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Exploring online social networks of school leaders in times of COVID-19

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Abstract

The COVID-19 pandemic has raised a wide range of challenges for school leaders that they now (rapidly) have to address. Consequently, they also turn to informal learning networks, in order to share and collect information and reach out to their communities. In this context, the current study investigates the underlying networks structures among school leaders, what type of information is being shared, and what differences can be identified when comparing a nation-wide and a localized sample. We collected data from a US nation-wide sample of 15 relevant Twitter conversations, as well as Tweets from an US urban mid-sized public school district. Using a mixed-methods approach, we discovered several key structural dimensions and a host of highly influential actors. Moreover, we found semantic evidence for users sharing information on topics such as status reports. Finally, we discovered that the urban sample did not overly use the nation-wide, very specific approach of including COVID-19 related hashtags. Instead, they used more localized terminologies. These findings are valuable for policy makers, as they map the underlying communication patterns and provide valuable insights into who is moving what types

of resources as part of the emerging governance approach on social media.

Practitioner notes

What is already known about this topic
- Informal networks can be instrumental in providing support during challenging circumstances.
- School leaders hold a critical position in these networks by accessing and sharing just-in-time information and knowledge.
- Social media provide a wide range of affordances that can support the development of informal networks.

What this paper adds
- Insights into the intersection between leadership and social networks.
- Information on how school leaders turn to informal networks on social media to access and share information that can help them to face the challenges caused by the global COVID-19 pandemic.
- Results on underlying informal learning network structures and topical discussions of a US nation-wide data sample.

Implications for practice and/or policy
- Insights are provided on how informal online networks develop, which can be instrumental when considering other networks that are of interest to practitioners and policy makers.
- Types of information and resources that are being shared are unraveled, which can act as an indicator of what type of information and resources school leaders are looking for, particularly in the face of a crisis like the global COVID-19 pandemic.
- Differences are shown in how informal learning networks are used comparing a nation-wide exchange with a localized, urban discussion, which can help to better target the applicable audiences.

FACING CHALLENGING TIMES

COVID-19 continues to have devastating effects on our world that are likely to continue well into the future (Hargreaves, 2020). The pandemic has impacted our daily lives and has not stopped at the schoolhouse door. School leaders and teachers had to adjust to the new circumstances overnight (Azorín, 2020a), requiring them to re-design and re-tool their schools as home-based, technology-enabled, distant learning facilities (Harris, 2020). In this article, we consider school leaders to be comprised of school principals and administrative leaders of school districts (e.g., superintendents). Even though the underlying types of learning and instruction have not changed, the online context and related challenges of accessing

relevant information and communicating with students, parents, and colleagues put sizeable pressure on teachers and school leaders (Kaden, 2020; Merrill, 2020).

Two strategies to mitigate these challenges have been identified. First, distributing just-in-time information within online communities. This supports members in keeping up-to-date with the latest developments and share information and resources with colleagues (Risser, 2013). Here, we consider just-in-time information to represent "*supportive [information] to the performance of the non-recurrent aspects of the complex skill*" (Kester et al., 2001, p. 377). In times of COVID-19, this information might translate into learning how to organize distance education for students without necessarily having the required IT infrastructure or instructional expertise. The second strategy involves teachers and school leaders increasingly turning to online means to re-connect, share and communicate with students, parents, and colleagues (Kaden, 2020). This suggestion underlines the "*need to develop networked […] communities*" (Azorín, 2020a, p. 3) to tackle the daily challenges of providing education during the pandemic. Even more so, there have been unprecedented efforts among educators to use social media to possibly cope with the situation (Azorín, 2020a; Doucet et al., 2020). Both strategies suggest the importance of informal learning networks in supporting teachers and school leaders in their professional development (del Fresno García et al., 2016; Daly et al., 2019, Rehm et al., 2020; Krutka & Carpenter, 2016). Yet, how these networks develop and what type of content is being shared therein remains under-researched. The current paper addresses this research gap.

Informal learning networks to cope with challenges

Informal learning networks have been identified as a crucial system that constitutes the backbone of our societies (Van Dijk, 2020). Following the definition of Richter and colleagues (2011), we define informal learning networks as "*not follow[ing] a specified curriculum and […] not [being] restricted to certain environments*" (p. 117). Conversely, formal learning networks are more traditional, "structured learning environments with a specified curriculum" (p. 117). In the context of education, Sliwka (2003) stated that informal learning networks, in general, "*represent vibrant motors of change*" (p. 63). Informal learning networks' potential to transform seems to be particularly prevalent "*in challenging contexts and vulnerable circumstances*" (Azorín, 2020b, p. 106). Similarly, informal learning networks can be the catalyst for educational innovation tailored to local communities' specific needs (Hargreaves & Fullan, 2015). However, it has been acknowledged that formal learning networks and interventions often only have limited relevance and impact on the work of school leaders (Bidwell, 2001). Instead, sustained access to relevant, just-in-time information, e.g., via online communities, may provide more favourable conditions to face today's complex educational challenges (del Fresno García et al., 2016; Parise & Spillane, 2010). Accordingly, informal learning networks might be a viable option to foster a collaborative process of reflecting on practice (Fox & Wilson, 2015) as they provide school leaders with an opportunity to continuously share ideas and update their practice (Hopkins, 2000). These informal exchanges may also offer greater flexibility than formal scenarios (Froehlich et al., 2014) and provide a context that is not detached from their working environments (Eraut, 2004).

Heller (2020) posited four reasons why informal learning networks, which often form and develop online, play a crucial role in helping actors adapt to the circumstances pertaining to the COVID-19 pandemic. First, informal learning networks can act as bridges over systemic gaps. For instance, someone in the network might have the needed information if the formal institution does not provide them. Second, informal learning networks are not instated but grow organically due to members' shared interest in a specific topic and their need for community. Therefore, these groups have a strong understanding of local communities. Third,

informal learning networks are typically from people for people. Actors tend to join because they care about the applicable topic and not because of public or commercial interests. Finally, informal learning networks have immense potential to have a real impact on our reality. For example, members jointly shape the way they share and exchange information and resources so that it suits their needs, which, in turn, may benefit the networks' members and cause.

THE SOCIAL ROLE OF SCHOOL LEADERS

Previous research has shown that online activities, such as participating in personal and/or professional networks, reading blogs and tweets, and accessing other online resources, can significantly contribute to school leaders' ability to adapt to new circumstances (Rodriguez-Gomez et al., 2020). Hence, an increasing number of studies have begun to look into this space (Greenhow et al., 2019; Ranieri et al., 2012). Prior to COVID-19, school leaders were predominantly concerned with running their schools and ensuring that regular teaching and learning activities ran smoothly. Suddenly, school leaders had to organize everything from behind their laptops and acquire information on how to best cope with the fast-changing situation and related challenges. Hence, it is important to better understand how contemporary school leaders, access just-in-time information and knowledge, e.g. via social media, and local contextual expertise in improving a host of outcomes (DeMatthews, 2018; Spillane et al., 2003).

