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Social Media, Collaboration, and Scientific Organizations

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Abstract

The use of social media by collaborative organizations has been studied in a variety of contexts, including virtual teams, enterprise organizations, and social movements. However, social media are not often examined within the context of scientific organizations. This article explores how an organization of 122 life scientists and science-related professionals—anonymized as Science City Network (SciCity)—combine monthly symposia with social media, including Twitter, Facebook, and blogs. Using an online survey, we found that younger SciCity members are more interested in using social media to support a collaborative community, whereas older members are more interested in social applications. Social media use was not found to significantly differ by gender. Using social network analysis, we found several individuals who act as hubs of information who keep the SciCity Twitter network alive. However, the hierarchical structure of the network reveals that it is better suited for information dissemination than innovation and collaboration. Our examination of this scientific organization ultimately offers insight into how a coalition of multiple social media technologies is used differentially by organizational members and that there is ultimately no general consensus of the utility of social media to scientific collaboration. This finding tempers some claims of the utility of social media for scientific collaboration.

Keywords

collaboration, social media, virtual organizations, scientific organizations, meetups, virtual science

The use of social media by collaborative organizations has been studied in a variety of contexts, including virtual teams (Muller et al., 2012; Murthy, Rodriguez, & Lewis, 2013), enterprise organizations (Brzozowski, 2009), and social movements (Juris, 2012). The notion that social media can foster trust and other preconditions for meaningful collaboration in organizations makes intuitive sense as these

technologies have the potential to increase interactions between organizational members and ultimately build social capital. Though social capital has been successfully used to study social movements within virtual communities (Cogburn & Espinoza-Vasquez, 2011), a key distinction of social capital online versus offline is that when it is acquired online, it can lack an affect-based dimension. Erving Goffman's (1967) studies of gestures and communication argue that this affect is part of the richness of face-to-face interactions. However, others have argued that social-media-driven technologies can successfully (albeit, sometimes minimally) encourage the affective dimensions that foster the accumulation of social capital (Valenzuela, Park, & Kee, 2009).

Emergent social media have forced us to expand our understanding of not only the types of social capital that the Internet can foster (Sander, 2005), but also the speed of social capital acquisition and new ways of using it. A particularly interesting case is that of hybrid organizations that combine meaningful aspects of online and offline social capital, potentially making them fruitful spaces for collaboration. Meetup.com, a virtual community that comes together face-to-face via offline meetings, termed "meetups," is a well-known example. Sander (2005) argues that these organizational hybrids can foster "alloy social capital," a strong form of social capital that leverages its ability to use the extensibility of the Internet and the low-friction context for interaction as well as stronger affect-based ties constructed through offline contact. This follows Jurgenson's (2012) argument that social media can "augment" offline interactions and should not be thought of as oppositional to face-to-face interactions.

This article explores one such hybrid community, anonymized as Science City Network (SciCity), a life science organization that combines regularly scheduled events with social-media-based interactions. SciCity consists of two intersecting operational modes: regularly scheduled meetings and an accompanying Twitter stream. In all, 122 people have attended SciCity events that generate significant Twitter activity during these organized face-to-face events. A recent event generated more than 4,000 tweets. SciCity's monthly meetings cycle through diverse themes in the sciences ranging from topical areas to science policy issues. Twitter feeds using the #SciCity hashtag support the conversation and experience high traffic during monthly events and low traffic otherwise. SciCity's virtual participants include geographically remote members who use the video streaming service Livestream to view the event and simultaneously use the Twitter hashtag to interact with the group as a whole regardless of physical attendance. Tweets are projected behind the conference speaker to unify the conversation.

Our case study is based around a survey administered during the summer of 2012. Survey questions gathered data regarding demographics, social media usage and perception, and the SciCity

Twitter network. We were interested in explaining how Twitter use complemented (or not) one's offline interactions with SciCity as well as understanding the nature of interpersonal relationships between SciCity Twitter users. We did not find evidence that respondents saw the use of SciCity-related social media as fostering collaboration. Rather, the structure of the network, with several individuals acting as hubs, served more as an information clearinghouse. This is a form of (weak) collaboration, in which links and other knowledge are shared via information brokers. However, stronger forms of collaboration, such as papers, grants, and so on, were not found to be directly facilitated by Twitter or other social media.

Literature Review

Offline → Online

Exclusively virtual communities can and have been meaningfully collaborative. This is particularly the case with virtual teams (Jarvenpaa & Leidner, 1999). However, even these communities and groups have found a positive "effect of offline gatherings on physically dispersed virtual communities" (Sessions, 2010, p. 375). In some cases, not having meetups "risks loss of weak ties" (Sessions, 2010). This can be ameliorated by videoconferencing technologies including Skype and Google Hangout. Knowledge-based organizations have found that the lack of face-to-face interactions in distributed virtual teams can lead to "individual profit . . . at the expense of the community" and the loss of bridging social capital (Sessions, 2010). "Multiplex relationships" with "media multiplexity" and meetups can be important for tie strength (Sessions, 2010). The augmented strength (or alloy social capital) gained by multiplexity is seen in the simple case where "meetup attendees strengthen their relationships with those they meet offline" (Sessions, 2010, p. 391). This echoes other virtual community literature (Rheingold, 1993; Sander 2005). Face-to-face interactions in geographically distributed organizations can be an important way to bring team members closer together. In addition, face-to-face interactions can tease out or create new relationships that would not have organically formed online. For example, introverts can be more gregarious on social media than in face-to-face interactions (Correa, Hinsley, & De Zuniga, 2010). McCully et al. found that "online communities may benefit from face-to-face meetings to fulfill a variety of needs and motivations for both the users and the site" and these meetups can deter the "creation of sub-groups and a disconnection from the broader community" (McCully, Lampe, Sarkar, Velasquez, & Sreevinasan, 2011). Of importance, offline meetups can foster trust, which becomes manifested through substantive changes in online interactions, such as shifting some of their public posting to private

messaging with other users (McCully et al., 2011). These strengthened relationships can be better foundations for collaborative processes.

