year comparisons of the volume of posts from 2010 to 2014. This study identified 4,114 organizational tweets and 539 organizational Facebook posts over the 4-year period. We provided an overview of the volume of posts on the two social networking sites (see Figure 1). However, it is important to note that as not all NanoDays visitors may include the keyword of "NanoDays" in their social media posts, NanoDays may have a much larger digital footprint than Figure 1 suggests.

Over the 4-year period, discussions occurred with greater frequency between March and May. This finding is consistent with the fact that NanoDays events are organized nationwide during that period. A closer examination revealed that tweets have increased steadily while Facebook posts increased gradually from 2010 and 2013 but largely decreased in 2014. However, the overall volume of public Facebook posts is relatively little, which leads our further content analysis to focus specifically on Twitter.

Figure 1. Volume of NanoDays-related posts on Twitter and Facebook from July 2010 through June 2014



Functions of organizational social media use. As shown in Table 2, 6 types of organizational tweets emerged from the coding process. We grouped the 6 categories into three major functions: information, engagement, and community. We view "information" as the basic social media utilization focus of the science public relations practitioners. This taps into distributing information about the NanoDays events and other scientific activities. The second function, "engagement," involves how museums and science centers encourage public participation through sharing their own experiences and mobilize volunteer engagement. The focus of this function is the attempt of the science centers to engage their stakeholders and the general public. The third function, "community," follows the central concept of building a community and creating a sense of belonging through sharing and asking for post-event updates, photos, and news coverage. From our analysis, science centers are most likely to employ the information function on Twitter (64%), while engagement (16%) and community functions (18%) are less likely served.

Table 2. Tweet functions

Category	Example of tweets	Twitter (%)
Information		**64**
General event information	The 3rd Annual NanoDays event will be held at Explore More on Sun., April 14 from 1 - 4 PM.	12
Event information highlighting other features	Did you know that a nanometer is a billionth of a meter? Learn more during #NanoDays at McWane Science Center! http://t.co/JWWCRXc1F7	29
Information about multiple events	Rabbit Rabbit. March is here & we are busy! Tot Day, Cavalcade, Nano Day, Spring Break Camp, Sustainable Science Fun-- ALL THIS MONTH!	23
Engagement		**16**
Organizational experience sharing	I am off to the museum for nano days. Come see me if you want to have your mind blown and the foundations of your belief shattered.	9
Call for volunteers & Volunteer experience sharing	We're looking for 20 Volunteers for our NanoDay on March 29th from 9a to 5p at Oakland Mall. Training is on March 9th 3-4p @wblib	7
Community		**18**
Community building	Get inspired for your NanoDays 2014 events – see phots from last year's event in Chicago http://on.fb.ne/1cRzuAm #NanoDays #nisenet	18
Total		**100**

We also performed cross-year analyses of the ways that scientific organizations had been using Twitter between 2010 and 2014. Results suggest that the reliance on information function increased from 31% in 2010 to 79% in 2014, while the use of engagement function reduced significantly from 34% in 2010 to 8% in 2013 and 13% in 2014 (see Table 3).

Table 3. Cross-year comparison of tweet functions

Category	2010-2011 (N = 400) (%)	2011-2012 (N = 936) (%)	2012-2013 (N = 1,261) (%)	2013-2014 (N = 1,517) (%)
Information	**31**	**60**	**80**	**67**
General event information	1	10	16	14
Event information highlighting other features	30	35	29	28
Information about multiple events	<1	15	35	25
Engagement	**34**	**22**	**8**	**13**
Organizational experience sharing	18	14	6	6
Call for volunteers	16	8	2	7
Community	**35**	**18**	**12**	**20**
Community building	35	18	12	20

Utilization of Twitter communication tools. Approximately 16% of the tweets by NISE Network partners who tweeted about NanoDays had shared other users' tweets (i.e., retweets), while 24% of the total tweets were public messages (i.e., usage of the "@" symbol). Collectively, approximately 60% of the tweets do not employ retweets and public messages which are characterized as dialogic and two-way communication. In addition, we examined the utilization of hyperlinks by NISE Network partners (see Table 4). The majority of the NISE Network partners' tweets (78%) included hyperlinks that encourage followers to retrieve more information by following links to external websites. This matches with the earlier finding that the informational tweets were most likely to emerge.

