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Drinking from the Firehose: The Structural and Cognitive Dimensions of Sharing Information on Twitter

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The continuous professional development of teachers is a pivotal element in the provision of high-quality education. Informal social networking sites (SNS), such as Twitter, can contribute to this process by enabling teachers to share their ideas and collaboratively reflect on their practice. In this context, educational scientists have increasingly acknowledged that the concept of social capital can contribute to our understanding of how such networks develop and evolve over time. This study uses a multi-method approach to investigate the role of structural and cognitive social capital in the #observeme Twitter conversation. Moreover, our results show that Twitter users are able to gain structural and cognitive social capital.

Social Media as an Opportunity Space to Informally Network

The continuous professional development of teachers is a pivotal element in the provision of high-quality education (e.g., Hokka and Etelapelto 2013). Teachers

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and educational professionals do not have to rely solely on formal support roles and institutions. Instead, they can draw on informal networks wherein they can share their ideas and collaboratively reflect on their practice (e.g., Fox and Wilson 2015). Even more so, scholars such as Rhodes (2000) propose a new, more dynamic network approach that focuses on the informal, horizontal communication between actors, highlighting their interdependence. This notion is supported by research suggesting that professional development can be fostered through social interactions, where individuals gain access to each other's resources, such as information, experience, and knowledge (Borgatti and Foster 2003; Bourdieu 1986; Coleman 1988; Lin 1999). Furthermore, Hattie (2013) found that teacher-driven activities, being conducted within collaborative communication networks, tend to be more effective than professional development interventions imposed by formally instated actors and institutions. Currently a growing number of studies of professional development and educational reform have begun to illustrate the importance of networks and social interactions among teachers and leaders in schools (e.g., Daly et al. 2010) as well as in the educational system in which these schools are embedded (Moolenaar et al. 2012). However, despite the recent surge of social media use, there is little empirical evidence about the way educators interact in educational networks online. This study aims to contribute to filling this empirical gap and focusing on better understanding the social interaction in this online informal network dimension.

This study departs from the work of Richter et al. and defines formal learning as “structured learning environments with a specified curriculum” and informal learning as “not follow[ing] a specified curriculum and . . . not [being] restricted to certain environments” (2011, 117). García-Peñalvo et al. (2012) posited that

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informal learning often involves a combination of different activities, including observing others, sharing experiences, and engaging in casual conversations about topics of shared interest. Similarly, Hofman and Dijkstra (2010) propose that informal learning networks can provide teachers with a platform to engage in a collaborative communication processes, exchanging insights and ideas and thereby contributing to each other's professional development. Boyle et al. (2005) were able to show that these theoretical considerations are met by the perceptions of teachers who consider sharing their practices an important element for their longer-term professional development activities. Scholars have postulated that the potential advantage of informal learning networks lies in their possibility to provide teachers with a platform where they can continuously share their practice and collaboratively engage in informal professional learning (e.g., Butler and Schnellert 2012; Hopkins 2000).

In this context, the rise of social networking sites (SNS), also referred to as social media, has led to a panoply of online communication spaces wherein individuals can informally network and communicate with each other. On the basis of their structure and general characteristics, SNS connect individuals via networked devices (Wellman 2001). The growing popularity and application across a wide range of different contexts have been paired with a growing amount of research that investigated the potential of SNS for informal learning. Moreover, a growing number of studies have shown that teachers use SNS, such as Twitter, to collect the latest news on education and share resources with colleagues (Risser 2013). More specifically, scholars have been able to show that SNS provide a valuable tool to contribute and share information on a nationwide Twitter discussion around the implementation of the Common Core State Standards in the United States (Supovitz et al. 2015). Furthermore, Carpenter and Krutka conducted a survey among K–16 educators and found out that despite a critical stance toward Twitter, many teachers use the platform to “to combat teacher isolation” (2015, 709). Similarly, Kelly and Antonio (2016), while focusing on Facebook, found similar evidence suggesting that teachers use SNS to connect with others, socialize, and support each other with practical advice for each other's teaching. In another study, Greenhalgh and Koehler (2017) investigated how teachers used Twitter to respond to the terrorist attacks carried out in Paris on November 13, 2015. Analyzing 1,208 original tweets and 4,333 retweets, the authors found that Twitter allowed “teachers [to] drive their own learning by pursuing the knowledge and resources that meet their needs” (278). Using machine learning, Xing and Gao (2018) analyzed more than 600,000 tweets and discovered cognitive and interactive dimensions in the communication patterns, which allowed users to gain new insights and contribute to a collaborative problem-solving process.

From a more conceptual and theoretical perspective, Macià and Garcia (2016) conducted a literature review of 99 studies, highlighting the potential of

SNS for teachers' informal professional development. More specifically, the authors suggest that SNS contribute to a community of like-minded individuals who tend to share experiences and teaching materials, reflect on practice, and support each other by answering questions. Similarly, Marotzki (2004) identified an unprecedented opportunity for SNS to connect people with differing backgrounds, thereby enabling them to exchange information and learn from each other's practical experiences. SNS thereby contribute to the creation of informal learning spaces wherein individuals can engage into their professional development (Spanhel 2010). However, the primary focus is not on the acquisition and transfer of knowledge (Marotzki and Jörissen 2008). Instead, these online spaces provide individuals with access to a plurality of different opinions and experiences on a shared interest or topic (Mynatt et al. 1998). They socially connect and combine the personal learning spaces of a wide range of individuals, thereby providing a collaborative foundation for informal learning (McPherson et al. 2015). Yet, despite their potential, when entering such informal learning spaces neither learning nor knowledge creation are guaranteed. They rather provide an opportunity for informal, professional development (Tynjälä 2012). We therefore argue that SNS constitute social opportunity spaces, which provide the meta-context wherein knowledge creation is fostered and learning processes are stimulated by the complex interplay of various underlying relations and factors (Rehm 2016; Rehm and Notten 2016). Within these spaces, individuals can engage in "environmental scanning" (Lohman 2005, 505), which enables them to access new information that can then be possibly integrated into their informal learning. Williams has described this notion as enabling individuals to look outside their "narrow daily existence" (2006, 600).

The Social and Cognitive Dimensions of Sharing Information: The Example of Twitter

Educational scientists have increasingly acknowledged that the concept of social capital can contribute to our understanding of how informal learning networks develop and evolve over time (e.g., Moolenaar et al. 2012; Rehm 2016; Rehm and Notten 2016; Risser 2013). In addition, social capital can help to explain potential benefits from networking (e.g., Fox and Wilson 2015) and has already been used to better understand professional development (e.g., Baker-Doyle and Yoon 2011). Social capital allows us to capture the value of informal learning networks "as a resource that teachers can draw upon to improve their teaching" (Hofman and Dijkstra 2010, 1032). Social capital can further be defined as "relational resources embedded in the cross-cutting personal ties" that "are useful for the personal development of individuals" (Tsai and Ghoshal 1998,

464). Nahapiet and Ghoshal (1998) distinguish between three dimensions of social capital, namely a structural, a cognitive, and a relational dimension. The structural dimension is concerned with the social interactions between individuals within a particular setting, such as a SNS. Who is contacting whom? How often do they communicate? How active is an individual in comparison to others? Is everybody talking to everyone? Those types of questions are at the center of the investigations about the structural dimension. The cognitive dimension deals with the question of whether participating actors share a common understanding and terminology, which improves the potential of exchanging ideas and information. The guiding questions here are: What are individuals talking about? What type of reoccurring keywords and phrases can be identified? Are they used by the majority of participants? Finally, the relational dimension of social capital describes issues such as trust and common values among individuals. One can consider the following questions as a basis for determining this dimension: Why do participants engage with each other? What are participants' aims and goals? Do they share their aims and goals? In the context of this study, we focused on the structural and cognitive dimension of social capital and examined informal networks on Twitter to better understand the development of social capital in SNS.