Online → Offline

The converse is also true and online interactions can and do shape face-to-face interactions. In the United States, for example, incoming college students use Facebook to interact with their soon-to-be roommates (Israel, 2006), mediated interactions that deeply shape their first face-to-face encounter. The importance of online interactions to offline interactions has been studied in a diverse range of organizational contexts (Lin, 2007; Subrahmanyam, Reich, Waechter, & Espinoza, 2008). Liu et al. (2012) found that an event-based social network "does not only contain online social interactions as in other conventional social networks, but also includes valuable offline social interactions captured in offline activities." They found that online social networks act as a "convening technology" where the online is an offline catalyst. Bode (2008) found that "various types of Facebook behaviors have clear and significant effects on several types of positive offline political participation." Cummings (2008) highlights that collaboration is fostered by homophily, proximity, and familiarity. These can, of course, be fostered through face-to-face and social-media-based interactions. For example, the regular social familiarity bred by tweets and Facebook status updates can potentially strengthen proximity and familiarity via "watercooler moments" (Zhao & Rosson, 2009) and even test levels of homophily (e.g., do we share similar hobbies, interests, and friends?).

SciCity is a hybrid community that finds its offline and online interactions important to its organizational goals. Both offline and online environments are an integral part of building prosocial behaviors such as trust, mentorship, and collaboration. In contrast to Anderson, Steinerte, and Russell's (2010) reading of online communities and trust in which they theorize that online collaboration is to some extent incompatible with the development of interpersonal trust, Way and Austin (2012) argue it is not a question of incompatibility, but rather the development of interpersonal trust online can be qualitatively different than similar trust formed offline. Abfalter, Zaglia, and Mueller (2012) suggest the notion of "sense of virtual community" (SVOC), the concept that "feelings of membership, identity, and belonging, and attachment to a group that interacts primarily through electronic communication," an idea that helps us understand how an organization can have SVOC despite having a significant and regular offline component. In other words, SVOC and offline meetings are not mutually exclusive. Indeed, SVOC can be strong and compel or encourage offline interactions that would have otherwise not been possible or likely (perhaps because of geographical or organizational differences that were bridged by SVOC).

Scientific communities who actively use Twitter are growing, but still remain in the minority. Twitter's use during scientific conferences (Reinhardt, Ebner, Beham, & Costa, 2009) and as a tool to disseminate scientific knowledge to broader audiences (Letierce, Passant, Decker, & Breslin, 2010) has been explored, but the medium's ability to promote scientific knowledge development remains underexplored. Scientific organizations are not usually early adopters of social technologies and a certain level of conservatism can grow. Kling and McKim (2000) argue that science lags technology organizations because of institutional friction, different conventions, and different predominant media. For example, programmers have a high regard for online collaborative knowledge producing spaces such as stackoverflow.com (Hanrahan, Convertino, & Nelson, 2012). A notable exception is when the prominent publication *Scientific American* blogged about its favorite Twitter accounts in 2009 (Wong, 2009), when fewer than 2% of young Americans used the site on a typical day and well before Twitter use grew to 8% in 2012 (Smith, 2012). Kling and McKim argue that the focus on collaboration parallels trends in science toward international collaboration. For example, Olson, Zimmerman, and Bos (2008) found that there has been far more scientific collaboration using the Internet, which is directly reflected in an increase from 7% to 17% in international coauthorship in the sciences (from the 1980s to the 1990s).

Because social media are often used to share knowledge (e.g., links, grant solicitations, etc.), a distinction needs to be made between sharing and collaboration. Hyde et al. (2012) argue that "sharing of content alone does not directly lead to collaboration" and that collaboration on social media needs "an additional layer of coordination." This additional layer could be an instruction that compels you to tweet under a particular hash tag (e.g., #occupywallst), to tweet photographs during disasters, and so on. The important argument here is that aggregation can be a type of collaboration, though it may be a weaker form of collaboration than an experimental project, paper, or grant. This is not to say that weak collaboration is not important; rather, it is the aggregated strength of weak contributions that is important to collaborative knowledge production. A classic and well-studied example of this is Wikipedia (Ransbotham & Kane, 2011).

Method

Data were collected during the summer of 2012 via an extensive online survey. Respondents were recruited through a SciCity event in New York, Twitter, and targeted emails. Snowball sampling (Biernacki & Waldorf, 1981) was used to achieve high levels of coverage. Our survey response rate provided coverage of 19% of the estimated SciCity population. Despite the drawbacks that a nonrandomized survey incurs,

it was necessary to use a snowball method to increase coverage rates given the small size of the community, the diversity of groups involved, and the approximate time it took to complete the survey (well over 10 minutes).

The survey included Likert-type questions (Maranell, 2007), questions regarding members' media consumption, and a network section that asked users to report on their Twitter-based interactions with specific (self-identified) members of the SciCity community. Likert-type questions were used to assess community satisfaction on Twitter with the first asking whether the respondent felt part of a community on SciCity and the second asking whether the SciCity community was a place where users could seek guidance. Of importance, Likert-type questions asked respondents to assess whether Twitter was a suitable place for scientific collaboration.

The survey was simultaneously advertised at a monthly face-to-face event and via social media, consistent with the online/offline organizational structure of SciCity. The survey link was retweeted by several influential SciCity members. Publicizing surveys via Twitter has found some success in market research (Patino, Pitta, & Quinones, 2012). However, reach on Twitter is highly dependent on the following of the tweeting account and the numbers of retweets (and their follower counts). Following Solomon's (2001) suggestion that personalized email appeals significantly increased response rate, we used targeted emails. In our case, these efforts helped boost response rates. Social network analysis (Knoke, Yang, & Knoke, 2008) was used to study the self-reported Twitter network. Specifically, members were asked to report whom they interacted with on Twitter, their level of trust of that user, their level of collaboration, as well as several other measures. The network was studied for density, individual degree (the number of inbound connections to an individual in the network), and clustering to understand the structure and hierarchy of the SciCity Twitter network.

Results

The success of SciCity has been built on high levels of social media usage, including Facebook, Twitter, blogs, and Livestream. The SciCity community uses social media such as blogs to build critical topical discussion, archives tweet conversations into a narrative using the Storify.com platform, and curates discussion on Facebook pages. Livestream allows those unable to attend the event in person to participate and even collaborate on the Twitter stream live (a process aided by the live video stream). In addition to the Twitter hashtag, an official Twitter account coordinates Twitter followers and publicizes events. SciCity members are varied by occupation, race, gender, education, and age. They represent a communal "coalition" whose cohesion is heavily dependent on both social media and face-to-face events.