Table 4. Utilization of Twitter communication tools

Tools	Example of tweets	%
Public message ("@" symbol)	@ShawnPButler Thanks for sharing our Harlem Shake Nano Edition. We had fun! #harlemshake #nanodays #nanoscience	24
Retweet ("@Username")	RT @Sci_Quest Hands-on Trucks, Summer Camps, NanoDays and more! http://t.co/LJBtFFcail	16
Other	Help us build a huge scale model of a carbon nanotube out of balloons tomorrow during Nano Days! - http://t.co/OEtjDgzQ	60

Examination of science public relations efforts. We also used an OLS regression model to test whether the presence of science centers predicts the difference in the overall volume of tweets in a specific state. An OLS regression is used to examine the influence of multiple predictors on an outcome. Through entering predictors in different blocks, we are able to estimate how a specific predictor influences the outcome, controlling for the influences from other predictors that were entered earlier. Model 1 through model 4 listed in Table 5 indicate the process of consecutively entering additional control variables into block 1 through block 4. In model 2 for example, a β of 0.83 suggests a significant positive relationship between the predictor – state population – and the outcome – the volume of NanoDays-related Tweets by state – while different levels of educational attainment entered in block 1 are controlled for. Our analysis showed that presence of NanoDays participating centers (β = 0.57, $p \leq .001$) was positively correlated with the volume of Tweets per state after controlling for educational attainment rates, state population, and number of Twitter active users by state (see Table 5). This allows us to examine the extent to which the presence of NanoDays participating centers uniquely predicted the volume of tweets in a specific state.

Table 5. Predicting volume of NanoDays-related Tweets by state

	Zero-Order	Model 1	Model 2	Model 3	Model 4
Block 1: Educational attainment					
% residents with baccalaureate degree or more	.27	.27	.15*	.14	.08
Incremental R^2 (%)		*7.2*			
Block 2: State population					
Population	.85***		.83***	.56*	.26
Incremental R^2 (%)			*67.8*		
Block 3: Twitter active users by state					
Number of Twitter active users	.85***			.29	.10
Incremental R^2 (%)				*0.8*	
Block 4: Presence of NISE Network partners by state					
Number of participating partners by state	.89***				.57***
Incremental R^2 (%)					*7.2****
Total R^2 (%)					*83.0****

* p ≤ .05; ** p ≤ .01; *** p ≤ .001

The geographic clustering of Tweets around states that have more NISE Network partners that participate in NanoDays, controlling for average levels of educational attainment, state population, and number of active Twitter public users by state, suggests that states with

NISE Network partners show a higher frequency of discussions about NanoDays events. In other words, states with more NISE Network partners hosting NanoDays events have higher proportions of Twitter users who post items related to NanoDays activities and are engaged in communicating about the topic. This further illustrates the potential real world impacts of institutions, such as NISE Net, on nanotechnology communication and outreach.

III. Research Area 2: Nano Mini-Exhibition

Research Background

In the second part of this project, we examine the real-world impact of the NISE Net using the *Nano* mini-exhibition as a case study. The *Nano* mini-exhibition is an interactive museum exhibition that displays hands-on exhibits to present the basics of nanoscience; over 90 copies were distributed to locations nationwide (although not all of the 90 copies were distributed at the time of this study). We collaborated with other NISE Net researchers through utilizing their data about the mini-exhibition to refine search strings and to examine the extent to which other NISE Net-related activities in terms of online discussions can amplify mini-exhibit themes. We rely on CATPAC II software to analyze the transcripts of conversations that have occurred between visitors of *Nano* mini-exhibitions. The themes emerging from the semantic network analysis inform the underlying concepts embedded in the popular discourses about *Nano* mini-exhibitions. We used the conceptual words that showed up in discussions surrounding mini-exhibits to refine search strings that were later utilized in the content analysis using the ForSight program.

This part of the research helps us to better track the public impact of NISE Net-related work on public debates about nanotechnology. We explore two aspects of the *Nano* mini-exhibition:

1. Tracking the conceptual and exhibit themes emerging from the transcripts of opinions exchanged between visitors.
2. Comparing the volume of online discourse surrounding nanotechnology in general versus the volume of discourse surrounding nanotechnology with the focus on a particular exhibit theme in order to examine the real-world impact of NISE Net-related events in shaping online discourse.