Twitter is a lightweight tool for easy communication that enables individuals to share information about any topic in so-called tweets that are limited to 280 characters. It is one of the most frequently used SNS to share information and news (Rudat and Buder 2015). As a matter of fact, according to Statista,¹ in July 2017 an average of 456,000 tweets were shared by all Twitter users per minute. This vast amount of information being shared has led researchers like Choo et al. to refer to the process of collecting information via Twitter as “drinking from the firehose” (2015, 3). It is therefore important to consider filter mechanisms that help to identify important and interesting users within the Twitter realm and what type of content they contribute to a certain topic of interest. Once this has been achieved, it will be possible for individual users to more effectively find and identify useful information and select groups or subgroups of others with whom they can engage and collaboratively contribute to each other's informal learning processes. Ultimately, this can then contribute to what Cairncross has referred to as the partial “death of distance” (2001, 4) by effectively simplifying how information can be shared among large groups of people, irrespective of time and place (Ye et al. 2012).

The main modes of communication on Twitter are direct messages, mentions, replies, and using hashtags. Including hashtags in tweets allows individuals to categorize their contribution and include their tweet in a larger conversation about a certain topic. Particularly the latter aspect has been identified as an opportunity for individuals to enhance their possibility of accessing new networks and expanding on their already existing ones (Letierce et al. 2010). Moreover,

by providing access to a persistent conversational log, all tweets are searchable and contribute to a growing pool of collaboratively shared information and knowledge (Isari et al. 2016). As a result, Twitter has started to evolve into an opportunity space where users can informally learn from each other (Honeycutt and Herring 2009). Boyd et al. (2010) even concluded that Twitter is not just merely about sharing information but rather about engaging with others and reflecting on one's own practice. In addition, a growing amount of research has investigated Twitter as a platform for community building and development (e.g., Gruzdt et al. 2011; Isari et al. 2016; Jussila et al. 2013; Takahashi et al. 2015). To this end, conversations on Twitter have been labeled a "collaborative memory aid" (Aramo-Immonen et al. 2016, 586), which individuals can use to create personal notes. Twitter is thereby able to turn the isolated information and expertise of an individual into something that others can access and use as part of their informal professional development (Tseng and Kuo 2010). Similarly, Rudat and Buder (2015, 76) stipulate that Twitter contributes to a so-called awareness information, which can be subdivided into agent awareness and informational value. Agent awareness refers to acknowledging one's surrounding within a network and being able to position oneself in the wider context of the network. This type of awareness contributes to social interaction and the active sharing of information (Lefebvre et al. 2016), which fosters the development of informational overlap and shared language (Borgatti and Cross 2003; Nooteboom 2000), which in turn has been attributed to the creation of social capital (Tsai and Ghoshal 1998). In that sense, one can identify certain similarities to the structural (social interactions between individuals) and the cognitive (common understanding and terminology) dimensions of social capital. Generally, the development and evolution of social capital within SNS has already been the subject of previous research (e.g., Fox and Wilson 2015; Hofer and Aubert 2013; Ranieri et al. 2012; Steinfield et al. 2008; Yoon 2014). The underlying notion is that SNS such as Twitter can increase individuals' social capital by enabling them to connect with new people and maintain relationships across geographical regions (e.g., Ye et al. 2012). Moreover, according to Chiu et al. (2006), it can be argued that individuals' driving force to join SNS is not only to acquire information but also to indeed connect with other people and thereby gain potential access to their resources.

In this context, one noteworthy, practical example of how SNS can contribute to community building and information sharing among educational professionals is the Twitter conversation #observeme. This hashtag conversation was initiated by the American math teacher Robert Kaplinsky, who worked in the Downey Unified School District in California. While browsing Twitter for some interesting content for his class, Kaplinsky discovered a picture that showed a sign outside a classroom door encouraging passersby to observe the present teacher and provide critical feedback on how he was doing as a teacher. This sparked

Kaplinsky's interest, and he began to promote the underlying idea by promoting the hashtag #observeme through social media, encouraging teachers to open their doors and welcome feedback. This was very well received by the teaching community, so the hashtag rapidly spread through Twitter, gaining increasing momentum to the extent that various teacher portals and blogs (e.g., *Education Post* and *Edutopia*) and funding agencies (e.g., Gates Foundation) have started reporting on the initiative and following its development. Even more so, according to some bloggers, the hashtag is now also being used as part of some preservice teacher programs to provide insights into the daily activities of teachers at school (Teague-Bowling 2017).

However, despite these types of examples from SNS and the general awareness that informal networking and social capital formation play an ever-growing part in individuals' professional development, research on this topic within SNS receives only limited attention (e.g., Aramo-Immonen et al. 2016), and previous research can be criticized on the basis of three main issues. First, the specific role of social capital within the context of informal learning remains uncertain (e.g., Boyd and Ellison 2007; Panzarasa et al. 2009). Second, previous research has largely been conducted in experimental settings, often within schools and among students. Consequently, although the applicable results have certainly contributed to our understanding of how social capital works in SNS, they have only limited relevance for the context of informal learning and professional development among working professionals (e.g., Eraut 2004). Third, despite a growing number of studies on teachers' use of SNS, a great amount of uncertainty persists on how informal learning and social capital formation within SNS apply to teachers and other educational professionals (e.g., Kukulska-Hulme 2007; Owen et al. 2016). The present study addresses these shortcomings by investigating whether conversations on Twitter have the potential to contribute to social capital formation and informal learning among teachers. Building upon the aforementioned considerations and perceived gaps in prior research, we formulate our overarching research question as: Can we identify the structural and cognitive social capital dimensions of sharing information on Twitter? In addition, we set out to provide insights on these underlying research questions:

1. To what extent does participation in Twitter conversation contribute to teachers' formation of (a) structural social capital and (b) cognitive social capital?
2. To what extent are individuals able to attain a central position within a Twitter conversation network?
3. To what extent are central individuals able to influence the information that is being shared within a Twitter conversation?

Method

We employ a multi-method approach to analyze a Twitter conversation. First, we use social network analyses to identify underlying activity patterns (Bruns and Stieglitz 2013), user clusters (De Nooy et al. 2011), and individuals or groups of individuals that could be viewed as having prominent roles in the conversation (Burt 2009). Second, we use natural language processing techniques, such as latent Dirichlet allocation (Blei and Lafferty 2009) and topic modeling (Alsumait et al. 2010), to investigate what teachers and educational professionals are talking about via Twitter, as well as whether individuals' network position influences what is shared and how it spreads throughout the network. Finally, we use web scraping techniques to collect all textual internet resources that have been shared by the applicable Twitter users.

Social Network Analyses

In this context, social network theory has been widely acknowledged as a valuable tool to assess the structural dimension of social capital (e.g., Moolenaar et al. 2012; Rehm 2016; Rehm and Notten 2016; Rienties et al. 2013; Tsai and Ghoshal 1998). Generally speaking, social network theory is concerned with the patterns of social relationships that exist between people in a social network (Scott 2017). A social network perspective extends the primary focus on individuals to understanding the interaction with the larger social infrastructure in which they reside (Borgatti and Foster 2003; Cross et al. 2001). It has been increasingly employed to analyze and visualize communication processes within SNS (Buccafurri et al. 2015; Steinfield et al. 2008; Yoon 2014) and provides insights into the social structures and processes involved in changing education (Moolenaar et al. 2012).

In applying this method to the Twitter conversations in question, we first collected data on the Twitter users that have contributed to the applicable hashtag conversation (Bruns and Stieglitz 2013). Subsequently, using the R library "igraph," we built a directed 1-mode network. Here, each node represents an individual Twitter account. The edges were constructed if one account mentioned or replied to (e.g., @userX) another account's tweet(s). Although being mentioned or being replied to can have different connotations and implications, we chose for the purpose of this study to combine the two types of communication to get a first, preliminary insight into the patterns and developments of the underlying hashtag conversation. Moreover, as it is possible to mention or reply to other accounts on multiple occasions, we considered a weighted network (e.g., Opsahl et al. 2010). Second, we computed the in-, out-, and overall degree

centrality metrics of all users (nodes) taking part in the applicable hashtag discussions. These metrics provide an indication of how often an individual has been contacted or has contacted others, respectively. These metrics are commonly used to assess and determine social capital within network structures (Moolenaar et al. 2012).