Previous research indicates that school leaders typically engage with their teachers in creating multiple learning communities where instructional practices are shared, used, and improved. Also, being part of several learning communities allows school leaders to lead and influence the teachers (Giles, 2006). Moreover, it has been suggested that being resourceful, instrumental, and collaborative constitute traits that are key for school leaders to shape learning communities. In this context, accessing just-in-time information and contextual expertise is of great importance (Fullan, 2016). In addition, there is growing recognition that building interpersonal relationships is particularly important for school leaders since relationships create and sustain the conditions to address pressing educational and social issues within schools (Daly et al., 2010). Furthermore, these interpersonal relationships and underlying social processes can contribute to improved school outcomes (Francera & Bliss, 2011).

Social processes of involving leaders have been found as an important mechanism that drives leadership (Daly et al., 2010), as social relations allow leaders to gain access to resources and information necessary to achieve individual and collective outcomes (e.g. Duguid, 2005; Panahi et al., 2013). These considerations represent a social network perspective (Cross et al., 2008), which highlights the interdependence among actors within a social system (e.g., online communities) and offers insights into the affordances and constraints related to the flow of information and relational resources, such as expertise and insights (Supovitz et al., 2015). Moreover, studies have shown that ties across systems (e.g., schools) can contribute to "*boundary crossing*" (Akkerman & Bakker, 2011, p. 133). The underlying notion of boundary crossing is that it enables individuals to expand their horizon and look outside of their "*narrow daily existence*" (Williams, 2006, p. 600) to discover information and insights that would otherwise be unavailable or hidden from them in their immediate environments (del Fresno García et al., 2016; Tynjälä, 2012). For example, a school leader might turn to colleagues from another geographical region that share a topical interest and might provide them with some valuable information. In terms of COVID-19 and home-schooling, this information might be related to experiences with Zoom calls to stay connected with students or using Padlet to provide learning materials on mathematics

for elementary school children. Yet, despite these developments, the intersection between leadership and online social networks has received only limited attention (Daly et al., 2010; del Fresno García et al., 2016; Van Waes et al., 2016; Daly et al., 2019).

SOCIAL CAPITAL TO ASSESS ROLES

Social capital has been promoted as a valuable theoretical construct to better understand how informal learning networks develop and evolve (e.g. Rehm & Notten, 2016; Rehm et al., 2020; Dubos, 2017; Phua et al., 2017). Tsai and Ghoshal (1998) consider social capital to be "relational resources embedded in the cross-cutting personal ties" that "are useful for the personal development of individuals" (p. 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 social networking site (SNS). Who is contacting who? 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 centre 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 re-occurring keywords and phrases can be identified? Are they used by the majority of participants? Finally, the *relational dimension* describes issues such as motivations and common values among individuals. For this study, we focus on the *structural* and *cognitive* dimensions of social capital.

The case of social media

The rise of social media has led to a panoply of online communication spaces, such as Facebook and Twitter, wherein individuals can potentially access and share a wide variety of resources (Owen et al., 2016). Moreover, a growing number of studies have shown that educational professionals use social media, such as Twitter, to access and share information that helps them and others to face their everyday challenges (Rehm et al., 2020; Risser, 2013). As social media are embedded in educators' immediate personal and professional environments, they constitute social opportunity spaces (del Fresno García et al., 2016, Rehm, 2018, Rehm et al., 2020) that provide affordances to connect with others, share information, resources, and insights, and foster a process of critical reflection.

In this paper, social media is considered to be a set of online technology platforms focusing on synchronous and asynchronous that has reached levels of interaction far beyond anything before in human history (Perrin, 2015). Based on the structural and technical attributes, they represent a combination of personal spaces that are socially connected (Megan McPherson et al., 2015). Additionally, these spaces are neither bound by time and place nor exclusive in terms of membership (Brüggen & Schemmerling, 2014). Instead, individuals can continuously be present in a wide variety of topical spaces that span time and the entire globe. For example, a school leader can easily share with students and parents the latest information on how the COVID-19 pandemic is affecting everyday teaching procedures. Simultaneously, the same leader can use social media channels to organize informational staff exchange. Similarly, if the school leader lacks relevant information in their immediate surroundings, they can also easily turn to other social media spaces to access a plurality of opinions and experiences (Mynatt et al., 1998) on, for example, how to successfully incorporate Zoom meetings during a COVID-19 related lockdown.

Yet, while the role of school leadership has become increasingly important in the process of supporting change and facing new challenges (Penuel et al., 2009; Pitts & Spillane, 2009), we continue to have a lack of research that examines the role of school leaders, particularly in terms of accessing and leveraging informal learning networks situated in social media (Rehm et al., 2020; Cho & Jimerson, 2017). Current research on informal learning networks in social media has either focused on Facebook (Sibona & Walczak, 2011; Tang et al., 2016), has been conducted among students (Selwyn & Stirling, 2016; Zachos et al., 2018), or neglected the role and impact of school leaders (Antheunis et al., 2012; Chung, 2013). As a result, there has been a call for more research on how school leaders use social media as informal learning networks to acquire connections, as well as access and share information and resources (Kukulska-Hulme, 2007; Owen et al., 2016).

The present study addresses these shortcomings by investigating whether and how school leaders, who turn to informal networks on social media, access and share information to help them face the challenges caused by the global COVID-19 pandemic. Moreover, using a social capital perspective, this paper analyses the *structural* and *cognitive* dimensions of social capital and determines and analyses the social network structures and underlying topical discussions. This study is both timely and critical given the critical role of school leaders and their ability to shape the responses to lockdown scenarios and the increased need to organize and conduct distance education. In undertaking this important line of inquiry, this work is guided by the following research questions:

1. What type of networks develop among school leaders in the topic of COVID-19?
2. What type of information and resources on and around the COVID-19 pandemic are traceable within these networks?
3. What differences can be identified when comparing social media usage in a nation-wide and a localized sample?

METHOD

Setting

The point of departure for this study are two types of data sources. On the one hand, we collected data from a US nation-wide sample of 15 Twitter conversations on popular hashtags among school leaders[1] (Rehm et al., 2020). Moreover, we specifically searched for leadership and COVID-19 related discussions within this larger dataset (Bruns & Stieglitz, 2013; Kouzy et al., 2020). We selected this particular dataset to assess whether school leaders did cross boundaries and access information, resources, and experiences to collaboratively cope with the pandemic. Additionally, this dataset was chosen because growing empirical evidence suggests that school leaders and teachers turn to these large, nation-wide spaces to share and engage with colleagues, collaboratively contributing to each other's informal learning networks. (Gotlieb & Cheema, 2017; Tosato et al., 2014; Tseng & Kuo, 2014). On the other hand, we tracked the professional Twitter profiles of 97 school leaders working in an urban mid-sized public school district in the United States that serves more than 76,000 PK-12 students from a variety of backgrounds. These school leaders were part of a larger project that deals with informal learning networks, both inside of schools and districts, as well as online. While comparing hashtags conversations with data that is based on individual profiles has some methodological drawbacks, it allows, in the context of this exploratory study, to explore and contrast these two informal online networks of school leaders. This will help better understand the collective efforts to cope with the challenges caused by the COVID-19 pandemic at a national level. Also, It enables us to zoom-in on a more localized community,

which has been suggested to focus on other topics that are specific to local circumstances (Maggie McPherson & Nunes, 2004; Riel & Levin, 1990). Therefore, this comparison might offer insights into how a district-wide set of school leaders use social media compared to a nation-wide sample where the heterogeneity of information might be higher. Additionally, this work can inform both leadership and policy practice, as it can visualize how school leaders are connecting and highlight what they consider to be among the most pressing issues when dealing with the pandemic.