The community that participates in regular face-to-face events perceives knowledge sharing as a significant benefit from interacting with SciCity's social media incarnations. Indeed, social media helps constitute the community itself, which would otherwise be more geographically colocated. Age, race, gender, residence, education, occupation, Twitter usage, and offline-event attendance were important variables for understanding how this community maintains itself.

The SciCity Population

Our survey was launched simultaneously on Twitter and at a monthly offline meeting of SciCity in the summer of 2012. The face-to-face "pitching" of the survey was expected to increase response rates. Of interest, completion rates did not significantly vary by event attendance. Given the small size of SciCity (122 members), the result of 34 users answering at least one question of our survey and 23 completing all 14 required questions was strong. One complete survey, by a self-described "survey-enthusiast" was removed from analysis. Incomplete survey responses were used to understand how the missing data biased our results. The survey attracted respondents with varying degrees of interaction with SciCity. Of the 34 respondents answering at least one question, 38% had attended 6 or more events, 26% had attended 3 to 5 events, and 35% had attended 2 or fewer events. SciCity event attendance was correlated with survey completion. Of users who had attended more than 5 events, 85% completed the survey, whereas for users who had attended 5 or fewer events the completion rate was 57%. The survey was not completed by any user who had never attended an offline SciCity event. In other words, heavy attendees of offline SciCity events were oversampled and data about attendees who exclusively participate virtually are completely lacking.

Survey completion of those who had attended 3 to 5 events was lower than that of respondents who attended 1 to 2 events (56% and 77%, respectively). This may suggest that beyond the core group of enthusiasts (the 6 or more event attendees) that offline attendance does not indicate community commitment (as proxied by survey completion). Respondents who failed to complete the survey were subset out of our data, and all further results are based from fully completed surveys. A linear regression comparing respondent participation with the number of survey questions answered was inconclusive, though it had a negative slope (indicating that survey questions answered decreased as SciCity participation decreased). Of attendees of 6 or more events, 54% answered more than 20 survey questions, whereas 66% of attendees of 5 or fewer events answered no more than 20 questions.

SciCity users received information about SciCity most frequently through Twitter than any other form (computer mediated or not). Of SciCity users, 87% use the social media site and 70% of all respondents

reported getting information about SciCity through Twitter. Online blogs related to the community were negligibly cited as providing information about the community. Of respondents, 48% reported receiving information about SciCity through the online mailing list. Respondents who received information about the community through one medium were less likely to receive information through the other.

Notable features of the SciCity membership include the high proportion of women (64% of respondents), the geographical concentration of respondents in New York City (78% of respondents), the mode educational status (graduate degree), and the youthful skew in age (see Figure 1). It is important to note two archetypes of SciCity members: young, racially diverse, female scientists who have obtained their PhDs, and older, less diverse, graduate-degree-holding males in science-related fields. We hypothesized that early-career scientists would be interested in mentorship and collaboration and are knowledgeable about social media. We expected this to predict heavier use of the medium, particularly for urbanites for whom Twitter has been found to be especially popular (Fox, Zickuhr, & Smith, 2009).

Because age is highly correlated with social media use (Correa et al., 2010), it is an important variable for studying collaboration and social media. 26% of American 18- 29-year-olds are Internet users on Twitter, compared with only 14% of those ages 30 to 49 (Smith, 2012). The higher likelihood of young people to use Twitter suggests that the opportunities for virtual participation are skewed toward the very population among which SciCity members are concentrated; SciCity's population is generally young, with 48% of respondents 30 years old or younger (see Figure 2). The female dominance of this group is important, as women have been found to be more active in creating content on social networks (Hampton, Goulet, Marlow, & Rainie, 2012).

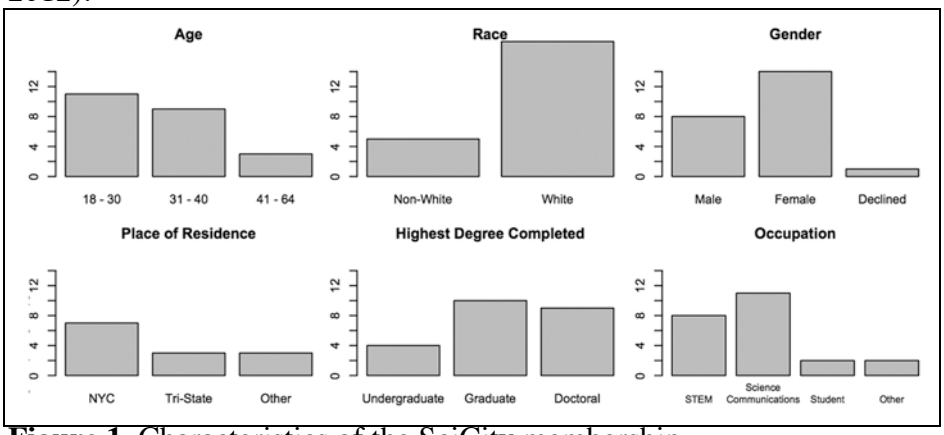

Figure 1. Characteristics of the SciCity membership.

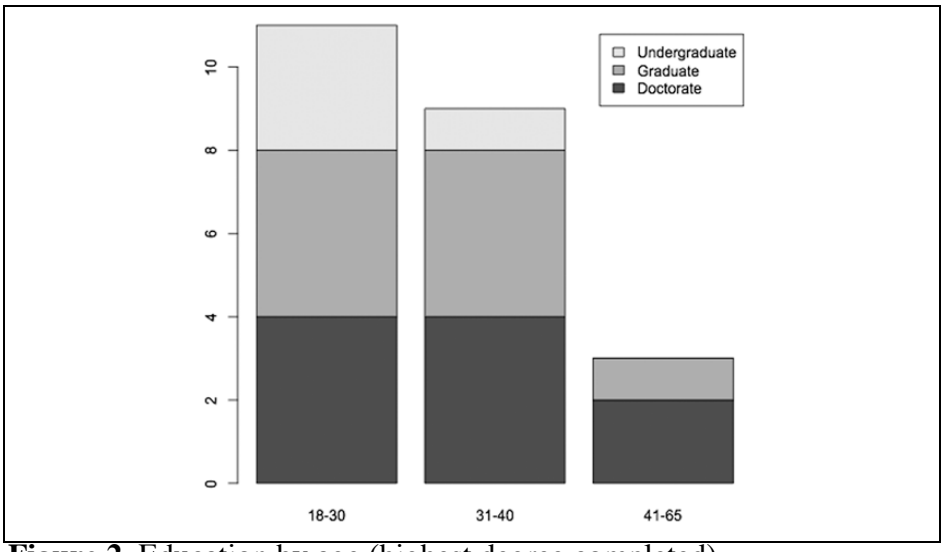

Figure 2. Education by age (highest degree completed).