However, we believe that these centrality metrics work better in an offline context, where individuals are in direct contact within a physical location. In an online realm, such as online social opportunity spaces, this distinctive feature becomes blurred, and the explanatory power might be diminished (Daly et al. 2013). Yet, despite the general agreement that determining centrality within networks is an important aspect in understanding how they form and what type of information is shared and distributed (Borgatti and Cross 2003; Casciaro 1998; Johnson-Cramer et al. 2007), identifying these type of network members may prove more difficult than expected (Boster et al. 2011).

In this context, we consider previous work on brokerage positions in general (e.g., Gould and Fernandez 1989), on Twitter (e.g., Anger and Kittl 2011), and in the context of hyperlinked content (e.g., Kleinberg 1999). More specifically, the work of authors like Gould and Fernandez (1989) provides valuable, theoretical considerations about brokers and how they can possibly influence communication flows within networks. However, as indicated earlier, it can be questioned whether these types of considerations and metrics are still valid within social opportunity spaces. Considering the work of authors like Anger and Kittl (2011) offered a more nuanced view on how individuals can possibly assert influence on communication patterns within Twitter discussions. Although their approach is rather straightforward, it reduces potential barriers to apply such considerations in practice by educational professionals. Finally, although it is not directly related to the focus of our work, we have considered work by authors like Kleinberg (1999), who have investigated how websites are interlinked and whether this contributes to certain websites being “hubs” or “authorities” (607). We stipulate that such hyperlinked environments provide a comparable space to social opportunity spaces such as Twitter. In essence, both types of settings are investigating how links (Websites: hyperlinks, Twitter: hashtags, mentions, replies to) contribute to a node’s position within a larger network. Building upon these considerations, we propose the social brokerage metric (SBI) that can help to answer research questions 2 and 3.

The SBI determines four categories based on individuals’ in- and out-degree centrality. More specifically, we devised our metric by first normalizing the degree difference and then rescaling this metric on a scale from -1 (more in- than out-degree) to $+1$ (more out- than in-degree). In addition, we determined four subcategories within the measure’s scale, which were based on the underlying quartiles and represent (1) very passive ($-1 \leq x < -0.5$), (2) mostly passive ($-0.5 \leq x < 0$), (3) mostly active ($0 \leq x < 0.5$), and (4) very active ($0.5 \leq x \leq 1$). Those

categories are then labeled as (1) social hub, (2) social authority, (3) social influencer, (4) social broker.

Social hubs are sought after by a large number of others, who name them in their contributions without necessarily expecting a reply from them. As illustration, Donald Trump is commonly included in a wide range of discussions on Twitter. However, in relation to the overall volume of tweets that tag his account, his input has been very limited. However, the account acts as a “magnet” that other accounts seem to use to either identify themselves with Trump or distinctively distance themselves from his ideology and mindset. It therefore acts as a hub wherein a wide range of information and views is exchanged.

A social authority is recognized by the Twittersphere as an account that regularly tweets valuable information to a variety of conversations, thereby attracting a high influx of communication (e.g., mentions and replies) from other Twitter users. Exemplary accounts from the realm of education include dedicated websites for teachers (e.g., Edutopia) and officially certified innovators (e.g., Google Certified teacher). Particularly, the latter type of account then also takes the time to engage in an exchange with a changing subset of followers. By using the terminology of “hub” and “authority,” we build upon the work of previous research, which has predominately been conducted in the context of websites rankings (e.g., PageRank), which are based on hypertext induced topic selection (e.g., Amento et al. 2000; Bharat and Henzinger 1998; Ding et al. 2002). Although the applicable algorithms and metrics are very useful starting points for our work, we believe that the underlying rationale is not well suited to describe active behavior among participants of a Twitter chat. Consequently, we use the terminology for the passive spectrum of our proposed metric.

The term “social influencer” describes an account that not only tweets valuable content but also actively engages in communication with other Twitter users, representing their opinions and sharing additional views and comments. These types of accounts share information with others by directly mentioning them in a tweet and engaging in discussions by replying to the contributions of others. Furthermore, these accounts tend to belong to individuals who are regularly invited as speakers at face-to-face events, such as workshops or EdCamps. These accounts also regularly organize and facilitate live Twitter conversations.

Finally, social brokers have a lot in common with social influencers. However, they are even more active in participating in a range of different Twitter conversations; they tend to win awards for outstanding performance and often have their own dedicated web space (e.g., blog) where they post their thoughts, observations, and opinions. Moreover, a preliminary, qualitative investigation of the applicable Twitter profile(s) and provided background information therein revealed that they also tend to be founders of hashtag conversations. Describing actors in network spaces as influencers or brokers also builds upon previous research in this area. More specifically, some scholars refer to the concept of

“opinion leaders” (del Fresno García et al. 2016, 25). Yet, in contrast to the previously mentioned account of Donald Trump, we believe that being influential does not necessarily equate to being active in a discussion or actively pursuing a brokerage role. Others have chosen the agent to be the broker to another domain. We therefore believe that our metric is better able to capture the active engagement of being a broker, which would translate into degree difference and therefore being categorized in group 4.

Bibliometric Analyses and Web Scraping

We used bibliometric analyses to assess the cognitive dimension of social capital formation (Nahapiet and Ghoshal 1998). Bibliometric analyses enable us to deal with the large amounts of text data that are being produced within SNS. It has been increasingly promoted as a valuable methodological approach to map what is being contributed and shared by actors within SNS (Alsumait et al. 2010). More specifically, we employed latent Dirichlet allocation (Blei and Lafferty 2009), which is also often referred to as topic modeling (Alsumait et al. 2010) and has increasingly been used to analyze the underlying topical structure of these big data sets (Chaney and Blei 2012). We employed the Gibbs sampling algorithm to identify this structure, which is the most commonly used method (Blei 2012). In the context of this method, one has to determine the amount of topics to be assigned ex-ante. For the purpose of this study, we ran the applicable analyses for five, seven, and 10 ex-ante topics. We then analyzed the results and qualitatively determined which option best describes the underlying communication flows. Furthermore, we distinguish between the collated texts directly from tweets and the texts that are shared via the tweets. More specifically, based on the 280-character limit for tweets, it has become common practice to include links (e.g., to blogs or websites) in the tweets, where the indicated information is then fully displayed and reported. Consequently, although tweets provide a good insight into the type and nature of information that is being shared via Twitter, they do not fully capture all the underlying information that forms the basis of the tweets. We therefore programmed a web scraper, based on the R library rvest, that enabled us to collect all textual elements from the links that were shared via Twitter (Mitchell 2015; Munzert et al. 2014). More specifically, we collected all text from the landing page of the applicable links that were marked as html elements “p—paragraph” and “div—division.” This allowed us to gather a wide range of additional data, but this method did not allow us to harvest information from protected websites. Overall, we were then able to run four types of bibliometric analysis. First, we could perform topic modeling on a full Twitter corpus. The applicable findings were then able to contribute to our understanding of research question 1b. Based on our findings in the context

FIG. 1.—Overview of bibliometric analyses. SBI = social brokerage metric.

of the structural dimension of social capital and our adjusted network metric (SBI), we were then able to use our SBI to filter the Twitter corpus according to our four categories and draw conclusions on research question 3. To expand our analyses and to incorporate the wider information exchange outside of Twitter, we then ran the same analyses for the text corpus of the websites that were shared via Twitter. Figure 1 provides a schematic overview of the applicable analyses.

Data

The data for our analyses is based on the aforementioned Twitter conversation #observeme. We chose this particular hashtag conversation because it constitutes a very different context as compared with other popular educational hashtags such as #edchat. The latter was initiated as a weekly Twitter conversation among like-minded teachers to discuss and learn about the latest trends and developments in teaching. It therefore started as a collaborative effort, whereas #observeme started out as an individual user's idea to collect feedback on his or her own practice.