Data

Using a dedicated server, we accessed Twitter's application programming interface (API), complying with the terms and conditions for Twitter (Rehm et al., 2020). The data was collected from January 01 to June 30, 2020, and contained all tweets and user profile information from the indicated setting. This process resulted in 50,424 Tweets. Next, we built a directed unweighted 1-mode network based on all collected Tweets, Mentions (e.g., @user), and Replies (e.g., RTuser) matrices. Additionally, in order to adhere to established, ethical standards of dealing with Big Data, which are impracticable to obtain informed consent (Bechmann & Kim, 2020), we followed the recommendation of the Internet Research Ethics Guidelines (Bechmann & Zevenbergen, 2019) and pseudonymized all users' names and profiles of the 97 school leaders.

Social network analyses

Social network theory has been widely acknowledged as a valuable tool to assess the *structural* dimension of social capital (Moolenaar et al., 2012; del Fresno García et al., 2016; Van Waes et al., 2016; Rienties et al., 2013; Tsai & Ghoshal, 1998), as it deals with patterns of social relationships that exist between people in social networks (Scott, 2017). While it acknowledges individuals and their role in a network, it extends the perspective also considers the larger social infrastructure in which they act and communicate (Borgatti & Cross, 2003; Cross et al., 2001). More specifically, it allows to analyse and visualize communication processes within SNS (Buccafurri et al., 2015; Yoon, 2014). In applying this perspective to Twitter discussions, we imported the collected data in the R software package and used the R library "igraph" to conduct the applicable analyses. For visualizing the social networks, we used the gephi. Connections (edges) between users (nodes) were constructed if one account mentioned or replied to (e.g., @userX) another account's Tweet(s). More specifically, we computed the in-, out-, and overall degree centrality metrics of all users (Borgatti, 2005; Freeman et al., 1979; Hahn et al., 2015). These metrics indicate how often an individual has been contacted (in-degree), has contacted others (out-degree), and how prominent that individual is in the communication (overall degree), respectively. We also determined underlying community structures (Newman, 2006) and determined individuals with prominent roles (as measured by the top one percent of users based on the overall degree) in the networks (Rehm et al., 2020; Burt, 2009; Lee et al., 2014).

Bibliometric analyses

To assess the content of what was being shared, thereby contributing to our understanding of the *cognitive* dimension of social capital in the Twitter discussion, we employed bibliometric analyses (Nahapiet & Ghoshal, 1998). These types of analyses are increasingly

promoted as a valuable methodological tool to map what is being contributed and shared in large text corpora from SNS (Alsumait et al., 2010). We employed latent dirichlet allocation (Blei et al., 2002), using the Gibbs sampling algorithm to identify this structure (Blei, 2012). In this method, one has to determine the number of topics to be assigned before running the algorithm. For the case at hand, we used five, seven, and ten ex-ante topics. We then analysed the results and qualitatively determined which option best describes the underlying communication flows. This step is necessary as five topics might lead to an overlap of topics that can actually be considered meaningfully different, e.g., video-conferencing and Padlet under the umbrella of online learning. Alternatively, it might be that some topics are separated, while it can be argued that they belong to the same overarching topic, e.g., MicrosoftTeams and Zoom, both being derivatives of video-conferencing. This method, also often referred to as topic modelling (Blei & Lafferty, 2009), allows analysing and visualizing the underlying topical structures of big data sets (Chaney & Blei, 2012). Furthermore, we acknowledge that Twitter instated a 280-character limit for Tweets. Therefore, it has become common practice to include links (e.g., to blogs or websites) in the Tweets to share more extensive information and resources. Hence, in order to also incorporate this information, we also disentangled the links and determined the underlying domains (Mitchell, 2015; Munzert et al., 2014), using the R libraries "longurl" and "urltools".

RESULTS

General

Table 1 provides an overview of the determined network metrics. As can be seen, there is quite some similarities between the two data sources, despite the differences in levels. Both networks are subject to a higher level of in-degree than out-degree centrality. Moreover, both networks seemed to be driven by a few (very) active users. Furthermore, while not reported in Table 1, both networks' density scores were below 0.001, which is typical for these types of networks. A closer look at the in-degrees of the nation-wide sample showed that these users were news channels (e.g., @CNN, @nytimes) or individuals who were mentioned from the realm of US politics (e.g., @realDonaldTrump, @JoeBiden). In the case of the urban data, high levels of in-degree were predominantly attained by institution-wide accounts (e.g., @DISTRICTNAME[2], @SCHOOLNAME) or central individuals from school districts' administration (e.g., @SUPERINTENDENT, @PRINCIPAL).

Social network structures

To put the overall metrics into perspective, we then determined the applicable social network structures. Figure 1 shows the relevant sociograms.

TABLE 1 Overview of network metrics

	inDegree		outDegree		overallDegree	
	Nation-Wide	Urban	Nation-Wide	Urban	Nation-Wide	Urban
Avg	0.97	3.24	0.97	3.24	1.94	6.49
StDev	4.62	16.59	2.57	4.72	5.31	18.51
Min	0	0	0	0	1	1
Max	751	551	60	74	751	590
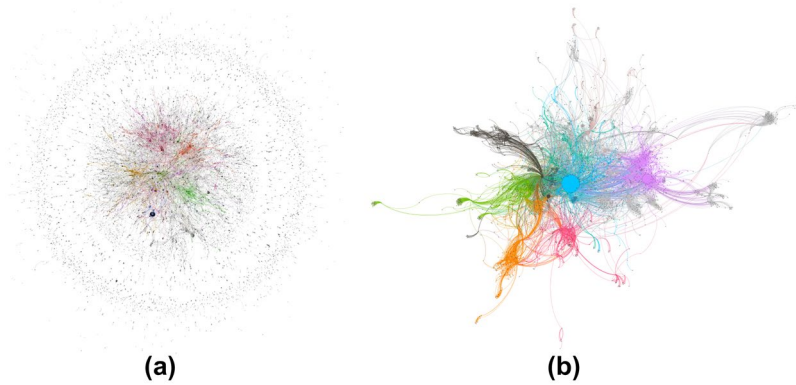
FIGURE 1 Sociograms of the overall networks. Dots—Nodes represent individual Twitter users; Lines—Edges indicate relationships (e.g., Mentions, Replies) between Nodes; Color of Nodes—Modularity Community Detection Algorithm. (a) Nation-wide sample. (b) Urban public school district.
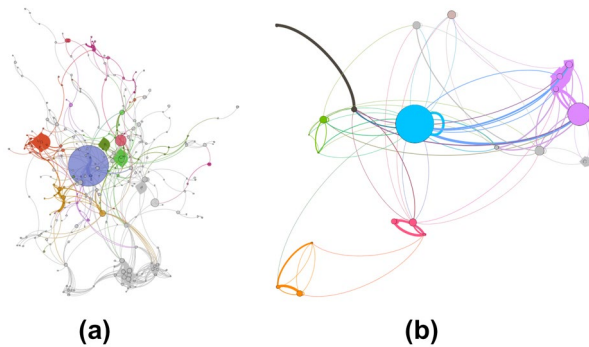
FIGURE 2 Sociograms of for top 1% (based on overall degree). Nation-wide sample: *n* = 349; urban public school district: *n* = 25. (a) Nation-wide sample (b) Urban public school district.