The most darkly shaded bars in Figure 2 illustrate SciCity participants with doctoral degrees by age group. The number of respondents with doctoral degrees peaks in the 18 to 30 age group and declines in members older than 40 (with only one respondent older than 40 who has obtained a doctorate). Not only does this fail to track with overall rates of doctoral degrees when compared to educational attainment in the United States as a whole (Bauman & Graf, 2003), it directly contradicts them. SciCity is therefore formed from a small pool of highly educated Americans and draws a much higher proportion of the young than it does of the old. This simultaneous success and failure—success at attracting young, educated participants and failure to attract established, tenured senior scientists—suggests a strong interaction effect between age and education. Respondent age was associated with being comfortable seeking guidance/mentorship from SciCity (Fisher's exact test, $p < .05$). This indicates a consensus opinion among younger members (reporting *agree* to *strongly agree*) and a split, more pessimistic result among older members.

Location

Location plays an important role in mediating SciCity's online and offline interactions (because much of the social media activity surges in the wake of offline events). The combination of cognitive-based trust, such as ability, and affect-based trust, such as personal trust, from both online and offline interactions supports a fully hybrid trust model. Our survey was targeted to those who had attended at least one SciCity event. The existence of an offline event that serves as a focal point of SciCity presents an obvious geographical constraint that appears to

circumscribe the limits of the community and is reflected in the respondent data (see Figure 1).

Of interest, one of the four "leaders" of SciCity is based overseas, which suggests that geographical isolation is possible within SciCity. However, this is the exception rather than the rule as proximity drives consolidated membership among New Yorkers. What is also interesting was the fact that extreme rather than relative proximity was a necessary pretext for the community. Living in the suburbs or adjacent states provides perceived inadequate proximity (or that SciCity is unappealing to those not in New York City) despite extensive virtual infrastructure supporting the offline exchange. These location data (see Figure 1) are important given that urban individuals are more likely to use Twitter than suburban or rural individuals (Smith, 2012). This suggests that SciCity is doubly local—it has offline (inherently local) meetings and deploys a technology popular (even native) to its locality. The overlapping coincidence of quasi-local social media and local face-to-face meetings may drive the extreme concentration of SciCity's users in physical space. Of importance, physical proximity has been found to be an important factor for collaboration success (Tierney, 2000).

Despite the seamless integration of social media within SciCity, the organization remained strongly anchored to the locality of its face-to-face events. There is a significant difference between those who regularly attend SciCity and the likelihood they attended the most recent event (Fisher's exact test, $p < .05$) and the likelihood they feel part of the SciCity community (Fisher's exact test, $p < .05$). Members who attended most SciCity events were found to be more positive about SciCity as a collaborative community and the ways in which social media facilitated collaborative interactions.

Twitter

87% of surveyed respondents are Twitter users and the mode response for number of followers was between 100 and 500. The mode for followed was between 100 and 500. The number of followers each respondent had clustered around 100 to 500, but the number of users each respondent followed varied widely, with the two most frequent responses at 100 to 500 (30%) and 2,000 or more (20%). Very few respondents reported "news gathering" accounts with low numbers of followers, but many accounts followed (i.e., lurkers). Rather, there is a range of Twitter participants in SciCity including "novices/disengaged" (low–low), "celebrity/thought leader" style accounts (low–high), and heavy users with a reciprocal, social orientation (high–high).

Twitter users and nonusers alike were fairly evenly split between receiving information through the mailing list and not. Unsurprisingly, respondents who answered that they also were not Twitter users (13% of respondents) also reported that they did not receive SciCity information through Twitter (providing an additional check on the validity of our

results). Twitter is actively used by the SciCity community for information dissemination. Of respondents, 65% both used Twitter and received information about SciCity through Twitter. Twitter users are evenly spread across different frequencies of use, although the mode response was weekly (30% of respondents), with monthly and daily the second and third most popular frequencies. Those who used Twitter no more than once daily tended to also be the users with low numbers of followers and low numbers of following, fitting the "novice" Twitter style. When following and follower numbers are compared with Twitter usage frequency, an interesting case arises. Low numbers of following and low frequency of Twitter use had frequent overlap (this is characteristic of an unattended account). Of respondents following large numbers of users, they were evenly split between high and low frequency of Twitter use. This is compatible with a try it but quickly tire of it behavior. Similarly, users were twice as likely to follow high numbers of users if they had a high frequency of Twitter use.

These trends are in part substantiated and in part reversed by a comparison of frequency of Twitter use and the number of followers. Low frequency Twitter use is associated with a high numbers of followers (54% of low frequency users also had high numbers of followers). And, of users who had high numbers of followers, 64% used Twitter infrequently. It is clear that Twitter usage is more strongly predicted by high numbers of followed rather than high followings. This does not speak strongly to the social power of Twitter in scientific organizations (as one would expect that a larger audience should drive more usage).

Of Twitter users, 90% reported using the SciCity hashtag. 95% reported that they retweet posts as a way of participating with SciCity on Twitter. For those users who tweeted with high frequency (at least once per day), 83% interacted with other SciCity members on Twitter and 66% posted links. Social uses such as nonscience discussion and social communication are frequent uses for Twitter (65% and 60% respectively). 50% of respondents shared science news and 45% shared blog posts.

Of interest, Twitter use was generally constant across age groups. Twitter frequency, Twitter usage, the number of followers, and the number of following were not dependent on the age of the respondent (see Table 1). There were no statistically significant results as to whether one age group received SciCity information through Twitter more often nor were members' views of Twitter's potential to enable collaboration significantly different (see Table 1). The rate of Twitter usage was not statistically significant among age groups, which suggests that professional organizations differ in their use of Twitter than the general population's use of the medium (which has been found to be age-related; Smith, 2012).