To harvest the applicable data, we accessed Twitter's streaming application program interface using a self-developed Java application. The data was collected over a period of approximately 6 months, from September 28, 2016, through April 7, 2017. Overall, 12,445 users shared 30,650 tweets that contained 4,358 links to websites such as blogs and teacher platforms. The collected data was then imported into the Pajek software packages to compute the standard social network analysis metrics and users' brokerage positions, as well as the R software package to produce sociograms and other visualizations, determine the SBI, and conduct the bibliometric analyses (mainly using the R libraries *igraph*, *rvest*, *quanteda*, *tm*, and *topicmodels*).

Results

Social Network Analyses

Results for the regular network metrics.—Table 1 provides an overview of the main characteristics of the hashtag conversation. As can be seen, there is a considerable standard deviation from the mean. Second, in- and out-degrees, despite acknowledging a sizeable standard deviation, tend to be rather similar to each other. This indicates that a large group of overall participants are consuming (receiving) and producing (sending out) information in rather similar amounts.

To put these metrics into perspective, figure 2 provides a sociogram to shed more light on how the network structure looked. As can be seen, that hashtag conversation contributed to a large set of interconnected nodes (giant-component) that are in contact with each other. Moreover, a cluster analysis revealed smaller subsets of Twitter users that were engaged more closely with each other than necessarily with others (indicated by the color of the nodes in fig. 2). There also appeared to be some Twitter users that gravitated toward the center of these subsets. However, there were also groups of isolated nodes and smaller subclusters that communicated amongst each other but did not actively join the larger discussion (as represented by the lower half of fig. 2). These networks were sparsely connected. Yet the nodes that were indeed connected regularly replied to each other and really did seem to engage into a discussion about the topics relevant for that particular hashtag chat.

Results for the new network metric: social brokerage index.—Figure 3 provides an overview of the social brokerage index and graphically shows how the index is composed and distributed within #observeme. Social hub (1): A close inspection reveals that this category is entirely made up of one account that can be connected to a large online teacher community, namely teacher2teacher. Social authority (2): This role exhibits a high degree of variability. Social influencer (3): This role essentially mirrors the social authority, but in the positive spectrum. There is a general trend toward zero. Social broker (4): This role has the same pattern to that of the social hub. Again, this category consists of only one account,

TABLE 1
Overview of Main Network Metrics

	Average	Standard Deviation
Overall degree	7.04	68.31
In-degree	3.52	33.58
Out-degree	3.52	47.43

FIG. 2.—Sociogram of the full network structure. Layout—multidimensional scaling; size of nodes—overall degree centrality $\times 0.1$; color of nodes—Louvain clustering algorithm.

FIG. 3.—Distribution of normalized degree difference (diff)

which can be traced back to a single math and computer science high-school teacher from California, who is an online certified teacher and an active member of the board of directors in California.

Bibliometric Analyses

Twitter.—To assess the cognitive dimension of social capital, we ran topic modeling for the different SBI categories, filtering out what their representatives contributed to #observeme and determining what topics predominantly occurred in their communication. Tables 2–5 represent the top 10 terms per topic and SBI category. We ran the analyses for five, seven, and 10 ex-ante topics and discovered that five topics provided the most coherent summary of the underlying hashtag conversations. A closer qualitative inspection of the findings of the seven and 10 ex-ante topics did not add any new topics, but rather subdivided the already discovered topics into sub-categories. SBI 1 (social hub) was composed of a single account that represents an online teacher community. As can

TABLE 2

Top 10 Terms per Topic (SBI 1: Social Hub—Tweets)

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
know	thank	whyiteach	observeme	community
let	edtech	story	sharing	help
school	year	pass	shoutout	great
looking	like	quoted	experience	shares
edchat	ecet	teachers	love	need
classroom	growthmindset	get	thanks	tips
ideas	chat	teach	share	happy
class	making	new	can	question
share	needs	students	keep	ever
teaching	edchat	educator	resources	welcome

be seen from table 2, this account appears to be used as a portal to spread information across different, other Twitter channels. More specifically, in the case at hand, other Twitter users mentioned the applicable social hub to push information into not only #observeme but also #edchat (topic 1), #edtech (topic 2), and #whyiteach (topic 3). Moreover, although these chats all have slightly different angles on the same topic, the used terminology shows clear similarities. Across all topics “share” and “thank” are reoccurring items that hint toward a community-building nature of the communication process. Furthermore, topic 5 is specifically composed of words that stipulate a process-related nature of communication, including words such as “welcome,” “community,” “need,” “shares,” “great,” and “happy.”

The results for SBI 2 (social authority) are represented in table 3. Again, the #observeme conversation seemed to have been used to also branch out into other

TABLE 3

Top 10 Terms per Topic (SBI 2: Social Authority—Tweets)

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
cateacherssummit	ecet	educolor	whyiteach	ecet
teachers	educolor	cultureed	ecet	mon
whyiteach	students	love	edchat	thu
cateacherssummit	teachers	observeme	teacher2teacher	dec
learning	chat	ecet	teacher	wed
great	can	know	classroom	nov
teacherteacher	need	teachers	passion	jan
day	take	dont	school	tue
today	work	school	great	barrykid
new	learn	join	teach	sat

TABLE 4

Top 10 Terms per Topic (SBI 3: Social Influencer—Tweets)

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
ecet	ecet	join	arsant	ecet
need	will	chat	ecetnatl	learning
students	ecetnjpa	tonight	dereklong	make
can	time	great	minuteecet	know
just	good	barrykid	new	teacher
think	leadership	est	love	teach
teachers	like	talk	right	best
thanks	school	night	want	talking
learn	fredende	sunday	nicholasadiaz	sure
share	teacherteacher	week	take	everyone

hashtag conversations. More specifically, we found references to #cateachersummit (Topic 1), #whyteach (Topic 4), and different combinations of #ecet together with #educolor (Topic 2) and #cultureed (Topic 3). We also found, particularly in topic 5, process-oriented communication that deals with the practicalities of organizing a Twitter hashtag conversation.

Social influencers (SBI 3), whose results are presented in table 4, also showed a comparable pattern to the overall findings. However, this closer look revealed that a particular, other hashtag conversation, namely #ecet, had a significant impact on this category’s communication. In addition, topic modeling revealed that certain individual Twitter accounts held distinctive positions as they were integral parts of the discussion (e.g., @barrykid, @nicholasadiaz and @dereklong).

The social broker (SBI 4), which was composed of an individual Twitter user in this case, used their very active role in the #observeme conversation to address issues and topics directly related to their place of work (California): #cateachersummit (topics 2 and 4) and #bettertogetherca (topic 3; table 5). Furthermore, topics 1 and 5 appear to refer to events that were supposedly held in the California region and invited members of the Twitter community to meet up face-to-face. Finally, combining these findings across the different SBI categories revealed that representatives of each category shared a common language by using the same hashtag or hashtag combinations during the #observeme conversation. More specifically, commonly used hashtags include #ecet, #cateachersummit, and #whyteach.

Websites.—The bibliometric analyses so far already provided valuable insights. However, the text corpus was limited to the tweets, which are limited to 280 characters. Consequently, to more fully capture the underlying information that constitutes the basis of the tweets, we used a web scraper to collect textual information from the links that were shared. Again, we ran the analyses for five, seven, and 10 ex-ante topics and discovered that seven topics provided the best fit

TABLE 5

Top 10 Terms per Topic (SBI 4: Social Broker—Tweets)

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
gallagher	cateacherssummit	writing	cateacherssummit	learning
students	importance	kellygtogo	fri	jul
teachers	twitter	together	join	kelly
get	july	bettertogether	hard	today
day	erniehudson	james	great	register
csuf	starting	suptdclosky	long	watch
ernie	life	writers	wytiwyg	keynote
powerful	lmusoe	bettertogetherca	bradmcurrie	hudson
baldwin	necessary	continue	chat	reached
life	poor	kqededspace	inaugural	clmooney

for the underlying topical discussions. The results are summarized in table 6. Here, a similar picture emerges as for the analyses of the Twitter corpus. #observeme (Topic 3) is clearly connected to a range of other discussions that are taking place at the same time. Again, we find links to #ecet (Topic 2), #cateacherssummit (Topic 1), #whyiteach (Topic 5) and #educolor (Topic 4). In addition, “teacher2-teacher” now has been identified as a separate topic. Moreover, we are now able to show a discussion topic, namely Topic 7, which is not assigned to any specific sub-domain, but rather discusses issues across topics, such as “students,” “kids,” “teach,” “learn,” and “help.” Moreover, the terminology and vocabulary being used suggest that the websites being referred to on Twitter are largely blogs and teacher portals. We also again ran the analysis for SBI subsets of the overall data set. However, in this case, no particular additional insights were gained other than the ones already summarized by tables 2–5.