As the metrics already suggested, both networks were subject to a few central Twitter accounts (as highlighted by the larger nodes in Figure 1). Moreover, we discovered a number of communities wherein individual Twitter accounts communicated more frequently than with users outside the community. The sociograms also show a clear difference between the two data samples. While the urban school district was comprised of a large giant-component (large network of interconnected nodes), the nation-wide sample had a sizeable outer fringe of nodes. In other words, there was a large group of accounts that participated in the overall hashtag discussion, while at the same time not connecting or being connected with others (e.g., in terms of mentioning other users or being mentioned by them). Zooming in on the top one percent of users, based on overall degree, revealed the network structures depicted in Figure 2.

Here, we see that the prominent users (as denoted by the larger size of the nodes) are at the centre of their community networks (which are denoted by the different colours). Additionally, we see that the discussions on COVID-19 were driven by a small number of communities (e.g., same-coloured nodes). Furthermore, we discovered that the prominent users were connected with and in reciprocal contact with each other.

Content being shared

Frequency of hashtags being used

After considering the structural dimension of social capital, as determined by the social network perspective, we turned to the content that was being discussed. More specifically, we started by considering the most commonly used hashtags used in the two data samples. The relevant results are summarized by means of wordclouds in Figure 3. The frequencies of the Top 10 most commonly used hashtags are provided in Table 2.

The wordclouds revealed a considerable difference between the nation-wide and the urban data. As can be seen, in the case of the nation-wide sample, #covid and #coronavirus were prominently addressed in the communication. In contrast, the urban sample only marginally included a reference to these hashtags. However, on closer inspection #weare-SCHOOL, #DISTRICTbettertogether and #DISTRICTstrong turned out to be regional and targeted derivatives of the national COVID-19 hashtags, all dealing with the situation around home-schooling, staying in touch with students, and keeping spirits up.

Top domains being shared

Next, we considered the links that were being shared within the applicable Tweets. More specifically, we determined the underlying domains to get preliminary insights into what types of resources school leaders might have shared. Overall, 5.069 links were shared in the nation-wide sample, compared to 79 in the context of the urban school district. The top ten domains per data sample are summarized in Table 3.

The common denominator for both data samples is that YouTube is the most frequently shared domain. In the case of the nation-wide data, a random sample of 50 URLs revealed that the shared videos seemed to focus on learning resources, such as learning the alphabet, experiments (e.g., liquid nitrogen balloon), and recorded expert panels on, for example, online safety for kids. Similarly, a closer look at the shared videos in the urban sample, which was also based on a random sample of 50 URLs, showed videos on safety (e.g., in times of COVID-19) and virtual concerts. The other domains included information portals specifically targeted at educational professionals and leaders (e.g., edsurge.com, naeyc.org) and online tools, such as applications for creating newsletters or effectively using social media (e.g., smore.com, careerarc.com). Additionally, general news sites (e.g., nytimes.com) and other social media platforms (e.g., facebook.com) were often included in the Tweets. The content

(a)   (b)

FIGURE 3   Wordclouds of most commonly used hashtags. (a) Nation-wide sample (b) urban public school district.

TABLE 2 Top 10 hashtags being used

Top	Nation-Wide	n	Urban	n
1	Climatechange	3660	weareSCHOOL	56
2	Education	2725	DISTRICTstrong	24
3	Science	2612	bettertogether	22
4	Covid	2404	DISTRICTbettertogether	21
5	Earthday	2308	STATEed	19
6	Stem	1261	DISTRICTnation	15
7	Edtech	1202	covid	12
8	Teachers	835	inspiringleaders	12
9	Coronavirus	806	STATEsupt	11
10	Students	789	DISTRICTNAME	10

TABLE 3 Top 10 domains being shared

Top	Nation-Wide	n	Urban	n
1	youtube.com	437	youtube.com	34
2	paper.li	225	wevideo.com	14
3	edsurge.com	80	smore.com	8
4	blog.iammarketingmedia.com	71	naeyc.org	6
5	amazon.com	67	openphysed.org	3
6	instagram.com	64	change.org	3
7	nytimes.com	48	paper.li	2
8	theguardian.com	45	kennedy-center.org	2
9	facebook.com	42	aumprojetos.com.br	1
10	careerarc.com	40	ideas.ted.com	1

of these sites provided general information and resources on the COVID-19 pandemic and a range of opinions and status reports on how individuals cope with the pandemic. Moreover, in the case of the urban sized school district, a range of links were shared that provided inputs for teaching virtually (e.g., openphysed.org), as well as joining online petitions, such as the request to find solutions for cancelled graduation ceremonies due to COVID-19 (e.g., change.org).

Topic modelling

To gain more insights into the *cognitive* dimension of social capital, we next employed topic modelling to identify common themes and terminologies in the Tweets. Table 4 summarizes our findings for the nation-wide data. As can be seen, in this context, we determined seven topics to effectively describe the discussions. Topics 1 and 4 dealt with COVID-19 related information. Whereas Topic 1 combined COVID-19 with other topics, such as climate change and world earth day, Topic 4 was more concerned with the lockdown and how distance education can be used to continue teaching. Similarly, Topic 7 contained information on remote learning and using different technologies, particularly video conferencing, to support the

TABLE 4 Topics for the nation-wide data

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7
Covid	Thank	Classroom	Science	Education	Free	New
Climatechange	Many	Human	Help	Join	People	Learning
Scientists	Podcast	Children	Research	Today	Work	Students
Coronavirus	Life	Community	Inspiration	Make	Realdonaldtrump	Teachers
Earthday	Love	Lesson	Talk	Week	Projects	School
World	Year	Activities	Inspiring	Webinar	Register	Online
Scientists	Episode	Planet	Distance	Live	Ownership	Remotelearning
Change	Citizenscience	Parents	Statistics	Leaders	Opportunity	Technology
Pandemic	Really	Challenges	Lockdown	Virtual	Public	Video
Global	Energy	Share	Teacher	Tomorrow	Program	Edtech

teaching. Topic 2 seemed to touch upon citizen science and refers to a series of podcasts that were shared. Topic 5 referred to live events, such as webinars, and their related information. Topic 3 appeared to have a strong community focus, and Topic 6 specifically targeted the upcoming US elections.

Turning to the urban data sample, Table 5 shows the relevant results. Here, we discovered five topics to capture the main themes and terminologies being used among the users. In particular, Topic 4 included a specific reference to COVID-19 and how a specific part of the school district dealt with the situation. Topics 2 and 5 are rather similar, as they all exhibited community-building tendencies for different geographical regions of the school district. Topic 3 covered another very recent (political) topic and discussion, namely #blacklivesmatter. Finally, Topic 1 appeared to represent the overall atmosphere within the entire school district, focusing on values (e.g., family, team) and "keeping spirits up" by highlighting terms like "fun" and "proud."

DISCUSSION

This paper set out to investigate how school leaders used social media to access just-in-time information and share resources on dealing with the consequences of the global COVID-19 pandemic. Departing from a social capital perspective, this paper analysed the *structural* and *cognitive* dimensions of social capital, using a combination of social network analyses and bibliometrics. More specifically, we collected data from two types of data sources, namely (i) a US nation-wide sample of 15 hashtag conversations on Twitter, and (ii) data tracked from the professional Twitter profiles of 97 school leaders working in an urban mid-size public school district in the United States. While the data was based on two types of collection techniques, this allowed us not only to better understand the collective efforts to cope with the challenges caused by the COVID-19 pandemic but also to investigate whether local communities might differ in how they use social media, as compared to a nation-wide sample. Overall, we identified three key findings connected to our three research questions.