Table 1. Relationship Between Demographic Variables and Community Variables

	Age	Race	Education	Gender	Occupation	STEM	SciComm
Online community sentiment							
I feel I am part of a community in SciCity.	.172	.652	.926	1	1	1	.489
SciCity is a community where I can seek guidance.	.012**	.092*	.685	.679	.593	.198	.85
Motivation for participating in online community							
No. of motivations	.042**	.39	.494	.732	.252	.393	.375
Intellectual stimulation	.59	.539	.771	.273	.161	.032**	.229
Mentorship	.59	1	.471	1	.677	1	1
Networking	1	.395	.308	.515	.435	.111	.486
Friendship	.014**	1	.266	1	.095*	.621	.339
Online media used to get info about community							
Number social media used	.684	.64	.298	.204	.326	.667	1
Facebook	.005***	.621	.421	.343	.445	.182	1
Mailing list	1	.037**	.209	1	.524	1	.68
Twitter	1	1	1	1	1	1	1
Twitter							
Twitter user	.59	.539	.771	.273	.578	1	1
Twitter frequency	.141	.255	.695	.596	1	1	1
Twitter followers	.37	1	.433	1	.647	.642	.406
Twitter following	.17	.117	.72	.633	.522	.642	1
Use community hashtag	1	1	1	.505	.429	1	1
SciCity info from Twitter	1	1	1	1	.398	.345	.65
Twitter useful for SciCity collaboration	.804	.753	.412	.139	.255	.146	.408
Ways respondent interacts with community on Twitter							
Number of ways	.005***	.587	.344	1	.778	.651	.642
Continue offline conv.	.065*	1	1	.352	.659	1	.67
Share links	.01***	.285	.159	.65	.449	.642	1
Retweet posts	.45	1	.2	.421	.15	1	1
Discuss science news	.07*	.582	.133	1	.459	1	.37
Nonscience	.16	.249	.242	1	.22	1	.374

conversations							
Blogs							
Number of blogs read	.092*	.46	.223	.461	.042**	.032**	.761
Read local blog	.667	.621	1	.649	.698	1	.685
Read general blog	1	.611	.055*	.386	.007***	.007***	.417
Read practice oriented blog	.069*	.272	.11	1	.445	.182	1

Significance based on Fisher's exact test. *$p \leq .1$. **$p \leq .05$. ***$p \leq .01$.

The results illustrated in Table 1 clearly reveal that age is the only variable that shows a high correlation to social media (though, of note, this was not the case in many of the Twitter questions). Overall, social media perception usage within SciCity was heavily mediated by age. That being said, the perceived utility of Twitter for collaboration on SciCity was low and was not significantly associated with any of the survey's core variables. SciCity members seek opportunities for mentorship and collaboration outside of traditional structures, which likely explains the high concentration of women in the organization. Gender is independent of all variables ($p < .1$), which indicates that gender does not predict SciCity user behavior. This is important given that social media use has been found to be influenced by gender (Correa et al., 2010), with, for example, increases in social media usage among teenage girls (Lenhart, Purcell, Smith, & Zickuhr, 2010). Gender is not similarly influential in the case of SciCity as Twitter usage patterns, and the types of social media that respondents use to interact with SciCity are not predicted by gender.

Both age and lower levels of education are significant deterrents to participation in SciCity. This has important implications for two of SciCity's core aims. First, SciCity's goal to extend membership beyond traditional academic boundaries is deterred by the high educational level of members. Second, in failing to capture highly educated older scientists (or even comparatively old in the case of the 31- 40-year-olds), SciCity risks being unable to offer a place for meaningful mentorship and collaboration between partners of diverse experience levels. Science research can be fundamentally transformed by the new perspectives of junior scientists (Rappa & Debackere, 1993), and some senior scientists see a range of benefits to mentoring and collaborating with junior scientists (Kahn & Greenblatt, 2009). As 68% of members are 18- 40-year-olds with at least a graduate degree, SciCity has the potential to be an effective collaborative space across ranks (contingent on recruitment of senior scientists).

Diverging Use of Technology

Social media usage in SciCity varied by age. Facebook was used more by older members as a means to receive information about SciCity, but

seldom used by younger members. This suggests an aversion to Facebook use as a means of professional interaction by younger members of SciCity. Older respondents were also more likely not to read SciCity's science practice-oriented blog. This divergence in Facebook and blog usage suggests a compartmentalizing of social and professional interactions for younger members. This is substantiated by a much lower rate of younger SciCity members seeking social interaction through social media when compared to older SciCity users ($p < .01$). Furthermore, the number of ways SciCity users interact with each other on Twitter varies strongly by age with older respondents using the medium socially (e.g., for chatting or keeping in touch).

Older and younger members exhibit distinguishable patterns of Twitter usage. This has implications not only for identifying younger or older Twitter "styles" but also for the professional-oriented use of Twitter by younger SciCity members. This finding supports Skeels and Grudin's (2009) conclusion that Twitter is being deployed in professional contexts. Older Twitter users were more likely to use Twitter in multiple ways (e.g., direct messaging, retweeting, and social tweets; Fisher's exact test, $p < .01$), less likely to post links (Fisher's exact test, $p < .05$), and more likely to continue conversations initiated face-to-face at events (Fisher's exact test, $p < .1$). This suggests a greater fluency with Twitter by younger users, which simultaneously reduces their investment in offline interaction (as demonstrated by their lower rates of continuing offline conversations). The Twitter style of younger SciCity members also legitimates the use of Twitter as a professional knowledge-sharing space for scientists.

However, this is not to say that social use by older members generated a higher frequency of Twitter activity than younger members. Rather, the latter were more likely to use Twitter to post and interact professionally. This suggests that while younger SciCity members are less social, they are neither withdrawn nor disengaged from the social media spaces of SciCity. We were interested in whether the social aspects of the medium could foster increased levels of collaboration. However, we found no statistically significant relationship between social interactions and collaboration on Twitter. This is an important finding as there is wide interest in evaluating whether the social aspects of social media foster collaboration (Murthy, 2013) by supporting affective-based trust development and, at a more limited level, cognitive-based trust. What we did find is that older users tend to be community generalists, who seek many types of interaction through SciCity (and welcome social interaction). This seems to pervade not only their community interactions, but also their online interactions within SciCity (with younger users interested in divesting their social interactions from SciCity, an organization they see as a more professional space).