Discussion

This study set out to investigate what is going on in Twitter conversations among teachers and educational professionals when they are supposedly “drinking from the firehose” (Choo et al. 2015, 3). Moreover, we were interested in whether Twitter would contribute to the social capital formation amongst our target group. Using a multi-method approach, we were able to combine insights from SNA and bibliometric analyses, which have been widely acknowledged as valuable tools to assess social capital (e.g., Moolenaar et al. 2012; Rehm 2016; Rehm and Notten 2016; Rienties et al. 2013; Tsai and Ghoshal 1998).

Based on the results of this study, we argue that participation in Twitter conversation contributed to teachers’ formation of structural social capital (RQ1a). Based on the results of our social network, we are able to show that participants

TABLE 6

Top 20 Terms per Topic (Entire #observeeme Corpus—Websites)

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7
teachers cateachersummit learning new today day year better cateachersummit excited first tomorrow together bamradionetwork ready writing getting thinking post bettertogether	ecet join chat tonight ecetmatl barrykid week great talk leadership arsant ecetrijpa discuss twitter welcome dereklong daily night latest mssackstein	observeeme love will get like time good feedback way think always class right give going community idea yes well robertkaplinsky	educolor education edchat educators check work people classroom looking find read chat many look another schools educolormvm color next forward	whyteach teacher great teaching thanks thank amazing sharing awesome much story everyone sta happy life grade tell math high team	teacher2teacher school know don share let cultured student important every use culture via classroom positive ideas educator something edtech kidsdeserveit	students can one need make teach kids want learn just help best take others must change come also things ecet

shared information, got connected, and thereby contributed to their own social capital and that of others. We are therefore able to second the conceptualizations and empirical findings of other scholars who have identified social capital as a useful concept to explain the potential benefits teachers can accrue from networking (Fox and Wilson 2015) and have already used the concept to help understand teachers' professional development (Baker-Doyle and Yoon 2011).

The results of our bibliometric analyses further contributed to our understanding of what is going on in Twitter conversations among teachers and educational professionals. First, we discovered "spin-offs" or "parallel discussions" that were connected to the #observeme discussion. For example, #whyiteach, #ecet, #educolor, and real-life events such as #cateacherssummit were all additional hashtag conversations that were included in the #observeme discussion. This suggests that individuals might target popular hashtag conversation to increase the scope and reach of the tweets. Based on the Twitter corpus, we were then also interested in the additional information conveyed via tweets in terms of hyperlinks to such resources as blogs and websites. We therefore programmed a web scraper that enabled us to collect all textual elements from the links that were shared via Twitter (Mitchell 2015; Munzert et al. 2014). We then ran another set of topic models and were able to expand on our findings, zooming in on more specific and nuanced terminology and vocabulary being used. Consequently, being able to identify underlying topics of the hashtag conversation and expanding the insights by using a web scraper, we conclude that participants in the #observeme conversation were able to establish a common terminology, as highlighted by the usage of common hashtags and key terms within the identified topics, thereby contributing to the creation of cognitive social capital for all participating actors (RQ1b).

Our findings also contributed to the assessment of our second research question, which was concerned with the extent to which individuals were able to attain a central position within their Twitter conversations (RQ2). Our sociogram (fig. 2) revealed that elements of the largest part of the network (giant-component) were in contact with each other and that some Twitter accounts were at the center of smaller subsets (clusters). Our SBI then allowed us to zoom in on these observations and determine whether these roles were actively pursued or put onto people. Focusing on the two extreme cases—social hub (very passive) and social broker (very active)—we were able to show that these roles were held by two individual Twitter accounts, respectively. Whereas the role of the hub was being assigned to an online teacher community, which acted as a kind of portal for relevant and interesting news for teachers and educational professionals, the role of social broker was actively pursued by an individual math and computer science high-school teacher from California. Hence, we considered this support for our criticism of the regularly used SNA metrics in SNS research and considered what type of network metric might be better able to capture the communication

processes and underlying network structures within SNS. Commonly used network metrics provide valuable insights into how networks are influenced by individuals. However, they originated from and were based on considerations from an offline context, where the only chance to really access an individual's knowledge and expertise was via direct contact. On the contrary, in an online social opportunity space, such as SNS, where the vast amount of communication is publicly available, this rather clear-cut distinction seemed to have diminishing explanatory power (Daly et al. 2013). Applying the SBI metric revealed that we were able to zoom in on the regular roles and provide a more fine-tuned measure to distinguish between active and passive positions. This in turn contributed to a better understanding of how communication processes are structured and develop within SNS.

Finally, we were interested in whether individual Twitter accounts would be able to influence the information being shared within a Twitter conversation, which constitutes our third research question (RQ3). By combining SNA with bibliometrics, we were able to shed some first light onto this issue. Specifically, our SBI provided insights into the different roles that could be taken on in the #observeme discussion. This metric was then used to filter out the messages and links from the applicable groups and identify them separately. In the case at hand, representatives from SBI 2 (social authority) and 3 (social influencer) were generally participating in a range of different hashtag conversations (e.g., #ecet, #cateachersummit, and #whyteach) highlighting certain Twitter users (e.g., @barrykid) and providing them with a stage to share their thoughts and ideas. In case of SBI 1 (social hub), our bibliometric analyses showed that their role was to act as a portal for others to share their information and expand the discussion into other, related hashtag conversations. This supports again not only the importance of our SBI metric but also the added value of our multi-method approach. Previously, the representative of SBI 1 would have merely been labeled important for the discussion, without knowing how the position was attained. Moreover, it would not have been possible to see how their position might have been affected by the content being shared by and with them. Similarly, our detailed analyses on SBI 4 (social broker) showed that the applicable Twitter user actively pursued their central role and engaged in bridging the gap between the virtual and actual world. The user provided information focused not only on a geographical region in the US (California) but also on upcoming events and activities where teachers and educational professionals could meet face-to-face and continue their discussion at a physical location. This is a very interesting finding as this type of information exchange has been said to support the creation and development of relational social capital (Lin et al. 2008; Nahapiet and Ghoshal 1998), attributed to issues such as trust and common values among individuals. One can consider the following questions as a basis for determining this dimension: Why do participants engage with each other? What are participants' aims and goals? Do they share their aims and goals? In the context of this study, we focused on the

structural and cognitive dimension of social capital and examined informal networks on Twitter to better understand the development of social capital in SNS.

Consequently, based on our findings, we argue that SNS, such as Twitter, really do constitute social opportunity spaces, wherein information is being shared, knowledge creation is fostered, and learning processes can be stimulated (Rehm 2016; Rehm and Notten 2016). Furthermore, we stipulate that social capital theory provides a valuable framework to analyze communication processes within SNS. Assessing the structural and cognitive dimension of social capital, using SNA and bibliometrics respectively, provides valuable insights on the underlying network structures and the types of information being shared. Assessing these types of processes and structures not only enables us to better understand how communication and informal learning processes develop and evolve in SNS, but also allows us to potentially profile SNS conversations and better understand which types of discussions draw which types of participants and how the dynamics might be influenced by this.