First, our analyses revealed that leaders were connecting via Twitter, thereby building social networks that can serve as a basis to share information, experiences, and resources to cope with the pandemic. Moreover, we discovered a small number of communities that appeared to organize the discussions. Each community was led by a single or a group of central user account(s), as determined by their high degree centrality. This network structure is relatively common in social media (del Fresno García et al., 2016; Daly et al., 2019; Rehm

TABLE 5 Discovered topics for the urban data

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
Congratulations	Districtname	Schoolname	Thank	Leadername8
School	Superintendent	Senior	Happy	Time
Work	Leadername4	Control	Love	Schoolname8
Family	Year	Gun	Leadernamel	Teacher
Team	Schoolbulldogs	Spotlight	Students	Theexeceffect
Hard	Leadername5	Bettertogether	Teachers	Appreciation
Class	Make	People	Covid	Welcome
Spirit	Schoolname2	Lives	Today	Graduation
Fun	Schoolname7	Black	Leadername2	Leadername9
Proud	Community	Matter	Amazing	Excited

et al., 2020, 2020a). Furthermore, we discovered some specific characteristics of the discussion at hand, thereby contributing to our third research question. In the nation-wide Twitter discussion, prominent users were predominantly news channels (e.g., New York Times), political actors from the US (e.g., Joe Biden, Donald Trump), and international activists or opinion leaders (e.g., Greta Thunberg). In contrast, the urban data revealed a stronger focus on school leaders from the respective school district (e.g., principals or superintendents). This result suggests that even though Twitter and social media, in general, are not restricted by boundaries of space and time (Ye et al., 2012), there are broad tendencies to localize information to make it more relevant and relatable to relevant environments (Rehm et al., 2020; Eraut, 2000, 2004) and maybe even more so during a pandemic.

Second, employing bibliometrics, we found that school leaders were actively discussing COVID-19. We also discovered that COVID-19-related and other topics were often discussed simultaneously, whereas conversations about the other topics had frequently started prior to the pandemic's outbreak (e.g., #climatechage, #edtech, #stem). This result suggests that school leaders were contextualizing their shared information. Additionally, by combining hashtags, such as #edtech and #covid, leaders could specifically access and share information on how to set up distance education using video-conferencing. A closer inspection of the shared links revealed that learning resources, other information portals, and online tools were among the most commonly shared links and resources among school leaders. Building upon these findings, we used topic modelling to determine underlying themes and terminologies used in the discussions. This method allowed us to really zoom in on the content and contribute to our understanding of what type of just-in-time information school leaders were looking for and sharing to quickly transition into an online-based modus operandi (Azorín, 2020a; Kaden, 2020). Thus, it constitutes an interesting, preliminary finding. Future research should extend on this type of analysis and consider employing web-scraping techniques (Mitchell, 2015; Munzert et al., 2014) to collect all textual elements from the links that were shared via Twitter (Rehm et al., 2020).

On a macro-level, we discovered that school leaders shared general information on the consequences and the perceived impact of COVID-19. Furthermore, we found clear signs of discussions around issues such as the lockdown and how distance education can be used to continue teaching and stay connected with students, parents, and colleagues (Kaden, 2020; Merrill, 2020). More specifically, on a more micro-level, school leaders shared specific tools, with an apparent focus on video conferencing and newsletters, suggestions on using educational technology, and readily available teaching resources to support each other's work and coping with the pandemic.

Finally, when considering possible differences between the nation-wide and urban data samples, we discovered that the urban mid-sized school district in question did not overly use the nation-wide, very specific approach of including COVID-19 related hashtags. Instead, they discussed the issue based on localized terminologies, such as #weareSCHOOL, and #DISTRICTstrong. In terms of discussed topics and themes, school leaders also had a stronger focus on dealing with local events, such as online petitions to arrange appropriate replacements or alternatives for a cancelled graduation ceremony due to COVID-19. We also found evidence for community building. However, in contrast to the nation-wide sample, the community building was very much attached to the different school leaders, such as superintendents and principals, who were responsible for specific geographical areas. Finally, we found an overall atmosphere that had a strong focus on community values (e.g., family, team) and "keeping spirits up" by highlighting terms like "fun" and "proud." In summary, the urban network was more focused on the social-emotional and support aspects of COVID-19. This finding is in line with previous research on *virtual social spaces* (Hodge et al., 2006). This research has suggested that geographical proximity, which usually supports community-based activities (Maggie McPherson & Nunes, 2004), can be mimicked

by creating a sense of belonging through referral to local events and developments (Riel & Levin, 1990). In contrast, the nation-wide sample dealt more with content-related issues. These issues included sharing information, experiences, and resources on coping with the sudden requirement to re-design and re-tool as home-based, technology-enabled, distant learning facilities (Harris, 2020).

Overall, our results show that school leaders actively engaged in informal learning networks on social media to build connections and access resources and information (Daly et al., 2014; Duguid, 2005; Hislop, 2002; Panahi et al., 2013). Moreover, when considering the content of what was shared, we determined three broad categories, namely, (i) updating information, (ii) status reports, and (iii) teaching resources. Updating information encompasses information from news portals (e.g., New York Times) and dedicated platforms for school leaders (e.g., naeyc.org). Here, school leaders can gather and access general information on relevant issues, including the pandemic. Status report entail contextualizing information from a normative perspective (Lasorsa et al., 2012). Here, news events and latest developments are commented on, and relevant consequences are described and interpreted from experts' and practitioners' point of view. This is a common practice on social media (Dubois & Gaffney, 2014; Jensen, 2016) and an important factor in establishing a community. As a matter of fact, it is part of the *cognitive* dimension of social capital, as it fostered the establishment of a common understanding and terminology. This shared understanding, in turn, will increase the likelihood of connecting with others (*structural* dimensions) and foster the creation of trust and common values (*relational* dimension). In order to shed more light on these inter-relations, future research should consider an extended mixed-methods analysis that also incorporates more qualitative research techniques, such as semi-structured interviews, which have can capture the *relational* dimension of social capital (Rehm et al., 2020; Nahapiet & Ghoshal, 1998; Van Waes et al., 2016).

Finally, considering the teaching resources being shared (e.g., experiments, tutorials, and recorded lectures) suggest a latent tendency to consider new and innovative ways to teach, triggered by the restrictions of school lockdowns. More specifically, while research has already been considering the concept of *flipped-classroom* for quite some time now (Jinlei et al., 2012; Tucker, 2012), it has not yet fully arrived in classrooms (Akçayır & Akçayır, 2018). This study's preliminary findings suggest that COVID-19 might have revealed gaps and potential shortcomings in the educational systems (Teräs et al., 2020), which school leaders are beginning to investigate.

Implications for practice and policy

The practical implications of this research can be summarized into three main aspects. First, we provide insights into how informal learning networks develop online, particularly in the context of school leaders needing to adapt to new circumstances and change (Rodriguez-Gomez et al., 2020). This information can be instrumental when considering other networks that are of interest to practitioners and policymakers.