Methods and Analysis

Methodologically, we first conducted a semantic network analysis of visitors' discussions about mini-exhibits, using data that documented the conversations between visitors while using the exhibition collected by other research programs within NISE Net (Kollmann, Svarovsky, Iacovelli, & Sandford, 2015). Using the artificial neural network program CATPAC II, we identified the keywords most frequently mentioned by interviewees and specified the most salient mini-exhibit themes that emerged from their narratives. CATPAC II determines the frequency of words and identifies similarity patterns based on the co-occurrence of conceptual words that appear in the transcripts (Woelfel, 1998).

The software reads the text using a scanning of n words (n=7 in our study) and assigns a neuron to each major word that appeared in the window. The learning algorithm of CATPAC records the connection between any two neurons that are activated in the same window. The connections between neurons that do not appear in the same window will be weakened following the Hebbian learning rule while the connections between neurons that are simultaneously active will be strengthened by the law of classical conditioning (Salisbury, 2001; Woelfel, 1998). The identified pattern of connections among neurons is presented as a covariance or correlation matrix. Each word and column in each cell entry indicates the strength of connection between pair of conceptual words (Woelfel, 1998). CATPAC II applies the hierarchical cluster analysis to describe the relationships between the most frequently mentioned concepts and generates a dendrogram to reflect the strength of the relationship between concepts (Woelfel, 1998, 2004). Each cluster within a given dendrogram can be viewed as a subtheme emerging from the transcripts since concepts clustered together indicate a relatively strong underlying relationship (Woelfel, 2004).

Before running the analysis, we prepared the dataset and made justifiable decisions on setting the analysis parameters following several procedures. First, we identified and removed words such as prepositions, articles, and adverbs that fail to contribute to text meanings from the analysis (Woelfel, 1998). Second, we set the number of unique concepts at 30 for mini-exhibition visitors. This relatively large number of unique concepts allowed us to capture as many existing concepts as possible as they showed up in the transcript. These unique words appear in the hierarchical cluster analysis and are presented in the form of dendrograms generated by CATPAC II. Third, we set a window size of five, indicating that the software would read five words at a time. According to Salisbury (2001), this particular window size is "sufficiently wide to accommodate the subject-verb-object syntax of English and not so wide as to allow words that are semantically unrelated to appear to be related" (p. 71). We left other parameters including the slide size, transfer function, threshold, decay rate, and learning rate at their defaulting values, which are acknowledged by the developers of CATPAC II as appropriate and sufficient for most semantic analysis (Woelfel, 1998).

Preliminary Results and Discussion

Hierarchical cluster analysis. As Table 6 shows, there are a total of 508 unduplicated words, 30 unique words, 504 windows, and 4,704 lines of text in the analysis of mini-exhibition participant interview data. The frequency (FREQ) column shows the number of times that the particular word showed up in the text. The percentage (PCNT) column indicates the percentage of time that a particular word was used in the text, while the case frequency (CASE FREQ) column suggests the total number of windows in which a word occurred. Other parameters such as threshold, restoring force, function, and clumping used in the analysis can be adjusted to determine the extent to which a neuron is activated (Woelfel, 1998).

Table 6. Frequency list of words extracted from the conversation transcripts of mini-exhibition visitors.

TOTAL WORDS	508	THRESHOLD	0.000
TOTAL UNIQUE WORDS	30	RESTORING FORCE	0.100
TOTAL EPISODES	504	CYCLES	1
TOTAL LINES	3796	FUNCTION	Sigmoid (-1 - +1)
		CLAMPING	Yes