Limitations and Future Research

This study, although rich in descriptive and analytical data, exhibits five main limitations that can provide valuable input to future research in this field. First, in this study, we focused on the structural and cognitive dimensions of social capital. Although this analysis provides a valuable contribution to our understanding of how individual Twitter accounts influence the social opportunity space of Twitter, it neglects the possible underlying reasons why individual Twitter accounts might have chosen to join a particular Twitter conversation (the relational dimension). Hence, to enhance our understanding of how social opportunity spaces are subject to the influence of social capital considerations, future studies should aim to triangulate all three dimensions of social capital and determine possible interaction effects between them. For example, future studies could conduct mixed-methods research and include semi-structured interviews with individual participants from a hashtag conversation to inquire about the relational dimension of social capital.

Second, the current data is based on user statistics from Twitter. Although this objectified approach has acknowledged benefits (Hofer and Aubert 2013), it also raises the question of how reliable Twitter data is. More specifically, Ruths and Pfeffer (2014) have been able to empirically show that an individual's Twitter timeline, which is the basis for harvesting the data, does not necessarily provide "an accurate representation of the overall platform's data" (Ruths and Pfeffer 2014, 1063). Consequently, even though the impact for the data set at hand can be argued to be limited, one needs to draw conclusions carefully when trying to

generalize the applicable findings. Moreover, scholars like Williams (2006) have designed questionnaires that can help to determine an individual's perceived value of social capital. Incorporating such questionnaires into the research design and analyses would extend the available data and add a more subjective, evaluative dimension.

Third, unlike other popular educational hashtags, #observeme specifically encourages individuals to take direct action in their classrooms based on the feedback and suggestions they receive as part of the hashtag conversation. It therefore strives to bridge the gap between cloud and classroom. Consequently, it can be argued that this scenario could have implications on the formation of social capital formation for individuals. Even more so, it provides the opportunity to investigate whether the social capital from the online realm does have meaning and currency in the offline world. Future research should investigate this issue, for example, by distributing questionnaires or conducting semi-structured interviews to investigate how the interaction between cloud to classroom might operate.

Fourth, although the simplicity of the proposed metric contributes to the ease of use, it also has drawbacks. The current specifications do not yet fully account for differences in levels of in- and out-degrees. Consequently, the scaling effect still needs to be fully accounted for. Moreover, future studies could consider incorporating theoretical and conceptual considerations developed in the context of dynamic influence models (e.g., AlFalahi et al. 2014), where possible changes in influence over time are accounted for. Alternatively, diffusion influence models (Domingos and Richardson 2001) could also provide a valuable source of inspiration for enhancing the SBI metric, as these types of models often include a threshold (e.g., Granovetter 1978) that takes into account the tendency of an individual to be influenced by their neighbors.

Finally, future research should include similar studies on a wider set of hashtags and incorporate images that are being shared. Investigating a wider set of hashtags would allow for testing and validating the suggested methodological setup and assessing the relevance and applicability of the underlying theoretical considerations. By incorporating images, future studies would acknowledge that visual content is an important part of social media communication and investigate the multileveled meaning and intent of the images that are being shared (Highfield and Leaver 2016).

By following these suggested pathways, we would be able to gain additional insights into how individuals shape their role within online social opportunity spaces such as Twitter, how this affects their network position, and how the content being shared might be influenced by certain groups of participants. This in turn would allow us to better understand how informal networking is initiated and fostered within social opportunity spaces. Moreover, we would attain valuable, additional insights on who are the driving forces behind these processes and what kind of topics are relevant for educational practitioners.

Notes

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1. “Media Usage in an Internet Minute,” Statista, accessed on December 14, 2017, <https://www.statista.com/statistics/195140/new-user-generated-content-uploaded-by-users-per-minute/>.

References

- AlFalahi, Kanna, Yacine Atif, and Ajith Abraham. 2014. “Models of Influence in Online Social Networks.” *International Journal of Intelligent Systems* 29 (2): 161–83.
- Alsumait, Loulwah, Pu Wang, Carlotta Domeniconi, and Daniel Barbará. 2010. “Embedding Semantics in LDA Topic Models.” In *Text Mining*, ed. Michael W. Berry and Jacob Kogan. Chichester: Wiley.
- Amento, Brian, Loren Terveen, and Will Hill. 2000. “Does ‘Authority’ Mean Quality? Predicting Expert Quality Ratings of Web Documents.” In *Proceedings of the 23rd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*. New York: ACM.
- Anger, I., and C. Kittl. 2011. “Measuring Influence on Twitter.” *Proceedings of the 11th International Conference on Knowledge Management and Knowledge Technologies* 31. <http://dl.acm.org/citation.cfm?id=2024326>
- Aramo-Immonen, Heli, Hannu Kärkkäinen, Jari J. Jussila, Sian Joel-Edgar, and Jukka Huhtamäki. 2016. “Visualizing Informal Learning Behavior from Conference Participants’ Twitter Data with the Ostinato Model.” *Computers in Human Behavior* 55, Part A (February): 584–95.
- Baker-Doyle, Kira J., and Susan A. Yoon. 2011. “In Search of Practitioner-Based Social Capital: A Social Network Analysis Tool for Understanding and Facilitating Teacher Collaboration in a US-Based STEM Professional Development Program.” *Professional Development in Education* 37 (1): 75–93.
- Bharat, Krishna, and Monika R. Henzinger. 1998. “Improved Algorithms for Topic Distillation in a Hyperlinked Environment.” In *Proceedings of the 21st Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*. New York: ACM.
- Blei, David M. 2012. “Probabilistic Topic Models.” *Communications of the ACM* 55 (4): 77–84.
- Blei, David M., and John D. Lafferty. 2009. *Topic Models*. Vol. 10. Boca Raton, FL: CRC.
- Borgatti, Stephen P., and Rob Cross. 2003. “A Relational View of Information Seeking and Learning in Social Networks.” *Management Science* 49 (4): 432–45.
- Borgatti, Stephen P., and P. C. Foster. 2003. “The Network Paradigm in Organizational Research: A Review and Typology.” *Journal of Management* 29 (6): 991–1013.
- Boster, Franklin J., Michael R. Kotowski, Kyle R. Andrews, and Kim Serota. 2011. “Identifying Influence: Development and Validation of the Connectivity, Persuasiveness, and Maven Scales.” *Journal of Communication* 61 (1): 178–96.
- Bourdieu, Pierre. 1986. “The Forms of Capital.” In *Handbook of Theory and Research for the Sociology of Education*, ed. John G. Richardson. Westport, CT: Greenwood.
- Boyd, Danah, and Nicole Ellison. 2007. “Social Network Sites: Definition, History, and Scholarship.” *Journal of Computer-Mediated Communication* 13 (1): 210–30.