Second, we have started to unravel the types of information and resources that are being shared. On the one hand, this can indicate what types of experiences and insights might be interesting for school leaders. On the other hand, it can also act as an indicator of what type of information and resources might be lacking (Bidwell, 2001), particularly in the face of a crisis like the global COVID-19 pandemic (Azorín, 2020b).

Third, we have shown differences in how informal learning networks are used, comparing a nation-wide exchange with a localized, urban Twitter discussion. While the nation-wide discussion can reach a large audience and provide valuable input, it also lacks the opportunity to consider differences in regions. Consequently, more localized communication can

help school leaders to put things in perspective and discuss and apply newly gained information according to their specific circumstances. Moreover, these discussions can also provide social-emotional support (Hodge et al., 2006) by contributing to a sense of belonging (Riel & Levin, 1990). This finding, in turn, constitutes a valuable input for policymakers, who might want to provide their own support in the current situation or during other events that have a similar reach and impact.

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CONFLICT OF INTEREST
There is no conflict of interest in the work we are reporting here.

ETHICS STATEMENT
Due to ethical considerations and in order to protect the identities, particularly of the school leaders from the urban mid-size public school district in the United States, the data cannot be openly accessed. Upon personal request it can be discussed how the data can be accessed by third parties.

DATA AVAILABILITY STATEMENT
In order to protect the identities of the underlying Twitter users and the urban mid-size public school district, the data has been anonymized.

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ENDNOTES
[1] The applicable hashtags are: #PrincipalsInAction, #PIAchat, #WeLeadEd, #APchat, #principallife, #MomsAsPrincipals, #JoyfulLeaders, #LeadUpChat, #EdAdmin, #EdLeadership, #FitLeaders, #Admin2B, #NoOfficeDay, #Onesmallthing, #cleartheair.

[2] In order to protect the identity of the district we have substituted names.

REFERENCES
Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. *Computers & Education*, *126*, 334–345.

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, *81*(2), 132–169. https://doi.org/10.3102/0034654311404435

Alsumait, L., Wang, P., Domeniconi, C., & Barbará, D. (2010). Embedding semantics in LDA topic models. In M. W. Berry, & J. Kogan (Eds.), *Text mining* (pp. 183–204). John Wiley & Sons, Ltd. https://doi.org/10.1002/97804 70689646.ch10

Antheunis, M. L., Valkenburg, P. M., & Peter, J. (2012). The quality of online, offline, and mixed-mode friendships among users of a social networking site. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, *6*(3).

Azorín, C. (2020a). Beyond COVID-19 supernova. Is another education coming? *Journal of Professional Capital and Community*, *5*(3/4), 381–390. https://doi.org/10.1108/JPCC-05-2020-0019

Azorín, C. (2020b). Leading networks. *School Leadership & Management*, *40*(2–3), 105–110. https://doi.org/10.1080/13632434.2020.1745396

Bechmann, A., & Kim, J. Y. (2020). Big data: A focus on social media research dilemmas. *Handbook of Research Ethics and Scientific Integrity*, 427–444.

Bechmann, A., & Zevenbergen, B. (2019). AI and Machine Learning: Internet Research Ethics Guidelines (IRE 3.0 6.1). *Internet Research: Ethical Guidelines 3.0 Association of Internet Researchers Unanimously Approved by the AoIR Membership October 6, 2019*, 33(2019). AI and Machine Learning: Internet Research Ethics

Guidelines (IRE 3.0 6.1). *Internet Research: Ethical Guidelines 3.0 Association of Internet Researchers Unanimously Approved by the AoIR Membership October 6, 2019*, 33

Bidwell, C. E. (2001). Analyzing schools as organizations: Long-term permanence and short-term change. *Sociology of Education*, *74*, 100–114. https://doi.org/10.2307/2673256

Blei, D. M. (2012). Probabilistic topic models. *Communications of the ACM*, *55*(4), 77–84.

Blei, D. M., & Lafferty, J. D. (2009). *Topic models* (Vol. 10). CRC Press. https://books.google.de/books?hl=de&lr=&id=BnvYaYhMI-MC&oi=fnd&pg=PA71&dq=topic+modeling+blei&ots=oj6Dvp-Yjn&sig=jtncvv5Dhj UkNzUllBaKA0RV9HU

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2002). Latent dirichlet allocation. *Advances in Neural Information Processing Systems*, *1*, 601–608.

Borgatti, S. P. (2005). Centrality and network flow. *Social Networks*, *27*(1), 55–71.

Borgatti, S. P., & Cross, R. (2003). A relational view of information seeking and learning in social networks. *Management Science*, *49*(4), 432–445.

Brüggen, N., & Schemmerling, M. (2014). Das Social Web und die Aneignung von Sozialräumen. *Sozialraum.De*, *6*(1). http://www.sozialraum.de/das-social-web-und-die-aneignung-von-sozialraeumen.php

Bruns, A., & Stieglitz, S. (2013). Towards more systematic Twitter analysis: Metrics for tweeting activities. *International Journal of Social Research Methodology*, *16*(2), 91–108. https://doi.org/10.1080/13645 579.2012.756095

Buccafurri, F., Lax, G., Nicolazzo, S., & Nocera, A. (2015). Comparing Twitter and Facebook user behavior: Privacy and other aspects. *Computers in Human Behavior*, *52*, 87–95. https://doi.org/10.1016/j.chb.2015.05.045

Burt, R. S. (2009). *Structural holes: The social structure of competition*. Harvard University Press.

Chaney, A.-J.-B., & Blei, D. M. (2012). Visualizing topic models. *ICWSM*. http://www.cs.columbia.edu/~blei/paper s/ChaneyBlei2012.pdf

Cho, V., & Jimerson, J. B. (2017). Managing digital identity on Twitter: The case of school administrators. *Educational Management Administration & Leadership*, *45*(5), 884–900.

Chung, J. E. (2013). Social interaction in online support groups: Preference for online social interaction over offline social interaction. *Computers in Human Behavior*, *29*(4), 1408–1414.

Cross, R., Ehrlich, K., Dawson, R., & Helferich, J. (2008). Managing collaboration: Improving team effectiveness through a network perspective. *California Management Review*, *50*(4), 74–98.

Cross, R., Parker, A., Prusak, A., & Borgatti, S. P. (2001). Knowing what we know: Supporting knowledge creation and sharing in social networks. *Organizational Dynamics*, *30*(2), 100–120. https://doi.org/10.1016/s0090-2616(01)00046-8

Daly, A. J., Liou, Y., Del Fresno García, M., Rehm, M., & Bjorklund Jr., P. (2019). Educational leadership in the Twitterverse: Social media, social networks and the new social continuum. *Teacher College Record*, 121.

Daly, A. J., Liou, Y.-H., Tran, N. A., Cornelissen, F., & Park, V. (2014). The rise of neurotics: Social networks, leadership, and efficacy in district reform. *Educational Administration Quarterly*, *50*(2), 233–278.

Daly, A. J., Moolenaar, N. M., Bolivar, J. M., & Burke, P. (2010). Relationships in reform: The role of teachers' social networks. *Journal of Educational Administration*, *48*(3), 359–391.

DeMatthews, D. E. (2018). *Community engaged leadership for social justice: A critical approach in urban schools*. Routledge.