The SciCity Twitter Network

The SciCity Twitter network is not particularly dense (density = 0.0383). This means the Twitter network only has 3.83% of all possible ties present. It is also not highly connected, as evidenced by an average degree of 1.84. In other words, the average user has 1.84 inbound interactions, which is low in comparison to "small-world" networks, with an average degree of 10 (Watts & Strogatz, 1998). This low degree means that most members of the network are not interconnected and need to route information via brokers much higher up in the network. This creates a deeply hierarchical network with two SciCity members (Users 3 and 4) acting as the center of the network and most other subgroups flowing through them (see Figure 3).

Collaboration levels are relatively weak on the #SciCity Twitter space, as reported by respondents (see Figure 4; thicker lines represent stronger levels of reported collaboration). Only one interaction (between Users 19 and 25) has a collaboration level of 3 out of 5. Most reported collaboration is between the levels of 1 and 2. The level of collaboration is indicated by the thickness of line between two SciCity Twitter users. As the network indicates, women are more central to the network (see Figure 9; larger dots indicate a higher network degree).

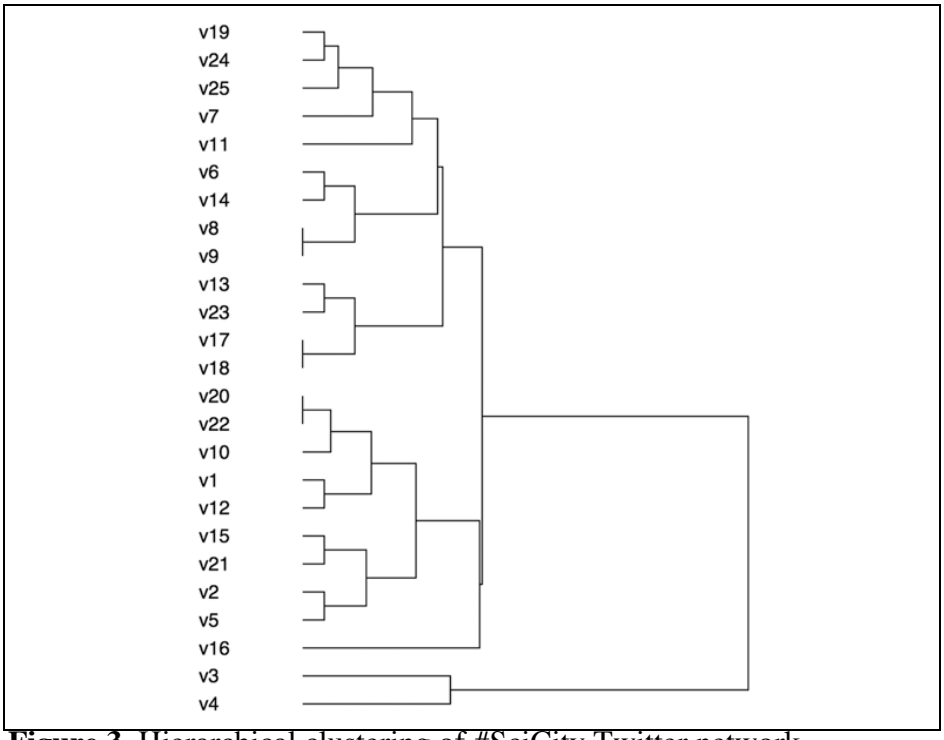

Figure 3. Hierarchical clustering of #SciCity Twitter network.

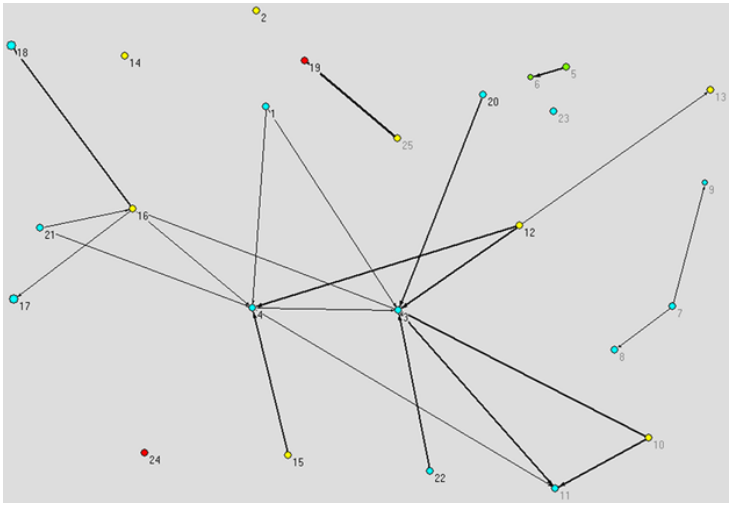

Figure 4. Collaboration level by gender (blue = female, yellow = male, green = organization, red = undisclosed in the online version of this article).

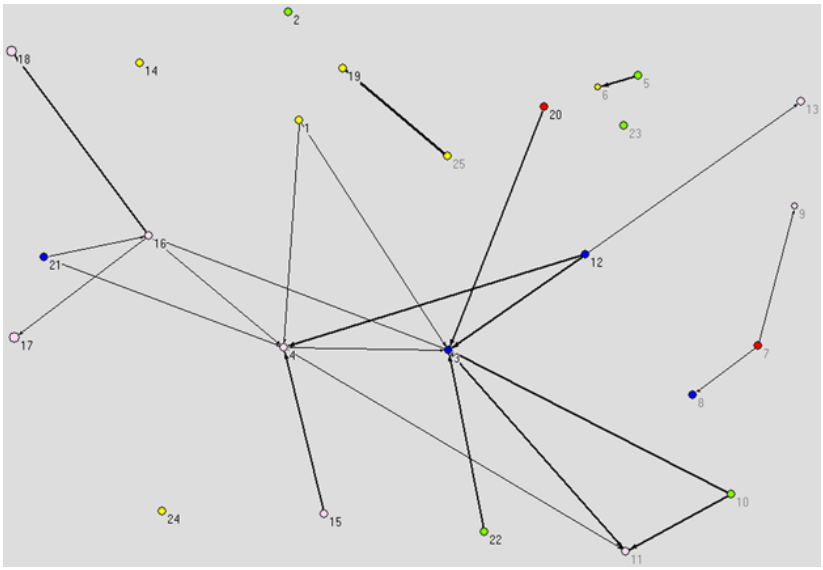

Figure 5. Collaboration level by number of followers (yellow = 0-100, green = 100-500, red = 500-1,000, blue = 1,000-2,000, pink = >2,000 followers in the online version of this article).