- Boyd, Danah, Scott Golder, and Gilad Lotan. 2010. "Tweet, Tweet, Retweet: Conversational Aspects of Retweeting on Twitter." In *2010 43rd Hawaii International Conference on System Sciences*, 1–10.
- Boyle, Bill, Iasonas Lamprianou, and Trudy Boyle. 2005. "A Longitudinal Study of Teacher Change: What Makes Professional Development Effective? Report of the Second Year of the Study." *School Effectiveness and School Improvement* 16 (1): 1–27.
- Bruns, A., and S. Stieglitz. 2013. "Towards More Systematic Twitter Analysis: Metrics for Tweeting Activities." *International Journal of Social Research Methodology* 16 (2): 91–108.
- Buccafurri, Francesco, Gianluca Lax, Serena Nicolazzo, and Antonino Nocera. 2015. "Comparing Twitter and Facebook User Behavior: Privacy and Other Aspects." *Computers in Human Behavior* 52 (November): 87–95.
- Burt, Ronald S. 2009. *Structural Holes: The Social Structure of Competition*. Cambridge, MA: Harvard University Press.
- Butler, Deborah L., and Leyton Schnellert. 2012. "Collaborative Inquiry in Teacher Professional Development." *Teaching and Teacher Education* 28 (8): 1206–20.
- Cairncross, Frances. 2001. *The Death of Distance: How the Communications Revolution Is Changing Our Lives*. Cambridge, MA: Harvard Business Press.
- Carpenter, J. P., and D. G. Krutka. 2015. "Engagement through Microblogging: Educator Professional Development via Twitter." *Professional Development in Education* 41 (4): 707–28.
- Casciaro, Tiziana. 1998. "Seeing Things Clearly: Social Structure, Personality, and Accuracy in Social Network Perception." *Social Networks* 20 (4): 331–51.
- Chaney, Allison June-Barlow, and David M. Blei. 2012. "Visualizing Topic Models." *ICWSM*. <http://www.cs.columbia.edu/~blei/papers/ChaneyBlei2012.pdf>.
- Chiu, C.-M., M.-H. Hsu, and E. T. G. Wang. 2006. "Understanding Knowledge Sharing in Virtual Communities: An Integration of Social Capital and Social Cognitive Theories." *Decision Support Systems* 42 (3): 1872–88.
- Choo, Esther K., Megan L. Ranney, Teresa M. Chan, N. Seth Trueger, Amy E. Walsh, Ken Tegtmeyer, Shannon O. McNamara, Ricky Y. Choi, and Christopher L. Carroll. 2015. "Twitter as a Tool for Communication and Knowledge Exchange in Academic Medicine: A Guide for Skeptics and Novices." *Medical Teacher* 37 (5): 411–16.
- Coleman, James S. 1988. "Social Capital in the Creation of Human Capital." *American Journal of Sociology* 94:95–120.
- Cross, R., A. Parker, A. Prusak, and S. P. Borgatti. 2001. "Knowing What We Know: Supporting Knowledge Creation and Sharing in Social Networks." *Organizational Dynamics* 30 (2): 100–20.
- Daly, Alan J., Yi-Hwa Liou, Natalie A. Tran, Frank Cornelissen, and Vicki Park. 2013. "The Rise of Neurotics Social Networks, Leadership, and Efficacy in District Reform." *Educational Administration Quarterly* 50 (2): 1–46.
- Daly, Alan J., Nienke M. Moolenaar, Jose M. Bolivar, and Peggy Burke. 2010. "Relationships in Reform: The Role of Teachers' Social Networks." *Journal of Educational Administration* 48 (3): 359–91.
- del Fresno Garcia, Miguel, Alan J. Daly, and Sagrario Segado Sánchez-Cabezudo. 2016. "Identifying the New Influences in the Internet Era: Social Media and Social Network Analysis." *Revista Española de Investigaciones Sociológicas* 153:23–40.
- De Nooy, Wouter, Andrej Mrvar, and Vladimir Batagelj. 2011. *Exploratory Social Network Analysis with Pajek*. Vol. 27, *Structural Analysis in the Social Sciences*. Cambridge: Cambridge University Press.
- Ding, Chris, Xiaofeng He, Parry Husbands, Hongyuan Zha, and Horst D. Simon. 2002. "PageRank, HITS and a Unified Framework for Link Analysis." In *Proceedings of the*

- 25th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval. New York: ACM.
- Domingos, P., and M. Richardson. 2001. "Mining the Network Value of Customers." In *ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*. New York: ACM Press.
- Eraut, Michael. 2004. "Informal Learning in the Workplace." *Studies in Continuing Education* 26 (2): 247–73.
- Fox, Alison R. C., and Elaine G. Wilson. 2015. "Networking and the Development of Professionals: Beginning Teachers Building Social Capital." *Teaching and Teacher Education* 47:93–107.
- García-Peñalvo, Francisco J., Ricardo Colomo-Palacios, and Miltiadis D. Lytras. 2012. "Informal Learning in Work Environments: Training with the Social Web in the Workplace." *Behaviour and Information Technology* 31 (8): 753–55.
- Gould, R. V., and R. M. Fernandez. 1989. "Structures of Mediation: A Formal Approach to Brokerage in Transaction Networks." *Sociological Methodology* 19:89–126.
- Granovetter, M. 1978. "Threshold Models of Collective Behavior." *American Journal of Sociology* 83 (6): 1420–43.
- Greenhalgh, Spencer P., and Matthew J. Koehler. 2017. "28 Days Later: Twitter Hashtags as 'Just in Time' Teacher Professional Development." *TechTrends* 61 (3): 273–81.
- Gruzd, Anatoliy, Barry Wellman, and Yuri Takhteyev. 2011. "Imagining Twitter as an Imagined Community." *American Behavioral Scientist* 55 (10): 1294–318.
- Hattie, John. 2013. *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London: Routledge.
- Highfield, T., and T. Leaver. 2016. "Instagrammatics and Digital Methods: Studying Visual Social Media, from Selfies and GIFs to Memes and Emoji." *Communication Research and Practice* 2 (1): 47–62.
- Hofer, M., and V. Aubert. 2013. "Perceived Bridging and Bonding Social Capital on Twitter: Differentiating between Followers and Followees." *Computers in Human Behavior* 29 (6): 2134–42.
- Hofman, Roelande H., and Bernadette J. Dijkstra. 2010. "Effective Teacher Professionalization in Networks?" *Teaching and Teacher Education* 26 (4): 1031–40.
- Hokka, P., and A. Etelapelto. 2013. "Seeking New Perspectives on the Development of Teacher Education: A Study of the Finnish Context." *Journal of Teacher Education* 65 (1): 39–52.
- Honeycutt, Courtenay, and Susan C. Herring. 2009. "Beyond Microblogging: Conversation and Collaboration via Twitter." In *Proceedings of the 42nd Hawaii International Conference on System Sciences*. Los Alamitos, CA: IEEE.
- Hopkins, D. 2000. "Schooling for Tomorrow: Innovation and Networks." In *Portuguese Seminar, Rapporteur's Report*. CERI/OECD, Lisbon, 14–15.
- Isari, Daniela, Andrea Pontiggia, and Francesco Virili. 2016. "Working with Tweets vs. Working with Chats: An Experiment on Collaborative Problem Solving." *Computers in Human Behavior* 58 (May): 130–40.
- Johnson-Cramer, Michael, Salvatore Parise, and Rob Cross. 2007. "Managing Change through Networks and Values." *California Management Review* 49 (3): 85–109.
- Jussila, Jari, Jukka Huhtamäki, Hannu Kärkkäinen, and Kaisa Still. 2013. "Information Visualization of Twitter Data for Co-Organizing Conferences." In *Proceedings of International Conference on Making Sense of Converging Media*. New York: ACM.
- Kelly, N., and A. Antonio. 2016. "Teacher Peer Support in Social Network Sites." *Teaching and Teacher Education* 56:138–49.