DESCENDING FREQUENCY LIST

WORD	FREQ	PCNT	CASE FREQ	CASE PCNT
NANO	86	16.9	284	56.3
LITTLE	42	8.3	166	32.9
SMALL	26	5.1	112	22.2
NANOTECHNOLOGY	22	4.3	83	16.5
BIG	21	4.1	70	13.9
HAIRS	21	4.1	49	9.7
TINY	19	3.7	89	17.7
BLUE	18	3.5	64	12.7
PARTICLES	18	3.5	67	13.3
LIGHT	17	3.3	69	13.7
SMALLER	17	3.3	76	15.1
CARBON	15	3.0	42	8.3
BUTTERFLY	13	2.6	54	10.7
IRON	13	2.6	54	10.7
MAGNET	13	2.6	46	9.1
SIZED	13	2.6	65	12.9
LIQUID	12	2.4	50	9.9
SIZE	12	2.4	50	9.9
BLOCKS	11	2.2	36	7.1
EXHIBIT	11	2.2	48	9.5
LONG	10	2.0	37	7.3
MAGNETS	10	2.0	34	6.7
STATIC	10	2.0	43	8.5
ELECTRICITY	9	1.8	38	7.5
FLUID	9	1.8	39	7.7
FERRO	8	1.6	35	6.9
FERROFLUID	8	1.6	40	7.9
LAB	8	1.6	26	5.2
RIDGES	8	1.6	31	6.2
RINGS	8	1.6	27	5.4

ALPHABETICALLY SORTED LIST

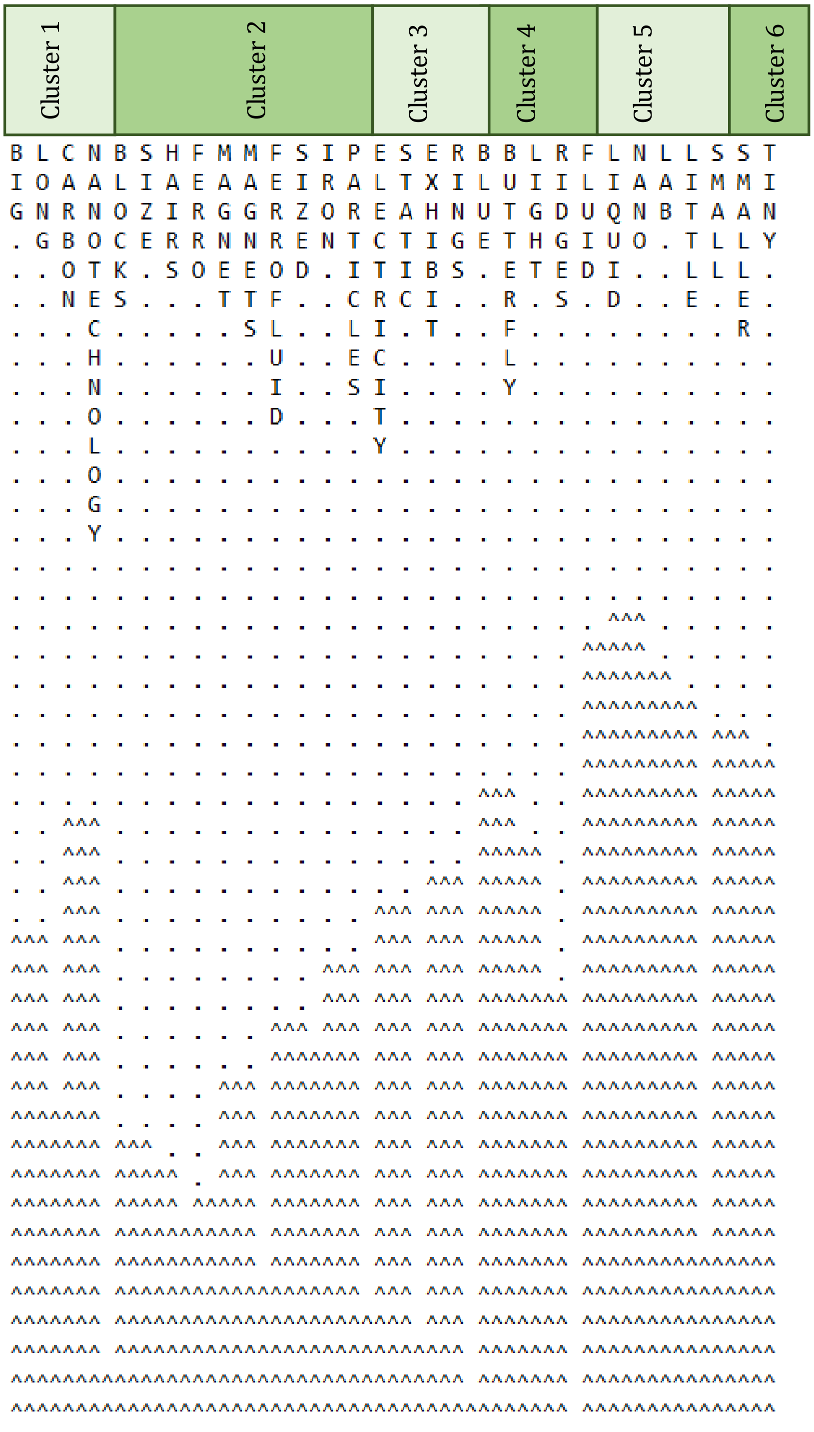
WORD	FREQ	PCNT	CASE FREQ	CASE PCNT
BIG	21	4.1	70	13.9
BLOCKS	11	2.2	36	7.1
BLUE	18	3.5	64	12.7
BUTTERFLY	13	2.6	54	10.7
CARBON	15	3.0	42	8.3
ELECTRICITY	9	1.8	38	7.5
EXHIBIT	11	2.2	48	9.5
FERRO	8	1.6	35	6.9
FERROFLUID	8	1.6	40	7.9
FLUID	9	1.8	39	7.7
HAIRS	21	4.1	49	9.7
IRON	13	2.6	54	10.7
LAB	8	1.6	26	5.2
LIGHT	17	3.3	69	13.7
LIQUID	12	2.4	50	9.9
LITTLE	42	8.3	166	32.9
LONG	10	2.0	37	7.3
MAGNET	13	2.6	46	9.1
MAGNETS	10	2.0	34	6.7
NANO	86	16.9	284	56.3
NANOTECHNOLOGY	22	4.3	83	16.5
PARTICLES	18	3.5	67	13.3
RIDGES	8	1.6	31	6.2
RINGS	8	1.6	27	5.4
SIZE	12	2.4	50	9.9
SIZED	13	2.6	65	12.9
SMALL	26	5.1	112	22.2
SMALLER	17	3.3	76	15.1
STATIC	10	2.0	43	8.5
TINY	19	3.7	89	17.7