The number of Twitter followers a SciCity member has does not significantly change the lack of collaborative sentiment within the SciCity Twitter network (see Figure 5). Because members generally have very high followings (evidenced by the red, blue, and pink dots in

Figure 5), the #SciCity Twitter network already has a high audience reach and a high relative threshold in terms of follower counts. Also, the strongest level of reported collaboration (between Users 19 and 25) involves interactants with the lowest category of follower counts (colored in yellow in the online version of this article).

The frequency by which SciCity members tweet within the #SciCity hashtag is also not significant to engendering collaborative interactions. Central members such as Users 4, 12, and 16 tweet within the hashtag daily (see Figure 6). However, User 4, for example, does not elicit high levels of collaborative sentiment in return. This suggests that activity within the hashtag can be kept to a minimum, but still obtain the average levels of collaborative sentiment reported within the network.

A noteworthy finding is that SciCity members report high levels of trust developed from their interactions on Twitter. As Figure 7 illustrates, this is not dependent on gender (thicker lines indicate higher levels of trust). Rather, the Twitter network indicates high levels of trust, which are the product of Twitter-mediated interactions. Given overall survey data, these high levels of trust are most likely affect-based, rather than cognitive-based. This is consistent with our finding of the lack of collaborative sentiment fostered by Twitter. Specifically, cognitive-based trust is an important prerequisite for many forms of collaboration, both online and offline. This is to say not that affect-based trust is unimportant, but that having high levels of affective but low levels of cognitive-based trust is not as useful as the converse.

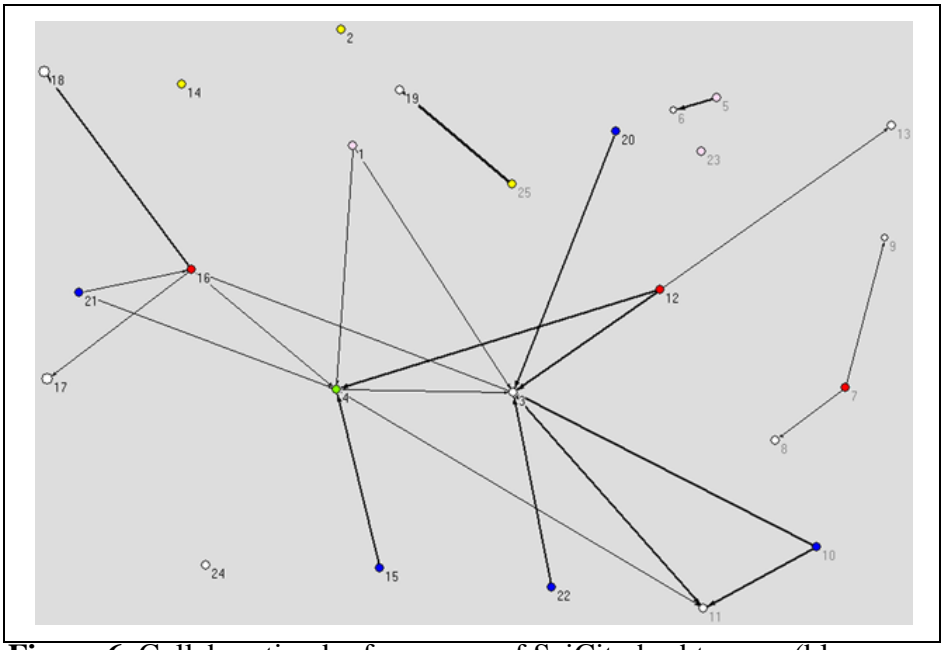

Figure 6. Collaboration by frequency of SciCity hashtag use (blue = weekly, white = not disclosed, yellow = never, pink = monthly, green =

several times daily, red = once daily in the online version of this article).

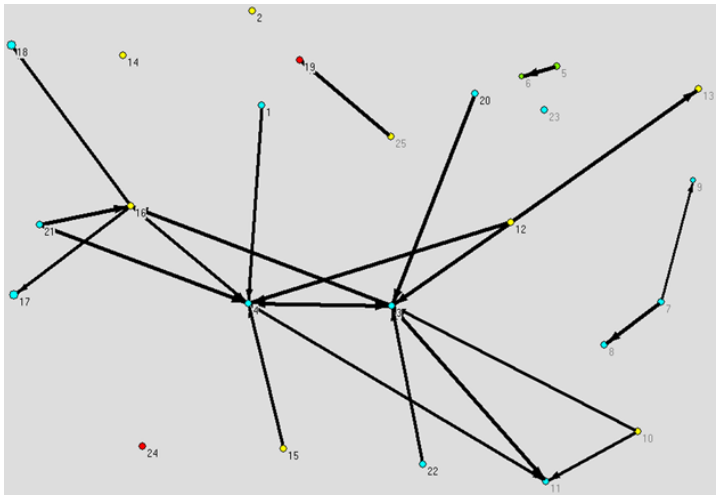

Figure 7. Trust by gender (blue = female, yellow = male, green = organization, red = undisclosed in the online version of this article).

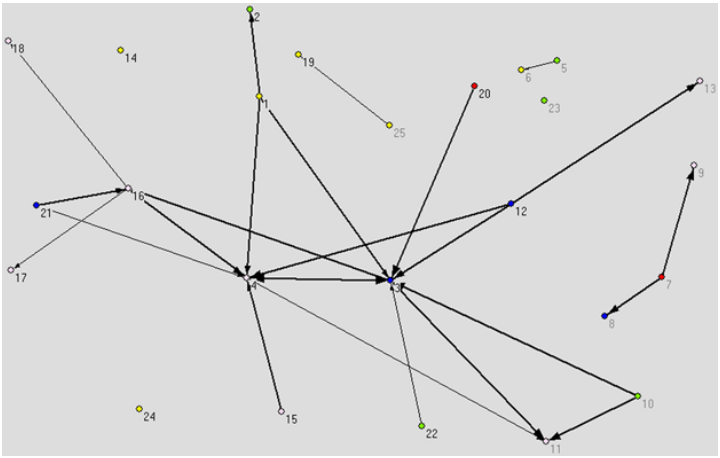

Figure 8. Communication frequency by number of followers (yellow = 0-100, green = 100-500, red = 500-1,000, blue = 1,000-2,000, pink = >2,000 followers in the online version of this article).