Doucet, A., Netolicky, D., Timmers, K., & Tuscano, F. J. (2020). Thinking about pedagogy in an unfolding pandemic: An independent report on approaches to distance learning during COVID19 school closures. *Education International & UNESCO*. https://www.Learntechlib.Org/p/216735

Dubois, E., & Gaffney, D. (2014). The multiple facets of influence: Identifying political influentials and opinion leaders on Twitter. *American Behavioral Scientist*, *58*(10), 1260–1277.

Dubos, R. (2017). *Social capital: Theory and research*. Routledge.

Duguid, P. (2005). "The art of knowing": Social and tacit dimensions of knowledge and the limits of the community of practice. *The Information Society*, *21*(2), 109–118.

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, *70*, 113–136.

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education*, *26*(2), 247–273. https://doi.org/10.1080/158037042000225245

Fox, A., & Wilson, E. (2015). Networking and the development of professionals: Beginning teachers building social capital. *Teaching and Teacher Education*, *47*, 93–107. https://doi.org/10.1016/j.tate.2014.12.004

Francera, S., & Bliss, J. (2011). Instructional leadership influence on collective teacher efficacy to improve student achievement. *Leadership and Policy in Schools*, *10*(3), 349–370.

Freeman, L. C., Roeder, D., & Mulholland, R. R. (1979). Centrality in social networks: Ii. *Experimental Results. Social Networks*, *2*(2), 119–141.

del Fresno García, M., Daly, A. J., & Segado Sánchez-Cabezudo, S. (2016). Identifying the new influences in the internet era: Social media and social network analysis. *Revista Española de Investigaciones Sociológicas*, *153*, 23–40.

Froehlich, D. E., Beausaert, S., Segers, M., & Gerken, M. (2014). Learning to stay employable. *Career Development International*, *19*(5), 508–525. https://doi.org/10.1108/CDI-11-2013-0139

Fullan, M. (2016). *Indelible leadership: Always leave them learning*. Corwin Press.

Giles, C. (2006). Transformational leadership in challenging urban elementary schools: A role for parent involvement? *Leadership and Policy in Schools*, *5*(3), 257–282.

Gotlieb, M. R., & Cheema, S. E. (2017). From consumer to producer: Motivations, internet use, and political consumerism. *Information, Communication & Society*, *20*(4), 570–586.

Greenhow, C., Galvin, S. M., & Staudt Willet, K. B. (2019). What should be the role of social media in education? *Policy Insights from the Behavioral and Brain Sciences*, *6*(2), 178–185.

Hahn, M. H., Lee, K. C., & Lee, D. S. (2015). Network structure, organizational learning culture, and employee creativity in system integration companies: The mediating effects of exploitation and exploration. *Computers in Human Behavior*, *42*, 167–175. https://doi.org/10.1016/j.chb.2013.10.026

Hargreaves, A. (2020). What's next for schools after coronavirus? Here are 5 big issues and opportunities. *The Conversation*., http://theconversation.com/whats-next-for-schools-after-coronavirus-here-are-5-big-issues-and-opportunities-135004

Hargreaves, A., & Fullan, M. (2015). *Professional capital: Transformng teaching in every school*. Teachers College Press.

Harris, A. (2020). COVID-19–school leadership in crisis? *Journal of Professional Capital and Community*, *5*(3/4), 321–326. https://doi.org/10.1108/JPCC-06-2020-0045

Heller, M. (2020). COVID-19: Why informal networks will be key to the recovery. *World Economic Forum*. https://www.weforum.org/agenda/2020/04/covid-19-why-informal-networks-will-be-key/

Hislop, D. (2002). Mission impossible? Communicating and sharing knowledge via information technology. *Journal of Information Technology*, *17*(3), 165–177. https://doi.org/10.1080/02683960210161230

Hodge, E., Bossé, M. J., Faulconer, J., & Fewell, M. (2006). Mimicking proximity: The role of distance education in forming communities of learning. *Instructional Technology*, 3.

Hopkins, D. (2000). *Schooling for tomorrow: Innovation and networks*. CERI/OECD.

Jensen, J. L. (2016). The social sharing of news: Gatekeeping and opinion leadership on Twitter. In *News Across Media* (pp. 142–161). Routledge.

Jinlei, Z., Ying, W., & Baohui, Z. (2012). Introducing a new teaching model: Flipped classroom. *Journal of Distance Education*, *4*(8), 46–51.

Kaden, U. (2020). COVID-19 school closure-related changes to the professional life of a K–12 teacher. *Education Sciences*, *10*(6), 165.

Kester, L., Kirschner, P. A., van Merriënboer, J. J., & Baumer, A. (2001). Just-in-time information presentation and the acquisition of complex cognitive skills. *Computers in Human Behavior*, *17*(4), 373–391.

Kouzy, R., Abi Jaoude, J., Kraitem, A., El Alam, M. B., Karam, B., Adib, E., Zarka, J., Traboulsi, C., Akl, E. W., & Baddour, K. (2020). Coronavirus goes viral: Quantifying the COVID-19 misinformation epidemic on Twitter. *Cureus*, *12*(3).

Krutka, D. G., & Carpenter, J. P. (2016). Participatory learning through social media: How and why social studies educators use Twitter. *Contemporary Issues in Technology and Teacher Education*, *16*(1), 38–59.

Kukulska-Hulme, A. (2007). Mobile usability in educational contexts: What have we learnt? *International Review of Research in Open and Distributed Learning*, *8*(2), 1–16.

Lasorsa, D. L., Lewis, S. C., & Holton, A. E. (2012). Normalizing Twitter: Journalism practice in an emerging communication space. *Journalism Studies*, *13*(1), 19–36.

Lee, E., Kim, Y. J., & Ahn, J. (2014). How do people use Facebook features to manage social capital? *Computers in Human Behavior*, *36*, 440–445. https://doi.org/10.1016/j.chb.2014.04.007

McPherson, M., Budge, K., & Lemon, N. (2015). New practices in doing academic development: Twitter as an informal learning space. *International Journal for Academic Development*, *20*(2), 126–136. https://doi.org/10.1080/1360144X.2015.1029485

McPherson, M., & Nunes, M. B. (2004). The failure of a virtual social space (VSS) designed to create a learning community: Lessons learned. *British Journal of Educational Technology*, *35*(3), 305–321.

Merrill, S. (2020). Teaching through a pandemic: A mindset for this moment. *Edutopia*. https://www.edutopia.org/article/teaching-through-pandemic-mindset-moment

Mitchell, R. (2015). *Web scraping with Python: Collecting data from the modern web*. O'Reilly Media Inc.

Moolenaar, N. M., Sleegers, P. J. C., & Daly, A. J. (2012). Teaming up: Linking collaboration networks, collective efficacy, and student achievement. *Teaching and Teacher Education*, *28*(2), 251–262. https://doi.org/10.1016/j.tate.2011.10.001

Munzert, S., Rubba, C., Meißner, P., & Nyhuis, D. (2014). *Automated data collection with R: A practical guide to web scraping and text mining*. John Wiley & Sons.

Mynatt, E. D., O'Day, V. L., Adler, A., & Ito, M. (1998). Network communities: Something old, something new, something borrowed. *Computer Supported Cooperative Work*, *7*(1–2), 123–156. https://doi.org/10.1023/A:1008688205872

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *The Academy of Management Review*, *23*(2), 242–266. https://doi.org/10.2307/259373

Newman, M. E. (2006). Modularity and community structure in networks. *Proceedings of the National Academy of Sciences*, *103*(23), 8577–8582.