Figure 2 shows the results of the hierarchical cluster analysis. The stacked shading (^) presents the strength of the relationship between the concepts. The words with a strong relationship were grouped together as one conceptual cluster. Six clusters were identified through an analysis of the most frequently mentioned words, labeled as "carbon," "ferro," "electricity," "butterfly," "liquid," and "tiny."

Cluster 1 was labeled as "carbon," as the concepts are related to the giant carbon nanotubes. Specifically, the words "big" and "long" occurred with "carbon," indicating the participant's impression of *"Build a Giant Carbon Nanotube"* component of the "What's New about Nano" exhibit. In Cluster 2, the concept "ferro" was related to the "*Small, Smaller, Nano"* component of the "What Happens When Things Get Smaller" exhibit. The words "iron," "ferro," and "magnetic" again indicate the participant awareness of the "*Small, Smaller, Nano"* exhibit. The words "sized" and "particles" may reflect how the participants conceptualize the exhibit.

Cluster 3 dealt with the "electricity" aspect of the static vs. gravity exhibit. The word "static" is a main theme of this exhibit, while the word "rings" refers to the bearing that is central to this particular exhibit. Cluster 4 included concepts tapping into the popular exhibit about the blue butterfly. The words "blue" and "butterfly" undoubtedly refer to the "*I Spy Nano*" component of the "Where Can You Find Nano" exhibit, while the words "light" and "ridge" highlight the features of the exhibit. The words "fluid" and "liquid" in Cluster 5 may address the liquid-based characteristic of some exhibits such as the "*Small, Smaller, Nano*" component. In Cluster 6, the words "tiny" and "small" referred to one of the core NISE Net content maps focusing on the small size of nanomaterials.

Figure 2. Hierarchical cluster analysis of 30 unique concepts for Nano mini-exhibition participants.