Communication frequency on Twitter is average (see Figure 7). More frequent interactions seem to occur between users with larger Twitter followings (see Figure 7; thickness of lines indicates communication frequency on Twitter). In addition, as previously discussed, central users of the network (e.g., Users 4, 3, 12, 16, and 11) all have 1,000 or

more followers on Twitter, which is well above Twitter's average follower levels of 208 (Roberts, 2012).

Social network analysis indicates that there is a central leadership within the Twitter network on SciCity (the larger dots in Figure 8 represent users with more reported inbound interactions). Though there is a dearth of high levels of collaboration, there are high levels of trust within the network (see Figure 6). The relatively high network degree for users within the center of the network (i.e., Users 3 and 4) reveals that there are hubs/brokers of information who also act as leaders who maintain the fabric of the #SciCity organization on Twitter. Those such as Users 3 and 4 who are central to the network help maintain the cohesiveness of #SciCity. In this case, they also exhibit high degrees of inbound trust sentiment (see Figure 6), average levels of collaboration sentiment (see Figure 3), and above-average frequency of contact (see Figure 7). The SciCity network on Twitter is active and vibrant, though it does not foster collaboration. Ultimately, it indicates that the types of trust developed on SciCity's Twitter network are more affect-based. This type of collaboration is much weaker and revolves around collaborating at the level of information sharing and aggregation of information, which Hyde et al. (2012) argue is a meaningful type of collaboration. Though the levels of collaboration sentiment are not high overall, this should not be conflated with a lack of a collaborative environment. First, information-sharing-based collaboration does not require high levels of collaboration sentiment. Second, there is potential for future, stronger collaborative networks to emerge

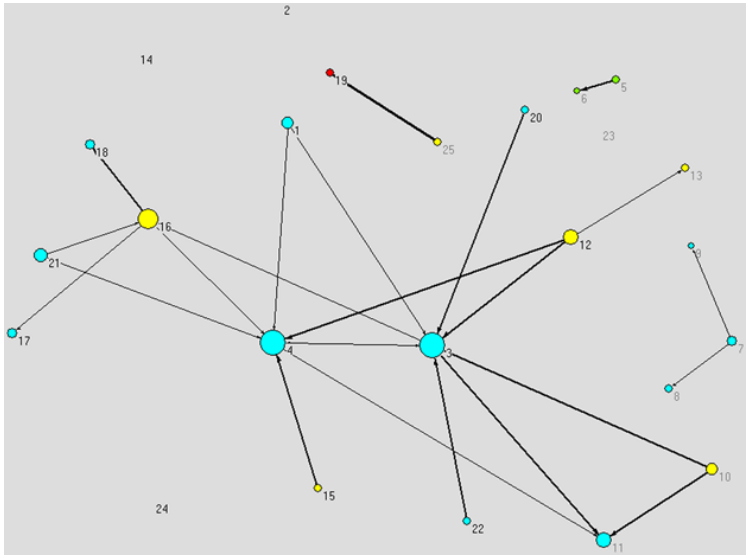

Figure 9. Collaboration by degree and gender (blue = female, yellow = male; larger vertex size = higher degree in the online version of this article).

(which do not exist now). In other words, Twitter discourse may serve as a starting point to encourage and kick start future collaborations that take place via other mediated communication or face-to-face. Therefore, though the value of Twitter itself in terms of fostering meaningful collaboration is not found to be significant directly, the knock-on effects in terms of fostering collaboration on other media (though beyond the remit of our study) could potentially be important to scientific work. Of importance, gender was not found to be a significant variable in terms of the ways in which the SciCity Twitter network operates. As Figures 4-7 indicate, gender is not a determining factor influencing social media perception or use in SciCity. That being said, SciCity users with higher degree centrality are more likely to be women. Brokerage of information on the SciCity Twitter network is therefore dependent on women, even if collaboration sentiment is not tied to gender.

Conclusion

This article has sought to understand the role social media play in scientific organizations and whether they foster meaningful collaboration. Scientific organizations have been conservative in adopting social media and have generally been pessimistic in their view of the utility of social media to advancing scientific collaboration. Social media literature has suggested that the social aspects of social media could help build trust in virtual teams and that this trust could provide an important foundation for collaboration (Calefato, Lanubile, & Novielli, 2013). The case of SciCity highlights that this is not generally the case. We found that social use of social media was more popular among older SciCity members and that these users were the same users least likely to use social media within SciCity to foster collaborative interactions. In addition, the community as a whole did not see Twitter as particularly useful to fostering scientific collaboration. SciCity is an interesting case study as it is not a purely virtual community, but a virtual/face-to-face hybrid. SciCity centers on two types of core interactions: online social media and offline monthly "meetups." The regularly scheduled events of this scientific organization create and maintain an active membership and social media interactions provide the cohesive glue between events. SciCity has emerged out of an "augmented" (Jurgenson, 2012) communication style in which digital communication is simply another layer of an individual's professional interactions. SciCity members who used social media for social purposes were in the minority. In SciCity, it appears that the interactions on social media do not merely extend the reach (through time and space) of SciCity, but deepens organizational

cohesion allowing some members to even interact on a daily basis, sharing links to scientific news, or grant opportunities for example. Collaboration is occurring on SciCity but at a weaker level—information aggregation and knowledge sharing, rather than project-based collaboration. Though this is not a "traditional" mode of collaboration, it is a form of aggregated collaboration based around collaborative knowledge sharing (akin to Wikipedia edits).

The #SciCity Twitter network is an important part of the community and is led by two well-followed Twitter users who act as central information brokers. Outside of them, the number of connections a user in the #SciCity Twitter network averages less than 2, making it a weakly connected network compared to "small-world" networks for example. This, combined with a low density measure and a hierarchical cluster, reveals the emergence of two dominant users. This structure is not ideal for using social media to foster collaboration. That being said, Twitter and other social media, including Facebook and blogs, have been important to SciCity and have helped foster affect-based trust (in distinction to knowledge-oriented cognitive trust). This indicates the possibility that social media can further trust within scientific organizations. However, the types of trust being fostered may be more confined to weaker forms of collaboration. Ultimately, the case of SciCity highlights the complexities of social media and collaboration. However, for example, if senior scientists begin to have a greater inclination to use social media professionally, there is real potential for social media to advance scientific collaboration.

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