Owen, N., Fox, A., & Bird, T. (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 & Method in Education*, *39*(2), 170–193. https://doi.org/10.1080/1743727X.2015.1041491

Panahi, S., Watson, J., & Partridge, H. (2013). Towards tacit knowledge sharing over social web tools. *Journal of Knowledge Management*, *17*(3), 379–397. https://doi.org/10.1108/jkm-11-2012-0364

Parise, L. M., & Spillane, J. P. (2010). Teacher learning and instructional change: How formal and on-the-job learning opportunities predict change in elementary school teachers' practice. *The Elementary School Journal*, *110*(3), 323–346.

Penuel, W. R., Riel, M., Krause, A., & Frank, K. A. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College Record*, *111*(1), 124–163.

Perrin, A. (2015). Social media usage. *Pew Research Center*, 52–68.

Phua, J., Jin, S. V., & Kim, J. J. (2017). Uses and gratifications of social networking sites for bridging and bonding social capital: A comparison of Facebook, Twitter, Instagram, and Snapchat. *Computers in Human Behavior*, *72*, 115–122.

Pitts, V. M., & Spillane, J. P. (2009). Using social network methods to study school leadership. *International Journal of Research & Method in Education*, *32*(2), 185–207.

Ranieri, M., Manca, S., & Fini, A. (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), 754–769. https://doi.org/10.1111/j.1467-8535.2012.01356.x

Rehm, M. (2018). Soziale Medien als Möglichkeitsräume für Informelles Lernen in der beruflichen Weiterentwicklung. *Netzwerk als neues Paradigma?* (pp. 101–121). Springer.

Rehm, M., Cornelissen, F., Daly, A. J., & García, M. D. F. (2020). Drinking from the Firehose: The structural and cognitive dimensions of sharing information on Twitter. *American Journal of Education*. https://doi.org/10.1086/711014

Rehm, M., Cornelissen, F., Notten, A., Daly, A., & Supovitz, J. (2020a). Power to the people?! Twitter discussions on (educational) policy processes. In D. Fröhlich, M. Rehm, & B. Rienties (Eds.), *Mixed methods approaches to social network analysis for learning and education* (pp. 231–244). Routledge.

Rehm, M., & Notten, A. (2016). Twitter as an informal learning space for teachers!? The role of social capital in Twitter conversations among teachers. *Teaching and Teacher Education*, *60*, 215–223. https://doi.org/10.1016/j.tate.2016.08.015

Richter, D., Kunter, M., Klusmann, U., Lüdtke, O., & Baumert, J. (2011). Professional development across the teaching career: Teachers' uptake of formal and informal learning opportunities. *Teaching and Teacher Education*, *27*(1), 116–126. https://doi.org/10.1016/j.tate.2010.07.008

Riel, M. M., & Levin, J. A. (1990). Building electronic communities: Success and failure in computer networking. *Instructional Science*, *19*(2), 145–169.

Rienties, B., Brouwer, N., & Lygo-Baker, S. (2013). The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology. *Teaching and Teacher Education*, *29*, 122–131. https://doi.org/10.1016/j.tate.2012.09.002

Risser, H. S. (2013). Virtual induction: A novice teacher's use of Twitter to form an informal mentoring network. *Teaching and Teacher Education*, *35*, 25–33. https://doi.org/10.1016/j.tate.2013.05.001

Rodriguez-Gomez, D., Ion, G., Mercader, C., & López-Crespo, S. (2020). Factors promoting informal and formal learning strategies among school leaders. *Studies in Continuing Education*, *42*(2), 240–255.

Scott, J. (2017). *Social network analysis*. Sage.

Selwyn, N., & Stirling, E. (2016). Social media and education… now the dust has settled. *Learning, Media and Technology*, *41*(1), 1–5.

Sibona, C., & Walczak, S. (2011). Unfriending on Facebook: Friend request and online/offline behavior analysis. *2011 44th Hawaii International Conference on System Sciences*, 1–10.

Sliwka, A. (2003). Networking for educational innovation: A comparative analysis. In I. D. Istance, & M. Kobayashi (Eds.), *Schooling for tomorrow: Networks of innovation, towards new models for managing schools and school systems* (pp. 49–63). OECD.

Spillane, J. P., Hallett, T., & Diamond, J. B. (2003). Forms of capital and the construction of leadership: Instructional leadership in urban elementary schools. *Sociology of Education*, *76*(1), 1–17. https://doi.org/10.2307/3090258

Supovitz, J. A., Daly, A. J., & del Fresno, M. (2015). *#CommonCore: How social media is changing the politics of education*. Retrieved from http://repository.upenn.edu/hashtagcommoncore/1/

Tang, J.-H., Chen, M.-C., Yang, C.-Y., Chung, T.-Y., & Lee, Y.-A. (2016). Personality traits, interpersonal relationships, online social support, and Facebook addiction. *Telematics and Informatics*, *33*(1), 102–108.

Teräs, M., Suoranta, J., Teräs, H., & Curcher, M. (2020). Post-Covid-19 education and education technology 'solutionism': A seller's market. *Postdigital Science and Education*, *2*(3), 863–878. https://doi.org/10.1007/s42438-020-00164-x

Tosato, P., Arranz, B. C., & Avi, B. R. (2014). Sharing resources in open educational communities. *Qualitative Research in Education*, *3*(2), 206–231.

Tsai, W., & Ghoshal, S. (1998). Social capital and value creation: The role of intrafirm networks. *The Academy of Management Journal*, *41*(4), 464–476. https://doi.org/10.2307/257085

Tseng, F.-C., & Kuo, F.-Y. (2014). A study of social participation and knowledge sharing in the teachers' online professional community of practice. *Computers & Education*, *72*, 37–47.

Tucker, B. (2012). The flipped classroom. *Education next*, *12*(1), 82–83.

Tynjälä, P. (2012). Toward a 3-P model of workplace learning: A literature review. *Vocations and Learning*, *6*(1), 11–36. https://doi.org/10.1007/s12186-012-9091-z

Van Dijk, J. (2020). *The network society* (2nd edn). Sage.

Van Waes, S., Moolenaar, N. M., Daly, A. J., Heldens, H. H. P. F., Donche, V., Van Petegem, P., & Van den Bossche, P. (2016). The networked instructor: The quality of networks in different stages of professional development. *Teaching and Teacher Education*, *59*, 295–308. https://doi.org/10.1016/j.tate.2016.05.022

Williams, D. (2006). On and off the net: Scales for social capital in an online era. *Journal of Computer-Mediated Communication*, *11*(2), 593–628. https://doi.org/10.1111/j.1083-6101.2006.00029.x

Ye, Q., Fang, B., He, W., & Hsieh, J.-P.-A. (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), 145–156.

Yoon, S. (2014). Does social capital affect SNS usage? A look at the roles of subjective well-being and social identity. *Computers in Human Behavior*, *41*, 295–303. https://doi.org/10.1016/j.chb.2014.09.043

Zachos, G., Paraskevopoulou-Kollia, E.-A., & Anagnostopoulos, I. (2018). Social media use in higher education: A review. *Education Sciences*, *8*(4), 194.