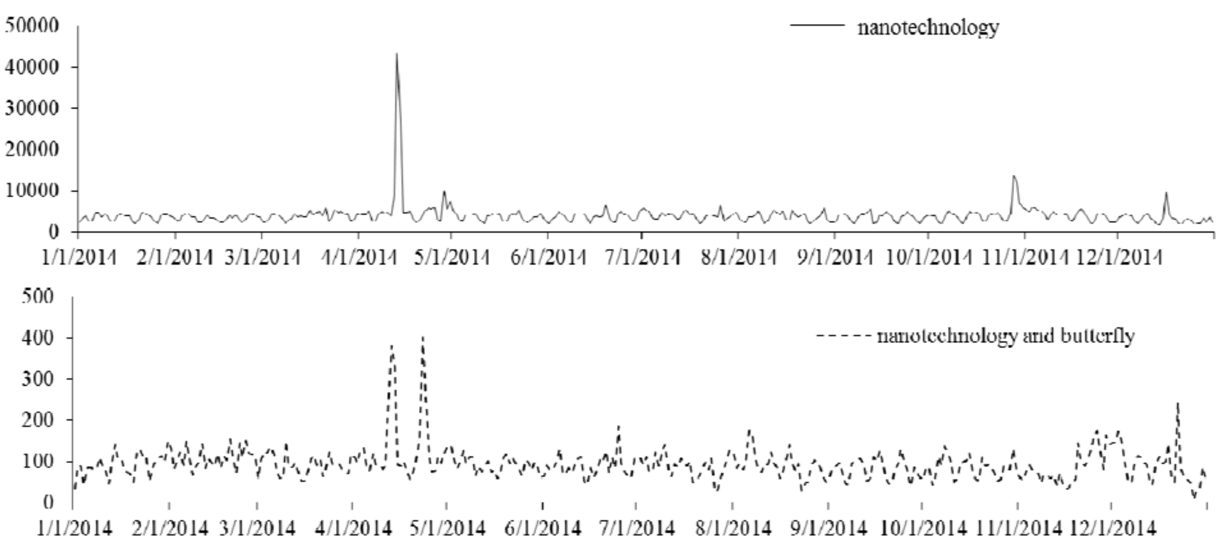


Note: The dendrogram is generated through Ward's method which represents clusters by their central point.

Using the Butterfly-related component of the exhibit as a case study. We focused on the identified concept surrounding *butterfly-related* materials, which are included as part of the "Where Can You Find Nano? I Spy Nano" exhibit as case studies to further examine the extent to which offline NISE Net events amplify the online discussion about nanotechnology. Toward this end, we utilized some conceptual words identified in Cluster 4 to refine the search string in order to analyze the volume of discussions that are surrounding nanotechnology while also being associated with the butterfly exhibit. With the assistance of the ForSight program, we examined the volume of discussion across online platforms, including blogs, forums, news sites, Facebook, Twitter, and comment sections.

We used the overall volume of online discussions about nanotechnology as a baseline and compared this with the volume of discourse that is not only surrounding nanotechnology but also is associated with the butterfly materials during a one-year period. Between January 1st and December 31st in 2014, approximately 480,669 posts were identified as being related to nanotechnology, while 34,544 posts not only tapped into nanotechnology but also focused on blue butterfly-related themes (see Figure 3).

Figure 3. Overall volume of discussions about nanotechnology (above) and nanotechnology associated with the Blue Morpho butterfly exhibit component (below) across online platforms



We observed the highest volume of online discussions surrounding nanotechnology in April. This finding is consistent with the fact that nationwide, NanoDays events are taking place around this time. Interestingly, discussions surrounding nanotechnology associated with the

Blue Morpho butterfly-related materials also occurred with visible spikes during the same period. The co-occurred peak volumes demonstrate that the discussions surrounding the butterfly may be attributed to both the *Nano* mini-exhibition and the NanoDays activities as butterfly-related materials are included in the "Where Can You Find Nano" and "What's New About Nano?" mini-exhibition components and NanoDays kits (e.g., "Zoom into a Blue Morpho Butterfly video"). The second peak volume that occurred at the end of April further suggests the lasting influence of offline events and exhibitions on the content of online discussions. These findings further suggest the real-world impact of NISE Net events on online discourse surrounding nanotechnology.