- Kleinberg, J. M. 1999. "Authoritative Sources in a Hyperlinked Environment." *Journal of the ACM* 46 (5): 604–32.
- Kukulska-Hulme, Agnes. 2007. "Mobile Usability in Educational Contexts: What Have We Learnt?" *International Review of Research in Open and Distributed Learning* 8 (2): 1–16.
- Lefebvre, Virginie Marie, Douglas Sorenson, Maeve Henchion, and Xavier Gellynck. 2016. "Social Capital and Knowledge Sharing Performance of Learning Networks." *International Journal of Information Management* 36 (4): 570–79.
- Letierce, Julie, Alexandre Passant, John Breslin, and Stefan Decker. 2010. "Understanding How Twitter Is Used to Spread Scientific Messages." In *Proceedings of the Web Science Conference (WebSci10): Extending the Frontiers of Society On-Line*, Raleigh, NC, USA. http://journal.webscience.org/314/2/websci10_submission_79.pdf.
- Lin, F. R., S. C. Lin, and T. P. Huang. 2008. "Knowledge Sharing and Creation in a Teachers' Professional Virtual Community." *Computers and Education* 50 (3): 742–56.
- Lin, Nan. 1999. "Building a Network Theory of Social Capital." *Connections* 22 (1): 28–51.
- Lohman, Margaret C. 2005. "A Survey of Factors Influencing the Engagement of Two Professional Groups in Informal Workplace Learning Activities." *Human Resource Development Quarterly* 16:501–27.
- Macià, M., and I. García. 2016. "Informal Online Communities and Networks as a Source of Teacher Professional Development: A Review." *Teaching and Teacher Education* 55:291–307.
- Marotzki, Winfried. 2004. "Von Der Medienkompetenz Zur Medienbildung." In *Lebensbegleitendes Lernen Als Kompetenzentwicklung. Analysen-Konzeptionen-Handlungsfelder*, ed. R. Brödel and J. Kreimeyer. Bielefeld: Bertelsmann.
- Marotzki, Winfried, and Benjamin Jörissen. 2008. "Medienbildung." In *Handbuch Medienpädagogik*, ed. U. Sander, F. Von Gross, and K. U. Hugger. Bielefeld: VS Verlag für Sozialwissenschaften.
- McPherson, Megan, Kylie Budge, and Narelle Lemon. 2015. "New Practices in Doing Academic Development: Twitter as an Informal Learning Space." *International Journal for Academic Development* 20 (2): 126–36.
- Mitchell, Ryan. 2015. *Web Scraping with Python: Collecting Data from the Modern Web*. Sebastopol, CA: O'Reilly Media.
- Moolenaar, Nienke M., Peter J. C. Sleegers, and Alan J. Daly. 2012. "Teaming Up: Linking Collaboration Networks, Collective Efficacy, and Student Achievement." *Teaching and Teacher Education* 28 (2): 251–62.
- Munzert, Simon, Christian Rubba, Peter Meißner, and Dominic Nyhuis. 2014. *Automated Data Collection with R: A Practical Guide to Web Scraping and Text Mining*. Chichester: Wiley.
- Mynatt, Elizabeth D., Vicki L. O'Day, Annette Adler, and Mizuko Ito. 1998. "Network Communities: Something Old, Something New, Something Borrowed . . ." *Computer Supported Cooperative Work* 7 (1–2): 123–56.
- Nahapiet, Janine, and Sumantra Ghoshal. 1998. "Social Capital, Intellectual Capital, and the Organizational Advantage." *Academy of Management Review* 23 (2): 242–66.
- Nooteboom, Bart. 2000. "Learning by Interaction: Absorptive Capacity, Cognitive Distance and Governance." *Journal of Management and Governance* 4 (1–2): 69–92.
- Opsahl, T., F. Agneessens, and J. Skvoretz. 2010. "Node Centrality in Weighted Networks: Generalizing Degree and Shortest Paths." *Social Networks* 32 (3): 245–51.
- Owen, Nathaniel, Alison Fox, and Terese Bird. 2016. "The Development of a Small-Scale Survey Instrument of UK Teachers to Study Professional Use (and Non-Use) of and Attitudes to Social Media." *International Journal of Research and Method in Education* 39 (2): 170–93.

- Panzarasa, Pietro, Tore Opsahl, and Kathleen M. Carley. 2009. "Patterns and Dynamics of Users' Behavior and Interaction: Network Analysis of an Online Community." *Journal of the American Society for Information Science and Technology* 60 (5): 911–32.
- Ranieri, M., S. Manca, and A. Fini. 2012. "Why (and How) Do Teachers Engage in Social Networks? An Exploratory Study of Professional Use of Facebook and Its Implications for Lifelong Learning." *British Journal of Educational Technology* 43 (5): 754–69.
- Rehm, M. 2016. "Informelles Lernen in Sozialen Medien—Sozial-Mediale Möglichkeitsräume und die Rolle des sozialen Kapitals. Eine quantitative Vergleichsstudie von Konversationen auf Twitter." In *Jahrbuch Medienpädagogik 13: Vernetzt und entgrenzt—Gestaltung von Lernumgebungen mit digitalen Medien*, ed. Kerstin Mayrberger and Johannes Fromme. Annual. Wiesbaden: Springer.
- Rehm, M., and A. Notten. 2016. "Twitter as an Informal Learning Space for Teachers!? The Role of Social Capital in Twitter Conversations among Teachers." *Teaching and Teacher Education* 60 (November): 215–23.
- Rhodes, Rod A. W. 2000. "Governance and Public Administration." In *Debating Governance: Authority, Steering and Democracy*, ed. Jon Pierre. Oxford: Oxford University Press.
- Richter, Dirk, Mareike Kunter, Uta Klusmann, Oliver Lüdtke, and Jürgen Baumert. 2011. "Professional Development across the Teaching Career: Teachers' Uptake of Formal and Informal Learning Opportunities." *Teaching and Teacher Education* 27 (1): 116–26.
- Rienties, Bart, Natasa Brouwer, and Simon Lygo-Baker. 2013. "The Effects of Online Professional Development on Higher Education Teachers' Beliefs and Intentions towards Learning Facilitation and Technology." *Teaching and Teacher Education* 29:122–31.
- Risser, H. S. 2013. "Virtual Induction: A Novice Teacher's Use of Twitter to Form an Informal Mentoring Network." *Teaching and Teacher Education* 35 (October): 25–33.
- Rudat, Anja, and Jürgen Buder. 2015. "Making Retweeting Social: The Influence of Content and Context Information on Sharing News in Twitter." *Computers in Human Behavior* 46 (May): 75–84.
- Ruths, Derek, and Jürgen Pfeffer. 2014. "Social Media for Large Studies of Behavior." *Science* 346 (6213): 1063–64.
- Scott, John. 2017. *Social Network Analysis*. Thousand Oaks, CA: Sage.
- Spanhel, Dieter. 2010. "Mediale Bildungsräume. Ihre Erschließung und Gestaltung als Handlungsfeld der Medienpädagogik." In *Medienpädagogik. Aktuelle Forschungs- und Handlungsfelder*, ed. Petra Bauer, Hannah Hoffmann, and Kerstin Mayrberger. Munich: Kopaed.
- Steinfeld, C., N. B. Ellison, and C. Lampe. 2008. "Social Capital, Self-Esteem, and Use of Online Social Network Sites: A Longitudinal Analysis." *Journal of Applied Developmental Psychology* 29 (6): 434–45.
- Supovitz, Jonathan A., Alan J. Daly, and Miguel del Fresno García. 2015. "#Common-Core: How Social Media Is Changing the Politics of Education." <http://repository.upenn.edu/hashtagcommoncore/1/>.
- Takahashi, Bruno, Edson C. Tandoc Jr., and Christine Carmichael. 2015. "Communicating on Twitter during a Disaster: An Analysis of Tweets during Typhoon Haiyan in the Philippines." *Computers in Human Behavior* 50 (September): 392–98.
- Teague-Bowling, Hope. 2017. "Goals for a New School Year: #ObserveMe." *Stories from School: Practice Meets Policy*, July 18. <http://storiesfromschool.org/goals-for-a-new-school-year-observeme/>.
- Tsai, W., and S. Ghoshal. 1998. "Social Capital and Value Creation: The Role of Intra-firm Networks." *Academy of Management Journal* 41 (4): 464–76.

- Tseng, F. C., and F. Y. Kuo. 2010. "The Way We Share and Learn: An Exploratory Study of the Self-Regulatory Mechanisms in the Professional Online Learning Community." *Computers in Human Behavior* 26 (5): 1043–53.
- Tynjälä, Päivi. 2012. "Toward a 3-P Model of Workplace Learning: A Literature Review." *Vocations and Learning* 6 (1): 11–36.
- Wellman, B. 2001. "Computer Networks as Social Networks." *Science* 293 (5537): 2031–34.
- Williams, Dmitri. 2006. "On and off the Net: Scales for Social Capital in an Online Era." *Journal of Computer-Mediated Communication* 11 (2): 593–628.
- Xing, W., and F. Gao. 2018. "Exploring the Relationship between Online Discourse and Commitment in Twitter Professional Learning Communities." *Computers and Education* 126:388–98.
- Ye, Qiang, Bin Fang, Wei He, and J. J. Po-An Hsieh. 2012. "Can Social Capital Be Transferred Cross the Boundary of the Real and Virtual World? An Empirical Investigation of Twitter." *Journal of Electronic Commerce Research* 13 (2): 145–56.
- Yoon, Sung-joon. 2014. "Does Social Capital Affect SNS Usage? A Look at the Roles of Subjective Well-Being and Social Identity." *Computers in Human Behavior* 41 (December): 295–303.