IV. Implications

First, the annually increasing volume of organizational tweets and significantly higher number of tweets over Facebook posts confirm the dominant use of Twitter in the public relations field (Barnes & Lescault, 2014; Lovejoy & Saxton, 2012). Originally, Facebook and Twitter allowed public figures, organizations, and the general public to set up and manage their own unique accounts without any costs. Facebook recently changed its algorithm, which has greatly decreased the possible reach for Facebook pages. Instead, the account holder of a Facebook page has to pay for a promotion service to reach more users, enlarge its fan base, and increase visits to the page. The increased financial burden may discourage public relations professionals using Facebook, which may explain the decreasing volume of Facebook posts between 2013 and 2014. However, it is important to keep in mind that NanoDays may have a greater digital footprint than our results suggest as not all the NanoDays visitors include the keyword of "NanoDays" in their social media posts when referring to the events.

Second, this project represents one of the first studies to analyze the content of NISE Network partners' Twitter posts to clarify the functions that social media updates serve in public relations. It also closely looks into the organizations' utilization of Twitter communication tools to examine whether they are tapping into dialogic and interactive communication in the current Web 2.0 environment. Taken together, the findings of the content analysis of media messages and examination of communication tool usage suggest that Twitter is predominantly used as a one-way message channel by NISE Network partners. The prevalent utilization function of Twitter is public information sharing, while the engagement function is the least likely to emerge across the texts, suggesting non-dialogic orientation to social media use by public relations professionals at NISE Network partner sites.

More substantially, longitudinal content analyses of the organizational tweets reveal that the informational use of microblogging increases annually, while organizations have been less likely to interactively communicate with stakeholders via engagement-encouraging and community-building practices. Over time, public relations professionals show an increasing tendency to use new media as unidirectional communication tools.

The additional analyses reflect similar findings in that one-way information dissemination (e.g., hyperlinks) was the dominant communication practice used by marketing professionals at the science centers. Twitter tools oriented toward dialogue and connection building, such as public messages and retweets, are largely ignored by scientific organizations. Although scientific organizations have realized the importance of social media and how these tools can be harnessed to supplement or even replace Web 1.0 tools, we found that social media are still largely and increasingly used by public relations practitioners at the NISE Network partner sites as an extension of information-excessive websites. The fact that the majority of online discussions surrounding NanoDays events is constituted by event-related information may largely reflect a "marketing perspective" among science centers and museums when communicating NanoDays using social media tools. These marketing efforts may help decrease recruitment gaps among potential audiences by reaching out to publics with more diversified backgrounds, given that social media have the potential to connect science center and museums with hard-to-reach audiences (Corley & Scheufele, 2010).

In fact, if the goal of an organization is simply to create a social media presence to improve the efficiency of information dissemination, one-way communication may seem to be preferred and appropriate. Nevertheless, for public relations professionals that are motivated to engage the public to cultivate mutual relationships through adopting the two-way communication model, using social media dialogically and interactively may yield the most gain for an organization. Practitioners' efforts on tapping into two-way engagement should be encouraged and facilitated to maximize the potential for long-term relationships (e.g., Grunig & Grunig, 2008).

In addition, the analysis suggests the importance of the organizational social media practices in relation to public engagement online. The geographic clustering of tweets around states that have more NISE Network partners that participate in NanoDays, shows that states with NISE Network partners exhibit a higher frequency of discussions. Namely, states with more NISE Network partners have higher proportions of scientific organizations and general public who are engaged in communicating about the topic on Twitter. This finding indicates a positive relationship between science public relations and online engagement rates, implying the importance of the presence of NISE Network partners and their public relations efforts in terms of creating greater online attention to a scientific event.

However, a closer examination of the overall tweets shows that only less than 10% of the online discussions were contributed by lay audiences. When looking into the whole picture of collective discussions about NanoDays, including posts constructed by NISE Network partners and the general public, the vast majority of the discussions originated from science centers on Twitter (92%). Although we cannot make a direct association between the dominant use of one-way communication strategies and low level of online public engagement, it is not illogical to suspect that the level of online public participation would have been higher had the practitioners been truly committed to two-way conversations (e.g., Cho, Schweickart, & Haase, 2014; Neiger, Thackeray, Burton, Giraud-Carrier, & Fagen, 2013). There may be no definite answer regarding what extent two-way public relations efforts by scientific organizations can be transferred into increased public engagement online. But using message content that is engagement- and community-based can further motivate the public to actively respond to the organizations and initiate new discussions.

On the other hand, this study demonstrates how researchers can track specific exhibit themes emerging from the transcripts of conversations conducted between participants at the *Nano* mini-exhibition. The preliminary findings of the hierarchical cluster analysis show that the hands-on exhibits that led to most discussions among their audiences include the "Build a Giant Carbon Nanotube," "I Spy Nano," "Small, Smaller, Nano," and "Static Beads" components. More importantly, several conceptual clusters are related to the small size of nanomaterials or mention keywords such as "small" and "tiny," suggesting that the participants are aware of the core concept of the NISE Net content map that highlights the smallness of nanometer-sized things. These findings indicate the potential of NISE Net-related events in educating members of the public so that they have the correct understanding of nanoscience.

In particular, the additional analysis that used the conceptual themes captured by the hierarchical cluster analysis as search strings reflected that discussions about components of NISE Net events such as NanoDays and mini exhibitions co-occur with each other. More importantly, the findings suggest the real-world impact of NISE Net in shaping online discussions about nanotechnology. However, it is important to note that the influence of

NISE Net-related events on directing online discourse does not last long, as the peak volume quickly ceases afterward.

V. Conclusions and Future Direction

The goal of this project is to refine and extend our current understandings of how different science institutions and the general public disseminate and communicate about the NISE Network and NISE Net-related events, using Twitter and Facebook. In addition, we explored the extent to which the presence of NISE Net-related science organizations and activities may shape the online discussions about nanotechnology. Our study focuses on analyzing online media platforms to explore real-world science communication and public engagement. There are at least three reasons for expanding this work in the future:

1. Online media are an increasingly significant platform for scientific information dissemination, serving as bridges among science community members, journalists and lay publics. Given the increasing importance of the Internet as a source of scientific information and a venue for discussions, improving our understandings of the flow of scientific information in online (social) media is essential and urgent (National Science Board, 2014).

2. Online networks are real-time information sources that allow users to access the latest stories and ideas shared by other users. In particular, online posts on Twitter and Facebook are relatively easy to construct and send. They lend themselves to near real-time response to current events and provide a constantly updated resource of public opinion expressions and reactions.

3. Online media enable high levels of interactivity and allow for discussions among users without geographical or temporal constraints. These web-based media provide researchers opportunities to examine potential communication channels with widely diverse publics and will produce rich data to improve science communication efforts.

As information sources, Twitter and Facebook allow us to examine the social structure of science communication online, which overcomes many of the constraints connected to efforts to tap these structures in face-to-face settings (Wu et al., 2011). Future research should not only seek to understand the role of different NISE Network community members in introducing and diffusing different kinds of scientific and exhibit information on social media sites, but also to quantify the influence of actors who participate in these scientific discussions. This type of research will help create more effective (online) interfaces between the NISE Network-affiliated science community and lay publics that will also be scalable to other outreach efforts, beyond NISE Net. In addition, future study should not only examine the messages that organizations and the public are posting, but explore the dialogue loops created. Analysis of how followers and organizations respond to social media messages allows researchers to extend the findings in this study. Researchers will have a better understanding of the two-way communication strategies in relation to dialogue building efforts.

VI. Relevant Presentations and Publications

Su, L. Y.-F., Scheufele, D. A., & Bell, L. (in preparation). Information and engagement: How organizations are using social media in science public relations. *Public Relations Review.*

Su, L. Y.-F., Scheufele, D. A., Brossard, D., & Xenos, M. (2015, August). *Information and engagement: How scientific organizations are using social media in science public relations.* Paper presented at the annual convention of the Association for Education in Journalism and Communication (AEJMC), Communicating Science, Health, Environment, and Risk Division. San Francisco, CA.

Su, L. Y.-F., Scheufele, D. A., Brossard, D., & Xenos, M. (2015, February). *Engaging the public in nano: How science museums and centers are using social media.* Paper presented at the annual convention of the American Association for the Advancement of Science (AAAS). San Jose, CA.

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